Electronics

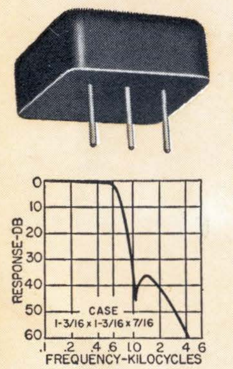
March 6, 1967
$1.00
A McGraw-Hill Publication

Below: Tapered Gunn device is voltage tunable, page 134

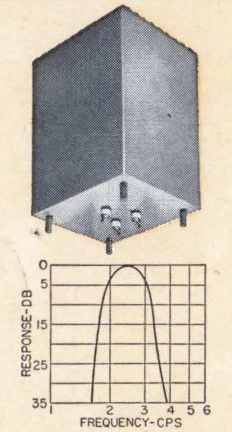
PIONEERS IN MINIATURIZATION

"SPECIAL" CUSTOM BUILT FILTERS

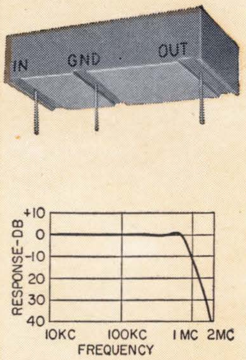
TO YOUR SPECIFICATIONS



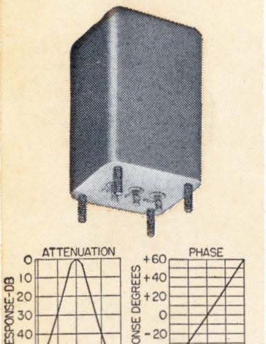
560 ∼ Telemetering low pass filter. Available from 400 ∼ to 70 KC. ± 7.5% band-width flat to 1 db. Attenuation greater than 35 db beyond the 2nd harmonic of — 7.5% frequency. Impedance 47K ohms. MIL-F-18327B. Wt. 0.8 oz.



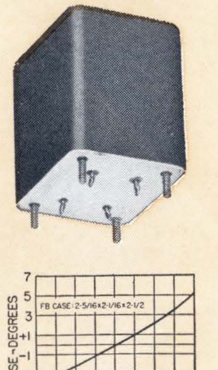
Low frequency band pass filter. Designed for 2.5 cps center frequency. At 2 to 3 cps within 3 db. At 1.5 cps and lower, and 4 cps and higher, greater than 30 db. Source and Load 10K ohms. Size: 4 x 4-11/16 x 6". MA MIL case, MIL-F-18327B.



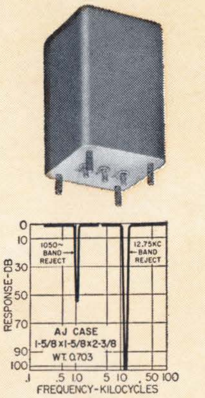
High frequency low pass filter. Zero to 700 KC within 1 db. 1.95 mc to 10 mc 40 db minimum. Source and Load 1000 ohms. Molded flat construction for printed circuit applications. Size: 1 x 2 x ½"; Wt: 1 oz. MIL-F-18327B.



Band pass 400 cycle Gaussian filter. Linear phase response in pass band. Attenuation 380 cps to 420 cps within 0.5 db. 2nd harmonic down 25 db, 3rd harmonic down 45 db. Source and load 5K ohms. MIL-F-18327B Wt., 0.9 lbs.



Minimum phase shift 400 cycle band pass filter. Within ± 1.5 db 370 to 430 cycles, greater than 45 db beyond 1100 cycles. 1K ohms to 100K ohms. MIL-F-18327B; 1 lb.



Band reject filters (two shown). The 1050 ∼ filter has 50 db attenuation and is only 3 db at 950 and 1150 cycles. The 12.75 KC filter has more than 100 db attenuation and is only 3 db at 10.8 and 15 KC. Source and load 600 ohms, both are MIL-F-18327B.

ILLUSTRATED ARE TYPICAL SPECIAL FILTERS

RANGE OF FREQUENCIES ON SPECIAL UNITS IS FROM 0.1 CYCLE TO 400 MC.

Over thirty years of experience in the design and production of special filters have resulted in UTC being a first source for difficult units. Present designs both military and commercial incorporate a wide variety of core structures, winding methods, and capacitors to provide maximum performance, stability, and reliability. Fully experienced, top engineering talent backed by complete environmental testing and life testing facilities assure the highest standard in the industry. Full analysis and evaluation of materials are conducted in UTC's Material and Chemical Laboratories. Rigid quality control measures coordinated with exhaustive statistical findings and latest production procedures results in the industry's highest degree of reliability.

MILITARY AND COMMERCIAL TYPES FOR EVERY PHASE OF THE ELECTRONICS ART

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UNITED® TRANSFORMER CO.

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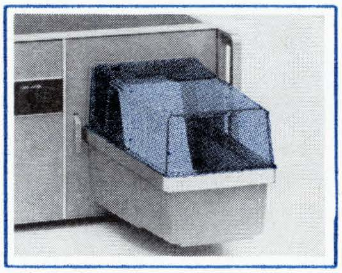
Introducing 'the strong, silent one.'



The HP 5050A Digital Recorder is no quitter. New mechanical techniques make this 20-line-per-second printer rugged, quiet, economical and simple. For example, there are no rotating electrical contacts for decoding, and no start-stop operation of printwheel and ink ribbon. Instead, photo-electric decoding is used, and the print drum rotates continually against an ink-impregnated roller. Fewer parts lead to increased reliability potential, which is necessary in printers with the 5050A's speed. Zero suppression is available.

The 5050A is quiet, too . . . measured noise is less than an electric typewriter, less than other printers in its speed class. It accepts 4-line BCD data from one or two sources, which can be in different BCD codes. For extra versatility, formats and codes are easily and economically changed by mechanical means without buying new circuitry for driving the printer.

The 5050A can print up to 18 columns at rates to 20 lines per second . . . and without making a lot of noise about it.

Notice the unusual transparent hood. It muffles the sound. It lets you hear yourself think. It keeps your printed records in a neatly folded stack, instead of streaming over equipment, bench and floor. And it stores completely within the recorder when you're not using it.

The 5050A is, of course, fully compatible with other HP solid-state equipment. Price is favorable, too: $1750 without the driving electronics (which are an additional $35 per column).

For more information call your local Hewlett-Packard field engineer or write Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304; Europe: 54 Route des Acacias, Geneva.

Brief Specifications

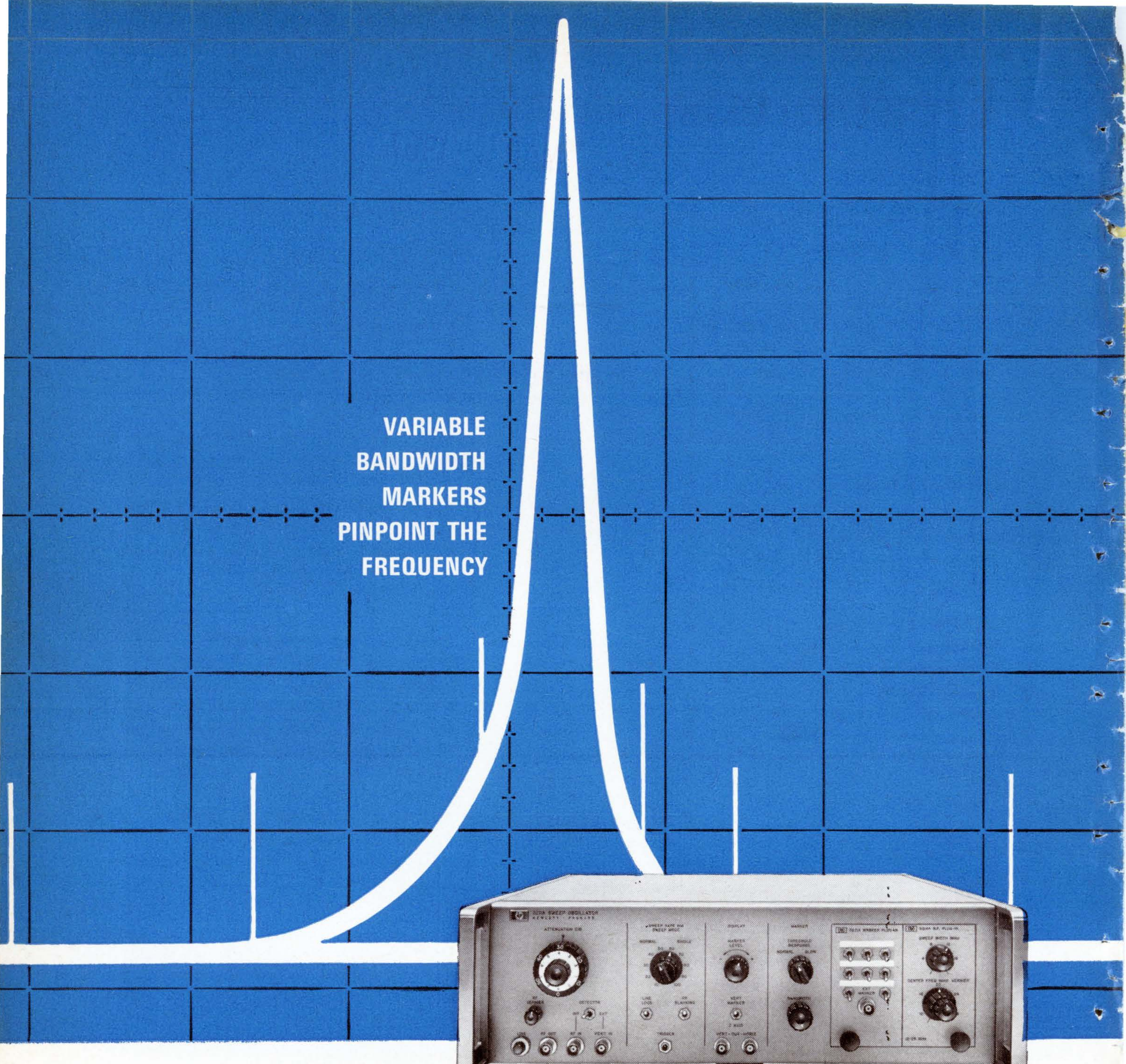
Print Cycle Time:	50 msec, asynchronous.
Maximum Capacity:	18 columns, 16 characters each.
Data Input:	Parallel entry, BCD (1-2-2-4, 1-2-4-8 or 1-2-4-2); "1" must differ from "0" by 4.5 V min. to 75 V max.
Reference Voltage:	±150 V max.; both "0" and "1" states are required.
Input Impedance:	Approximately two megohms.
Hold-off Signals:	Both polarities diode coupled, simultaneously available; 10 mA load max. +15 V open circuit from 1 K source −15 V open circuit from 1 K source
Print Command:	+ or − pulse, 6 to 20 V amplitude, 1 V/μsec min. rise time, 20 μsec or greater in width, AC coupled.

HEWLETT **hp** *PACKARD*

2561

See new Hewlett-Packard instrumentation at IEEE Show New York Coliseum March 20–23

Circle 1 on reader service card



Sweep Oscillator gives top performance in the 100 kHz to 110 MHz range

All solid-state Hewlett-Packard 3211A Sweep Oscillators with RF and marker plug-ins meet virtually all of your swept frequency testing requirements. Variable bandwidth markers permit accurate, well defined marking under a variety of test conditions.

The main frame of the 3211A contains everything you could hope to find in a sweeper. RF plug-ins operate at fundamental frequencies with good linearity and spurious mixing products are eliminated. Plug-in markers offer not only variable bandwidth, but also Z-axis or pulse-type marking. An accurate 59-db attenuator makes the unit a valuable tool for testing both high- and low-gain circuits.

Circle 2 on reader service card

The 3211A is ideal for general testing in the video to VHF range where flat, linear output and an accurate marking system is required. Typical applications are: alignment, calibration and design of FM tuners and receivers and testing filters, amplifiers, transformers, resonant circuits and IF sections of TV receivers, radar and communications systems. For complete specifications, contact your local Hewlett-Packard field engineer or write Hewlett-Packard, Green Pond Road, Rockaway, N.J. 07866.

HEWLETT hp PACKARD
measuring instruments for science and industry

Electronics

March 6, 1967
Volume 40, Number 5

News Features

Probing the News

Electronics Review

Electronics Abroad

Departments

Technical Articles

I. Design

II. Application

Electronics: March 6, 1967, Vol. 40, No. 5

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Readers Comment

Nothing new under the sun

To the Editor:

In the article "Tv cameras are slimmed down to follow action on sports field" [Feb. 6, p. 103], your Tokyo regional editor described a simplified color television pickup system, made and used by NHK. One essential part of this highly and deservedly praised development effort is a lenticular plate used before the pickup television camera and preceded by a primary color strip filter or dichroic mirror.

It may be of interest that a system using a lenticular plate with a tricolor filter on the pickup side for the purpose of producing color television was published by me in August 1937, in Television and Shortwave World, in a paper entitled:

"A Novel Scheme for Television in Colours."

Victor A. Babits
Vice President of Research
Marshall Laboratories
Torrance, Calif.

Ancient lore

To the Editor:

At the 1967 International Solid State Circuit Conference, after having heard the problems users had with integrated circuits and large-scale integration, I recalled an ancient form of circuitry, now in disrepute, known as DCC.

In this, the user has the following building block characteristics:

Transistors
- Types: PNP and NPN
- Max. voltage: 300 volts
- Max. current: 5 amperes

Capacitors
- Range: picofarads to microfarads
- Max. voltage: kilovolts

Resistors
- Initial tolerance: below .1%
- Range: fraction of an ohm to hundreds of megohms
- Temp. coeff.: 5 ppm
- Note: Resistors are linear and symmetrical

This ancient form requires a minimum investment by the user. All that is required is a workbench and a few hand tools available at the local hardware store. The building

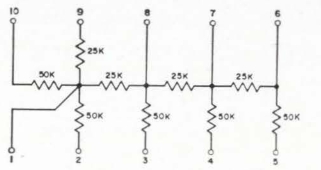
Only from Sprague!

HYBRID D to A CIRCUITS

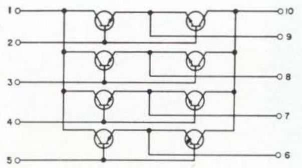
DIGITAL-TO-ANALOG

with precision components not found in monolithic integrated microcircuits

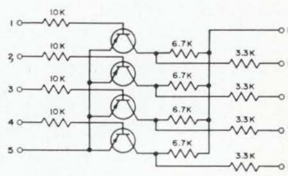
FOUR BIT SERIES



UT-1000 LADDER NETWORK

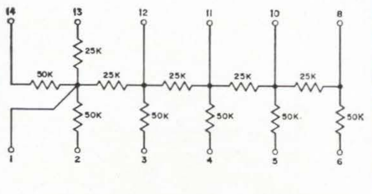


UD-4001 LADDER SWITCH

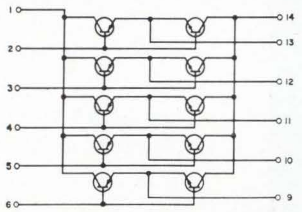


UD-4024 BUFFER AMPLIFIER

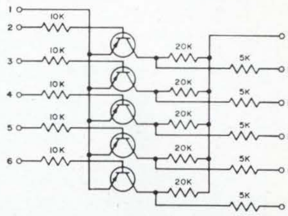
FIVE BIT SERIES



UT-1001 LADDER NETWORK



UD-4036 LADDER SWITCH



UD-4037 BUFFER AMPLIFIER

Up to 12 bits with less than ½ bit error!

- Silicon-base hybrid microcircuits in hermetically-sealed flat packs.
- 3 to 1 size reduction over conventional converters using discrete components.
- Improved tracking over temperature range of −55 C to +125 C.
- Reduced handling of components . . . fewer external connections . . . lower assembly costs.
- 4-bit series expandable to 8 or 12 bits . . . 5-bit series expandable to 10 bits.
- Combination of precision thin-film tantalum nitride resistors, nickel-chromium resistors, and active devices of planar construction.
- Packaged for compatibility with monolithic circuits.

For complete technical data on D-to-A microcircuits, write to Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Massachusetts 01247.

SPRAGUE COMPONENTS

THIN-FILM MICROCIRCUITS
INTEGRATED CIRCUITS
TRANSISTORS
CAPACITORS
RESISTORS

PULSE TRANSFORMERS
INTERFERENCE FILTERS
PULSE-FORMING NETWORKS
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ELECTRIC WAVE FILTERS

CERAMIC-BASE PRINTED NETWORKS
PACKAGED COMPONENT ASSEMBLIES
BOBBIN and TAPE WOUND MAGNETIC CORES
SILICON RECTIFIER GATE CONTROLS
FUNCTIONAL DIGITAL CIRCUITS

4SS-7101

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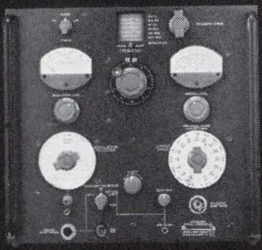
THE MARK OF RELIABILITY

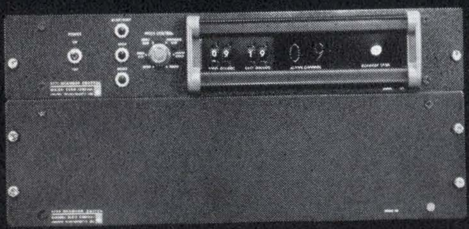
Introducing GR's new...



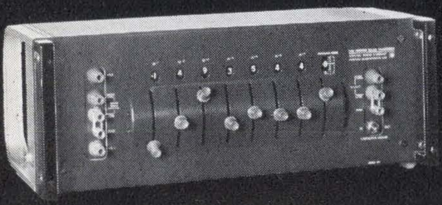
Standard-Signal Generator with a 9.5- to 500-MHz frequency range and 10-V, cw output behind 50 Ω; or 5 V, modulated, behind 50 Ω. It has automatic output leveling *in all modes of operation* and true single-dial tuning (no trimmer adjustment needed). The generator frequency can be phase-locked to an external standard frequency. Modulation distortion is less than 3% at 80% AM. Type 1026-A Standard Signal Generator . . . $6500.

Sweep and Marker Generator for use with GR Synthesizers. It has nine sweep speeds, from 0.02 to 60 seconds, and sweep excursion is adjustable from ±.001 Hz to ±1 MHz. Generates scope markers for quick calibration of the swept output. The synthesized center-frequency marker and side markers are accurate, stable, and precisely settable. Type 1160-P2 Sweep and Marker Generator . . . $495.

General-Purpose Laboratory Oscillator with its full 10-Hz to 50-kHz range covered by one turn of the dial. No range switch to wear out! This also means no range-switching transients and no ambiguous dial multipliers. Generates both sine and square waves, and can be synchronized to an external signal or can supply a sync signal. Has a calibrated 60-dB step attenuator and a 20-dB continuously adjustable attenuator. Type 1313-A Oscillator . . . $325.



Scanner System to connect up to 100 capacitors sequentially to GR's 1680-A automatic capacitance bridge. Also useful for other scanning applications. Modular construction offers great versatility in the number of input channels, number of lines switched per channel, and line termination. Preserves the three-terminal, guarded connection between bridge and unknown. Digital readout and BCD output of channel identification. Automatic, manual, or externally programmed operating modes. Type 1770 Scanner System . . . $3500 for a typical 50-channel guarded system.



Precision Decade Transformer with 0.2 PPM linearity and easily repeatable settings to 1 x 10^{-9}. Lever switches for easy, in-line readout plus infinite-resolution slide wire (that can be switched out of circuit for calibration). Type 1493 Precision Decade Transformer . . . $1100.

Other new products include the Type 1406 Coaxial Capacitance Standards and several additions to the GR874 and GR900 lines of coaxial equipment. You can see these and many other new GR instruments at the New York IEEE Show, Booth No. 2E26-2E36.

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

Prices apply only in U.S.A.

GENERAL RADIO

Circle 6 on reader service card

blocks can be obtained from a wide number of interchangeable, competing sources and are so cheap that they can be stocked by the user. It gives the manufacturer a much larger value added than integrated circuits or large-scale integration and he can use his own proprietary circuit.

The designer can use DCC blocks in a wide variety of digital logic configurations. The same elements can be used for analog as well as digital applications.

The parts can be readily repaired or changed as all parts are readily accessible.

The design turnaround time can be measured in minutes rather than months.

In case the reader has not guessed it by now, DCC is discrete component circuitry.

Philip D. Goodman
Narberth, Pa.

What's the time?

To the Editor:

It seems to me there's something missing from your report on the Harris-Intertype photographic typesetter [Feb. 6, p. 34], namely: the time required to transfer the text to the magnetic tape, the time required for the computer to justify lines, and the time to convert the crt display to a metal plate.

Surely you would not have us believe that all these steps are completed in 30 seconds.

Clarence W. Metcalf
Engineered Advertising
Stoughton, Mass.

▪ The telephone company supplies its subscriber information to the printer on magnetic tape that serves as an input to the computer typesetter. In 30 seconds, the machine sets each line, justifies it, and produces a complete page on film. Making the printing plate takes a few minutes more. Formerly, the telephone company supplied subscriber names on punched paper tape that ran an automatic linotype machine. Setting a page this way took an hour and a half.

The numbers game

To the Editor:

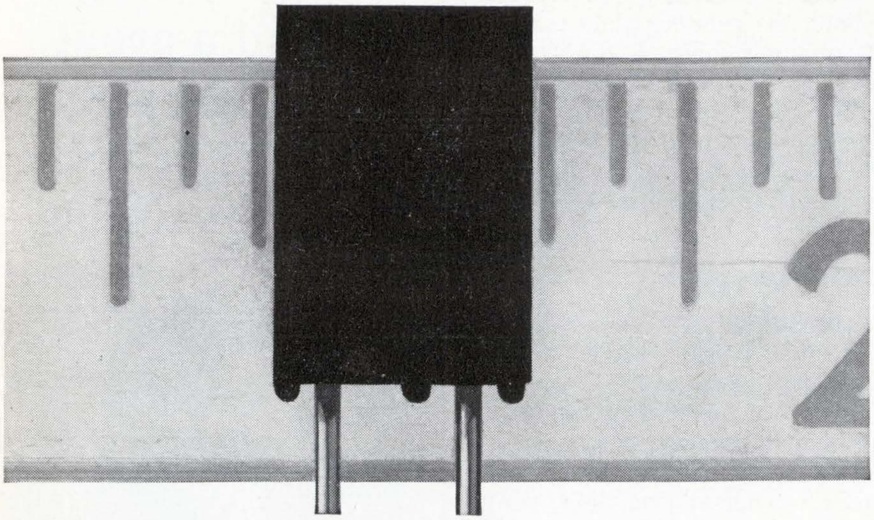
In the article "Light touch" [Dec. 26, 1966, p. 168], you included some misinformation.

Although you are, of course, at the mercy of manufacturers' exaggerated claims about their sales, this statement of 200 cameras sold with 80% to North American manufacturers is unusual. The general consensus around this country is that Marconi has delivered about 16 cameras and there are firm orders for about 34 more. With 50 cameras ordered in the U.S., this would mean 110 cameras in Canada and since the Canadian Broadcasting Corporation has ordered none of its color yet, this seems very unrealistic.

Generally our information indicates that Norelco and RCA are about equal in color camera sales at around 300 (excluding the earlier 3-tube image orthicon cameras which are no longer being built), GE is somewhere around half this number, and Marconi sales are well below that.

Charles E. Spicer
Vice President-Engineering
Visual Electronics Corp.
New York, N.Y.

▪ Executives at Marconi Co. in London insist they have received orders for 160 Mark Seven color tv cameras from the U.S. and Canada.



People

Northrop Corp.'s Nortronics division means to expand and intensify its efforts in inertial guidance work. It has just named **Helmut Schlitt,** an expert in the field, to the new post of director of advanced development.

Helmut Schlitt

Nortronics already has a capability in airborne digital computers, inertial platforms and gyroscopes. The division's biggest effort at the moment is for the C-5A systems.

Schlitt's plans for Nortronics go beyond the general type of work the division has been doing. "We want to become more systems oriented," he says.

Well rounded. While declining to be specific about his plans, he said they include tactical systems such as low-cost, precision navigation systems, target-location systems, and radars and doppler systems. He added that these are not necessarily all for aircraft.

Schlitt, a native of Germany, comes to Nortronics from Litton Industries Inc. He was vice president of new product technology at Litton's Guidance and Control Systems division, Woodland Hills, Calif., and was also in charge of its space science laboratory in Beverly Hills, Calif., where he directed work on plasma engines and space suits.

He holds many patents in the field of inertial guidance and is credited with development of the case-rotation concept for gyros.

In his new job, Schlitt is in charge of Nortronics' advanced avionics laboratory, the inertial systems applications group (marketing), and the commercial navigation systems group.

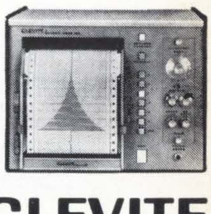
Although some electronic equipment makers do produce their own integrated circuits—or at least maintain an in-house capability—most still buy on the open market. But in the view of **William J. Mac-**

Here's an engineer's magazine even your wife will love

It's the *portable* chart paper magazine from our new Mark 250 Strip Chart Recorder. Now you can take the record home with you, or any place for that matter! Manual turning knobs let you roll the chart forward and back. Later, you can re-record on the same chart for side-by-side comparison. Chart take-up is automatic. And you can reload the magazine in seconds. (Many users get an extra magazine . . . study one while the other is in the recorder.)

But the world's slickest chart magazine is just one of the Mark 250's great new features. Step response over the full 4½-inch span (10% to 90%) is 40 milliseconds . . . records up to 100 cps . . . flat to 10 cps full scale! Choice of 21 interchangeable preamps. Pushbutton selection of 12 chart speeds. Crisp, clear, rectilinear presentation. Patented, pressurized inking system. Owners say there's no other strip chart recorder in the same league.

Words just don't do it. You have to *see* a Mark 250 to understand why it's called "the first strip chart recorder for the perfectionists of the world." A call to your local Brush Sales Engineer brings a Mark 250 right to your office or lab. Go ahead. Even *our* wives will love you for *that*. Clevite Corporation, Brush Instruments Division, 37th & Perkins, Cleveland, Ohio 44114.



CLEVITE

brush INSTRUMENTS DIVISION

People

Donald, the new president of a small Burlington, Mass., company, Film Microelectronics Inc., the number of companies with an in-house IC capability will soon rise sharply. Film Microelectronics is counting on this trend; it specializes in selling or leasing do-it-yourself hybrid IC production facilities.

W. J. MacDonald

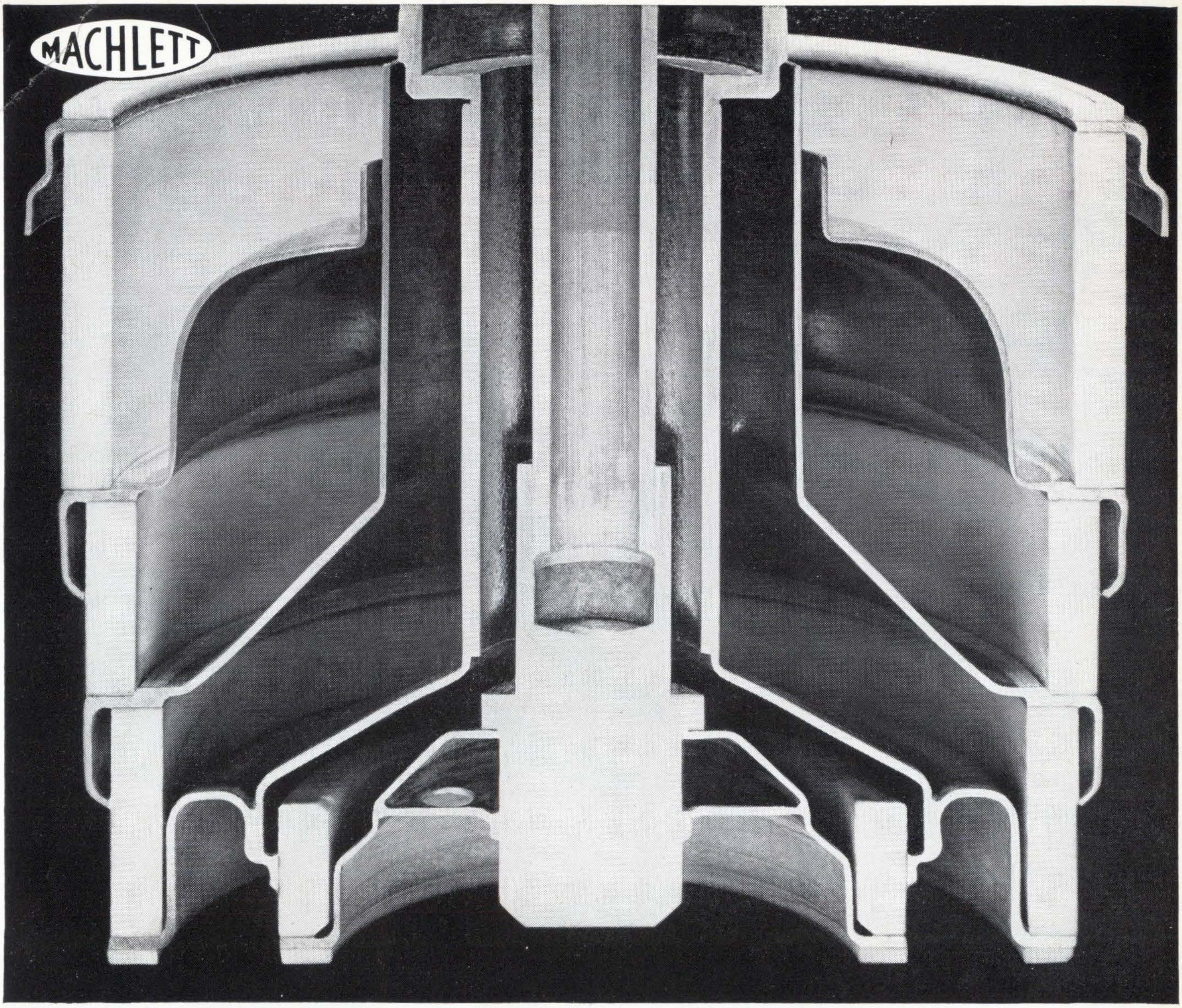
"The threat to equipment makers without an in-house capability is that they will be contributing less and less to their own equipment as time goes on," says MacDonald, a 41-year-old engineer.

Subtractive process. The do-it-yourself approach employs printed-circuit board techniques and etching to produce a passive network of resistors and conductors. It is a subtractive process. Starting with a resistor-conductor board that has already been coated with layers of metallic material, the circuit maker selectively etches to remove the unwanted portions, leaving the desired pattern of resistors, capacitors and interconnections.

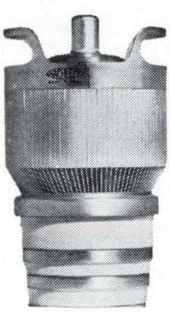
"If a device maker needs 20,000 circuits a year, or fewer, he should be using hybrids," MacDonald claims. "Development costs vary from $100 to $10,000 for a hybrid circuit, but it costs at least $50,000 to develop a monolithic IC."

He sees an increasing market in commercial applications, including television and hearing aids. The company recently bid on a new device proposed for installation on the wheels of automobiles to sense motion and trigger antiskid equipment.

MacDonald got where he is because the company did not grow faster. Film Microelectronics was founded in 1964 as Mallory-Xerox Corp., a joint venture of P.R. Mallory & Co. and the Xerox Corp. Xerox quickly bought out Mallory's interest and operated the company as Electronic Films Inc. until December 1966, when it offered to sell the business to MacDonald, then chief engineer.



Continuous cone electrode geometry: designed into all these tetrodes only by Machlett



ML-8170/
4CX5000A

ML-8171/
4CX10000D

ML-8281/
4CX15000A

The result: uniform internal r.f. energy distribution and high performance stability.

Write for complete details:
The Machlett Laboratories, Inc.,
Springdale (Stamford), Conn. 06879.

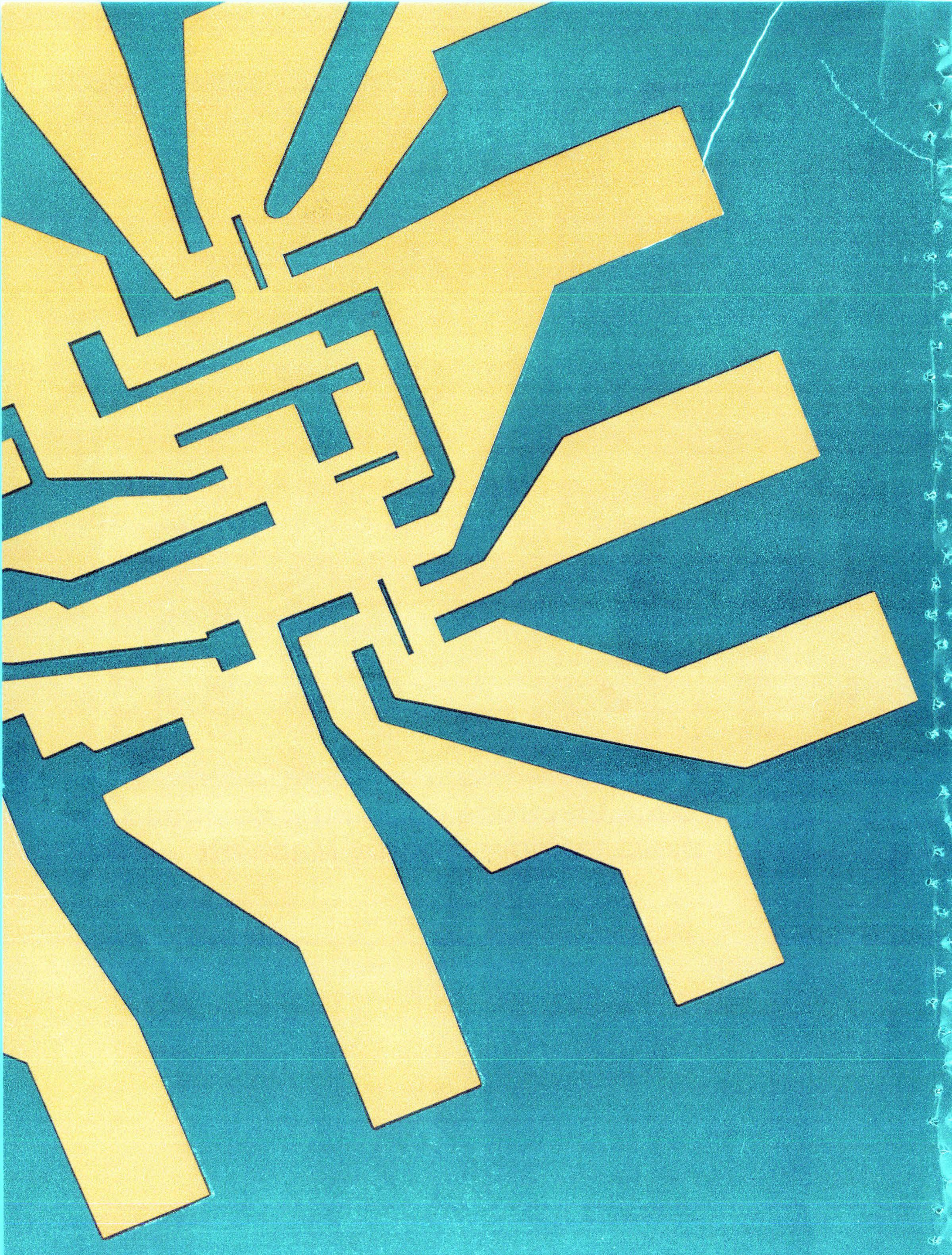
Engineers' resumes invited

RAYTHEON

THE MACHLETT LABORATORIES, INC.

A SUBSIDIARY OF RAYTHEON COMPANY

Circle 11 on reader service card



PATENT NO. 3117260: THE DIFFUSION ISOLATION TECHNIQUE

Meetings

Symposium on the Effects of Radiation in Semiconductor Components, Faculte de Sciences of the University of Toulouse; Toulouse, France, **March 7-10.**

International Symposium on Residual Gases in Electron Tubes and Sorption-Desorption Phenomena in High Vacuum, Italian Society of Physics; Rome, **March 14-17.**

National Convention, Air Force Association; Hilton and St. Francis Hotels, San Francisco, **March 14-17.**

Temperature Measurements Society Conference and Exhibit, Temperature Measurements Society; Hawthorne Memorial Center, Los Angeles, **March 14-15.**

International Convention, IEEE; New York Hilton Hotel and Coliseum, **March 20-24.**

Symposium on Modern Optics, Polytechnic Institute of Brooklyn; Waldorf-Astoria Hotel, New York, **March 22-24.***

Lectures on Glass in Electronics, New York State Science of Technology Foundation; Polytechnic Institute, Troy, New York, **March 28-29.**

Photovoltaic Specialists Conference, IEEE; Sheraton Cape Colony Inn, Cocoa Beach, Fla., **March 28-30.**

Advancing Technology & Purchasing Management Workshop, Institute of Science & Technology; University of Michigan, Ann Arbor, Mich., **March 29-30.**

Structures, Structural Dynamics & Materials Meetings, American Institute of Aeronautics and Astronautics; Palm Springs, Calif., **March 29-31.**

Symposium on Microwave Power, International Microwave Power Institute; Stanford University, Stanford, Calif., **March 29-31.**

Conference on the Transport Properties of Semiconductors, Solid State Physics Committee of Institute of Physics; Canterbury, Kent, England, **March 30-31.**

Rubber & Plastics Industries Technical Conference, IEEE; Sheraton-Mayflower Hotel, Akron, Ohio, **April 3-4.**

Call for papers

Union Radio Scientific International Meeting, IEEE; Ottawa, Canada, May 22-25. **March 15** is deadline for submission of abstracts to George Sinclair, department of electrical engineering, University of Toronto, Toronto 5, Canada.

Electrochemical Society, Luminescence Session; Dallas, Texas, May 7-12. **March 31** is deadline for submission of abstracts to Paul Goldberg, General Telephone & Electronics Laboratories Inc., 208-20 Willets Point Blvd., Bayside, N.Y. 11361.

Symposium on Adaptive Processes, IEEE; Chicago, Oct. 23-25. **April 1** is deadline for submission of abstracts to Lloyd Benningfield, Sixth Symposium on Adaptive Processes, University of Missouri-Columbia, Columbia, Mo.

Symposium on Microelectronics, IEEE; the Colony Motor Hotel, St. Louis, Mo., June 19-21. **April 1** is deadline for submission of papers to Dr. Remo Pellin, Inorganic Chemicals Division, the Monsanto Co., 800 North Lindberg Blvd., St. Louis, Mo. 63166.

Computer Conference, IEEE; Chicago, Sept. 6-8. **April 10** is deadline for submission of abstracts to S.S. Yau, Department of Electrical Engineering, Technological Institute, Northwestern University, Evanston, Ill., 60201.

Winter Meeting, American Society of Mechanical Engineers; Penn-Sheraton Hotel, Pittsburgh, Pa., Nov. 12-17. **April 15** is deadline for submission of abstracts to T.V. Sheehan, program representative, Brookhaven National Laboratory, 81 Cornell Ave., Upton, N.Y. 11973.

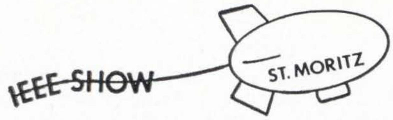
Fall Joint Computer Conference, American Federation of Information Processing Societies; Convention Center, Annaheim, Calif., Nov. 14-16. **April 17** is deadline for submission of papers to Mr. Larson, 1967 Fall Joint Computer Conference, P.O. Box 457, Costa Mesa, Calif. 92627.

Conference on High-Frequency Generation and Amplification, Cornell University, Aug. 29-31. **May 1** is deadline for submission of abstracts to Conference Committee, School of Electrical Engineering, Cornell University, Ithaca, N.Y.

*** Meeting preview on page 16**

the connector thing

A periodical periodical designed, quite frankly, to further the sales of Microdot Inc. connectors and cables. Published entirely in the interest of profit.



WIN

THE BROOKLYN BRIDGE!

Every March, rumblings of wanderlust begin to stir within the breast of every true electronic engineer. It is time for the IEEE convention. It is time once more to bend one's lance against the Visigoths of New York: waiters, cab drivers, mods on Bleeker Street, the maitre d' at 21, bilious brokers of theater tickets, the subway and just plain people who use words like "chic," "fabulous" and "devastating."

EVERYBODY WINS

In honor of all those beautiful people, simple of soul, broad of brow, and intrepid of heart, who stem from the provinces, Microdot is offering a genuine, invalid DEED OF TRUST TO THE BROOKLYN BRIDGE printed on equally invalid parchment. Or, if you prefer, Microdot will send you a handsome, invaluable booklet entitled NEW YORK DIETARY LAWS or How to Eat Dinner at the King Henry IV Without Floating a Loan from Chase Manhattan. Nothing to do.

You only get one of these, so choose carefully. There is a way you can get both. Patient reading will tell you how.

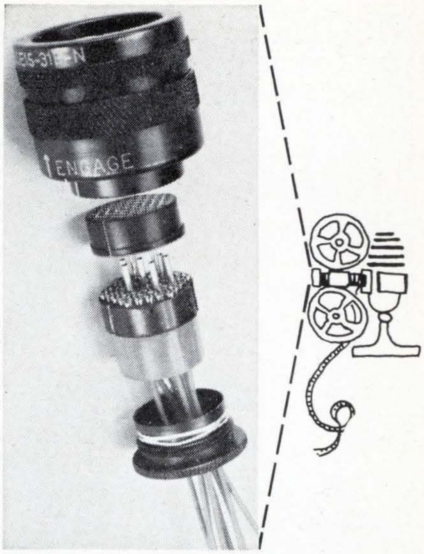
THE BEST CONNECTIONS IN NEW YORK! (PL. 5-5800)

Microdot makes connectors, as a matter of fact, the best microminiature coax connectors in the industry. Whether you're talking about the some 6000 standard off-the-shelf items or the high density, multi-pin MARC 53, Microdot has some rather surprising answers to connector problems. Of course, some of you will not have the advantage of exposing yourselves to the invectives of the hotel clerk in the St. Moritz for the IEEE show. Don't be sad. This is what you would have seen.

LEPRA/CON is Microdot's newest ultraminiature series of coax connectors. The screw-on has an OD of only 1/8 inch with a mated length of only one inch. Packaging can be reduced by as much as 50%. New versions of the LEPRA/CON include the slip-on, multi-pin and rack and panel based on the TWIST/CON concept. See below.

TWIST/CON is a concept as much as a product...the most economical microminiature pin and socket in the history of electronics. TWIST/CON permits high density packaging of contacts on .050″ centers, up to 420 contacts per square inch.

There are also the Microcrimp, Golden Crimp, Mini-Noise coaxial cable and those 6000 standards we were talking about.



MARC 53 is the world's smallest, high-performance circular connector with as many as 61 crimp contacts in a tiny 15/16 inch receptacle shell. "Posilock" push-pull coupling mates easily with no danger of damage and eliminates accidental disconnect. "Posiseal" guarantees an interfacial seal. *The new rear-insertable version of the MARC 53 is a revolution—field assembly without special insertion or extraction tools.* We will have a sound color film at the St. Moritz during IEEE which explains all about the MARC 53.

SEE US AT THE ST. MORITZ!

Microdot will not have a booth at the IEEE show. Instead it has set up a Bessarabian Harem at the St. Moritz, one of the finest combined inns and watering holes in the world. Here, any of you making the trek to Gotham can get all the hot Microdot news first hand. And while you are there you can pick up (free!!!!) at the St. Moritz BOTH your Brooklyn Bridge Deed and your copy of the New York Dietary Laws. By the way, we did say it was a watering hole.

MICRODOT INC.

Microdot Inc., 220 Pasadena Avenue, South Pasadena, California 91030

Dear Mr. Microdot:

- ☐ Please send me my personal Deed of Trust to the Brooklyn Bridge. I can understand people leaving Brooklyn to come to New York. But *going* to Brooklyn?
- ☐ Although I am a personal friend of David Rockefeller and could get a Chase Manhattan loan easily, I still want my free copy of the New York Dietary Laws.

NOTE: Only one of the above is available per person unless you visit the Microdot Pasha's suite at the St. Moritz in New York. Both will be sent only to those people who state in 25 words or less (1) why they are a hardship case and (2) why Microdot makes the best connectors in the world.

- ☐ Send me information on all those things like MARC 53 and TWIST/CON, etc. I am going to New York, but I have better things to do.

Name ______________________

Title ______________________

Firm ______________________

Address ______________________

City ______________________

State ______________ Zip ________

Meeting preview

Optics topics

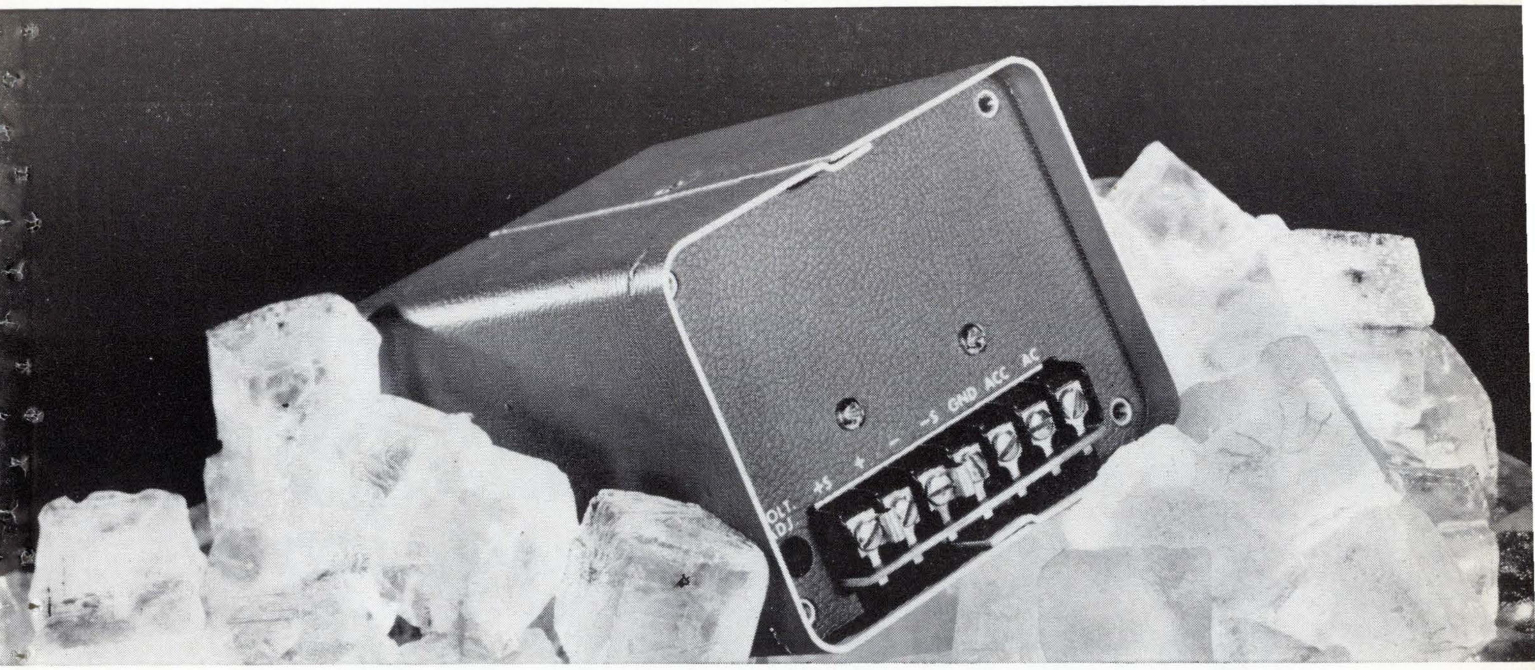
An optical recorder that may compete with magnetic tape in certain applications, real-time holographic techniques, and a single-frequency argon laser are among the advances to be discussed at the three-day Symposium on Modern Optics to be held at the Waldorf-Astoria Hotel in New York City beginning March 22. The session is sponsored by Brooklyn Polytechnic Institute, the IEEE and the military.

The recorder is a multichannel electro-optical device for pulsed signals being developed by Columbia University's electronic research laboratory for the Defense Department. Far smaller than conventional signal-processing equipment, the recorder is designed to save hours of computing time by processing signals optically. The recorder—currently working with 24 channels—is the first to convert multichannel parallel electric signals into optical signals that can be recorded on film. Moses Arm, the Columbia lab's supervisor, says that this recording technique will be used in telemetry, communications, and medical electronics systems. The recorder will be installed in existing radar systems in early 1969.

Real-time 3-D. Techniques for producing both magnified and real-time holograms that can be viewed continuously without requiring the development of a photographic plate will also be discussed. Theoretically, the combination of the magnification and holographic techniques will produce a "holoscope"—a real-time hologram that magnifies the subject. Such a system would permit the viewing of an entire volume of material rather than just the single plane upon which the conventional microscope can focus.

Among the laser work to be discussed will be an argon laser developed for NASA by Donald Caddes of Sylvania Electronic Systems, Mountain View, Calif. It's slated for installation in an optical radar system for tracking launch vehicles. The laser employs supermode control to convert output to a single frequency; it radiates in the blue-green portion of the spectrum.

new disciplines in DC



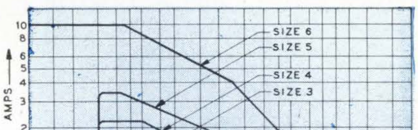
take the COOL slot supplies

No need to put 'em on ice • no need for added heat sinks

All Silicon • Fully Serviceable • No Encapsulated Components

HP's new SLOT Series of DC Regulated Power Supplies have a constant voltage output, screwdriver adjustable ±10%. Using four nuts imbedded in end plate, modules can be mounted inside instrument or on standard 19" rack panels available from hp. Barrier strip has terminals for AC input, DC output, and remote sensing.

Design insures operation to 50°C without derating or added heat sinks. Internal construction employs no cables, hand-soldered connections, or component encapsulation — units are fully serviceable. Stock models, available on a short-delivery basis, are listed below. The area below each curve at the right indicates limits of ratings available on special order.



STOCK MODELS

Output Voltage	Output Current	Package Size	Model Number	Price Qty. 1-9
6V ± 10%	0-3A	5	60065A	$100.
12V ± 10%	0-1A	3	60123A	79.
12V ± 10%	0-2.2A	5	60125A	100.
24V ± 10%	0-1A	4	60244A	88.
28V ± 10%	0-1.5A	5	60285A	100.

DIMENSIONS

Module Size	Mounting Surface	Length
2	3⅜" x 4⅛"	4⅛"
3	3⅜" x 4⅛"	6"
4	3⅜" x 5⅛"	6"
5	3⅜" x 5⅛"	7$\frac{5}{16}$"
6	4¼" x 5⅛"	11"

Load Regulation, 0.05%; Line Regulation, 0.05%; Ripple, less than 0.006% or 1 MV RMS, whichever is greater • Transient Recovery Time, less than 25 μ sec to within 10 MV • Short-Circuit-Proof, Current-Limited Output • No Overshoot on Turn-On, Turn-Off, or AC Power Removal • Operating Temperature, 0°C to 50°C; Storage — 40°C to +85°C

Contact your nearest Hewlett-Packard Sales Office for full specifications.

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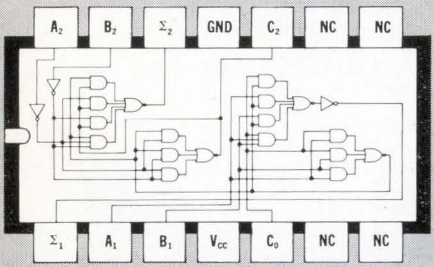
Five new complex-function ICs . . .

Cut costs, simplify designs and improve reliability . . . use these new Texas Instruments Series 74 TTL integrated circuits in your digital electronic systems.

Cut costs two ways. First, you pay less per circuit function than when buying conventional ICs. Second, you save on connectors, circuit boards, inventory, and assembly costs . . . since fewer packages and less area is required. Net result . . . you can often realize over-all savings in excess of 50 percent!

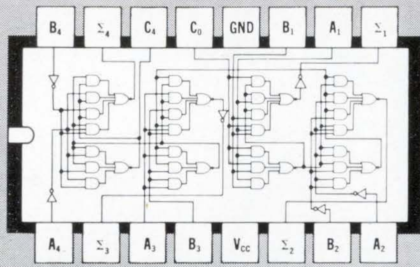
You simplify designs because TI has already done a lot of the work for you. These devices, which are fully compatible with



SN7482N DUAL ADDER

- Cost savings of 26% over two single IC adders.
- 15 nsec serial carry through both additions.
- Provides the Σ_1 of A_1 and B_1, and the Σ_2 of A_2 and B_2, including appropriate carry manipulations.

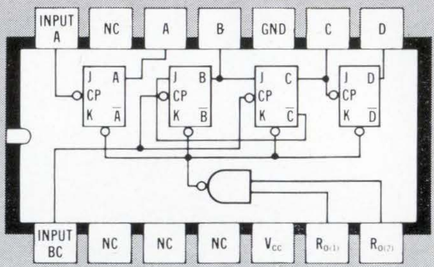
Circle 497 on Reader Service card for data sheet.



SN7483N QUAD ADDER

- Saves 41% over four single IC adders.
- 30 nsec serial carry through four additions
- Provides the Σ_1 of A_1 and B_1, the Σ_2 of A_2 and B_2, the Σ_3 of A_3 and B_3, and the Σ_4 of A_4 and B_4, including appropriate carry manipulations

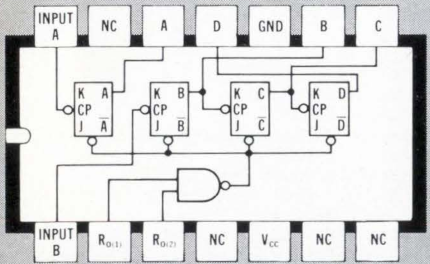
Circle 498 on Reader Service card for data sheet.



SN7492N DIVIDE-BY-12 COUNTER

- Saves 19% over four separate IC flip-flops and gating.
- Operates at 15 MHz.
- Frequency divides by twelve, six, three, or two.
- Simultaneous independent operation of divide-by-six and divide-by-two sections.

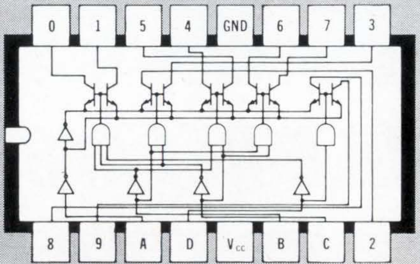
Circle 499 on Reader Service card for data sheet.



SN7493N FOUR BIT BINARY COUNTER

- Saves 16% over four separate IC flip-flops.
- Operates at 15 MHz.
- Ripple through operation provides frequency division by sixteen, eight, four, or two.
- Simultaneous independent operation of divide-by-eight and divide-by-two sections.

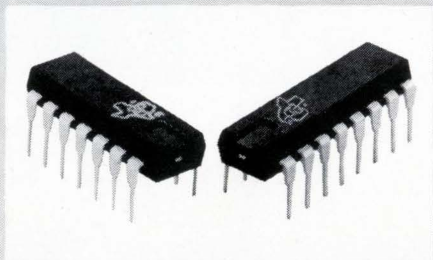
Circle 500 on Reader Service card for data sheet.



SN7441N BCD-TO-DECIMAL DECODER/DRIVER

- Saves 23% over separate IC decoding circuits and driver transistors.
- High-voltage output (65 volt guarantee) transistors directly drive gas-filled readout tubes.
- BCD inputs provided for use with SN7490N decade counter.

Circle 501 on Reader Service card for data sheet.



MOLDED PLUG-IN PACKAGES

All Series 74 TTL integrated circuits—including these five new complex functions—are available in TI's popular molded plug-in package. A new 16-pin configuration (right) is provided for circuits requiring more than 14 pins. Both packages have pins located on standard 100-mil centers. These packages provide highest reliability and greatest ease of handling at lowest possible cost.

Find out how TTL complex-function integrated circuits from Texas Instruments can fit into your programs. Ask your local TI Sales Engineer, or write us at P.O. Box 5012, Dallas, Texas 75222

here's how they can work for you!

all other Series 74 integrated circuits, will enable you to develop new systems faster, at reduced expense.

You also improve system reliability — because the increased circuit complexity per package means fewer soldered joints and plug-in connectors.

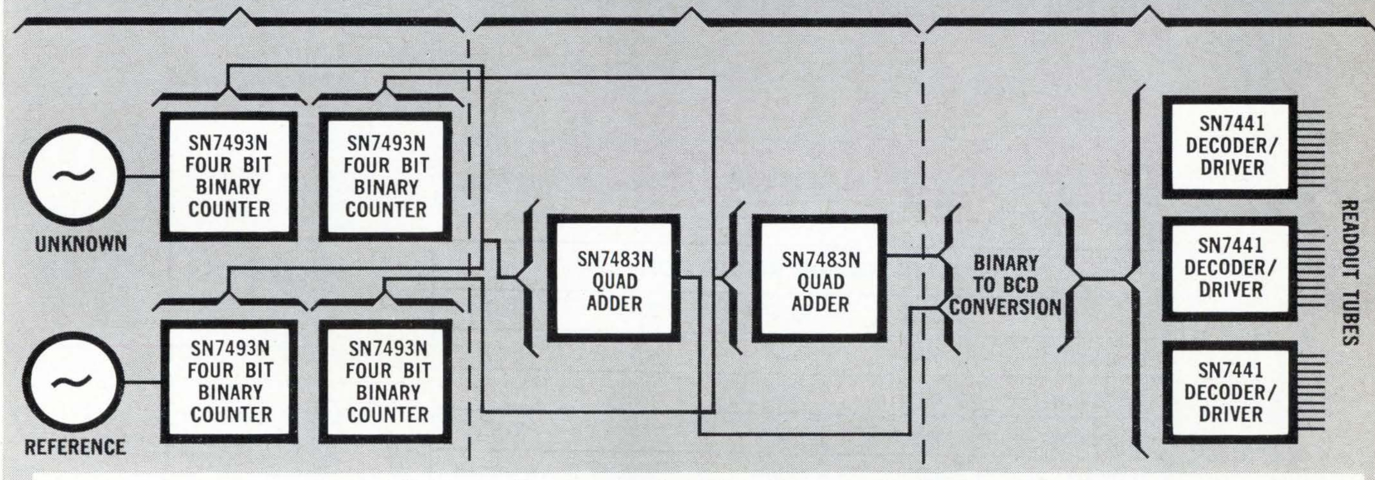
How can these new TI complex-function ICs work for you? For illustration, we have designed the frequency-measuring subsystem shown below, and compared it with a similar subsystem using conventional ICs. The savings realized here will give some idea of what you may expect.

PROBLEM:

To measure unknown frequency by comparing with known reference frequency and displaying difference frequency.

SOLUTION:

(A) count both frequencies	(B) subtract the two frequencies	(C) decode and display the difference



With new TI complex-function integrated circuits:

YOU SAVE...	YOU SAVE...	YOU SAVE...
16% in IC costs	19% in IC costs	23% in IC and transistor costs
75% in number of packages	87% in number of packages	93% in number of packages
168 soldered connections	178 soldered connections	196 soldered connections

HERE'S HOW...

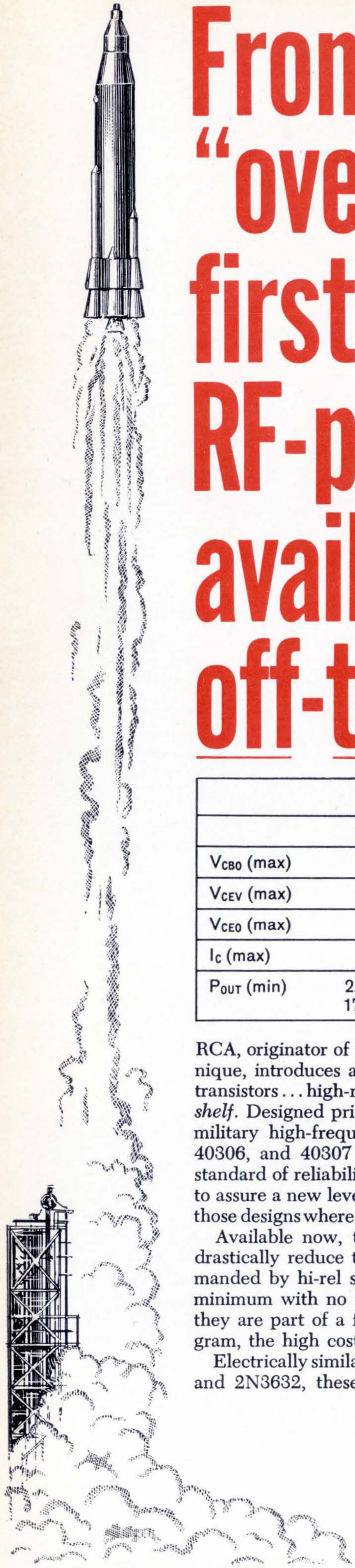
With new TI complex-function integrated circuits, you require:

Four SN7493N four bit binary counters	Two SN7483N quad adders connected to subtract	Three SN7441N BCD-to-decimal decoder drivers
56 pins are to be soldered	32 pins to be soldered	48 pins to be soldered

With conventional integrated circuits you would require:

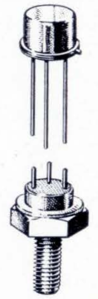
16 single flip-flops	12 quad two-input gates	Three dual four-input gates
224 pins to be soldered	2⅔ triple three-input gates	Six triple three-input gates
	210 pins to be soldered	1½ quad two-input gates
		30 driver transistors
		244 pins to be soldered

TEXAS INSTRUMENTS
INCORPORATED



From RCA "overlay"... first high-reliability RF-power transistors available off-the-shelf

RATINGS FOR RF SERVICE				
	40305	**40306**	**40307**	**Units**
V_{CBO} (max)	65	65	65	Volts
V_{CEV} (max)	65	65	65	Volts
V_{CEO} (max)	40	40	40	Volts
I_C (max)	1.0	1.5	3.0	Amperes
P_{OUT} (min)	2.5W @ 175 MHz	7.5W @ 100 MHz	13.5W @ 175 MHz	



RCA, originator of the revolutionary "overlay" technique, introduces another new concept in rf-power transistors... high-reliability units *available off-the-shelf*. Designed primarily for critical aerospace and military high-frequency applications, RCA 40305, 40306, and 40307 transistors go beyond the high standard of reliability established by RCA "overlay" to assure a new level of confidence... confidence for those designs where device failure cannot be tolerated.

Available now, these three "overlay" transistors drastically reduce the time and effort normally demanded by hi-rel specs... response time is kept to minimum with no delivery problems. And because they are part of a formal RCA high-reliability program, the high cost of "customizing" is eliminated.

Electrically similar to RCA types 2N3553, 2N3375, and 2N3632, these hi-rel devices are designed to meet MIL-S-19500. (Hi-rel selections of "overlay" types 2N3733, 2N4012, and 2N4440 are also available.) Each transistor is subjected to strictly controlled pre-conditioning tests including:

- Fine Leak, 1 x 10^{-8} cc/sec/max.
- Gross Leak, 70 psig, 16 hours min.
- Acceleration Test (2006 of MIL-STD-750, 10,000 G, Y_1 axis)
- Temperature Cycling (MIL-STD-202)
- Power Age (168 hours)
- X-ray Inspection, RCA Spec 1750326

For more information on RCA's "overlay" high-reliability capability, consult your RCA Representative. For technical data on 40305, 40306, and 40307, write: RCA Commercial Engineering, Section IN3-1, Harrison, N.J. 07029.

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Editorial

Credibility gap in hiring

There are more job openings for electronics engineers than there are engineers available and seeking to fill them. That's the conclusion of Electronics' annual survey of employment which begins on page 211. To hear the recruiters tell it, a good engineer with the right specialization can pick a top notch spot anywhere in the country.

But the survey produced one alarming note: fewer and fewer engineers believe what companies tell them about their jobs and their futures. In spite of—or maybe because of—the tantalizing descriptions in advertisements that would have applicants believe that the job is the way to wealth, power, prestige, and paradise, a credibility gap has opened. One executive of a personnel agency reported that some of his engineer applicants were insisting that companies guarantee the jobs will still exist in a year.

The disenchantment with what recruiters promise is part of a bigger picture of business's sagging reputation. Not too long ago, a study at Harvard University concluded that the brightest undergraduates don't want to work in private industry. The students associate industry with some distinctly distasteful characteristics, mainly exaggerated advertising whose claims are overstated or overdramatized, products that are delivered new but in unworkable condition, and unfilled promises of services. So, instead, they seek jobs at nonprofit foundations or in government agencies. An IBM executive complains that his company can't hire the cream of a college graduating class because the top students prefer nonindustrial work.

Fear of being drafted has caused some young engineers to go to work in industry when they preferred other work, but clearly their motivation is the poorest possible.

Unhappily, a lot of companies have earned this distrust. They have hired willy-nilly for a short-term project, completed the work, and promptly laid off the engineers. Then they've gone out and hired a batch of new technical men for a new project. Or a few companies have stockpiled engineers on the chance that they would receive a big contract. When the project went to another company, they promptly dumped the engineers they had so recently hired. Practically none of these defense-business-oriented companies were interested in cultivating long-time engineering employees, training engineers to keep pace with technology, or planning growth to build a solid enterprise.

Too often, a company has jumped on a technical fad, hired a lot of engineers to pursue it, then discovered the company had no management or marketing ability in this area so the executives closed down the entire new operation, throwing the engineers onto the street without warning.

At too many companies engineers have become expendable, like paper clips, staples, and typewriter ribbons. Now management is beginning to pay for this sloppy attitude and haphazard hiring practice.

Not enough companies can boast, as Hewlett-Packard Inc. did in an advertisement last month, that it has never had a layoff. Steady employment has not come easy to this progressive and profitable instrument company. It takes careful planning, painful patience, intimate knowledge of technical trends, aggressive product planning, and superb management. The company may have missed participating in one or two technical areas because its management couldn't be sure the developments wouldn't be just passing fancies, but it is represented in most of the important product lines.

The credibility gap makes hiring more difficult, but there is even a more important aspect that should concern the industry. If an engineer doesn't trust a company enough to go to work for it, will he trust its products in a critical application that could cost him his job? The answer clearly is no.

Thus electronics companies have several urgent reasons to improve their reputations—and quickly. The best method is not with a public relations campaign to improve the image, a favorite ploy in the 60's. What's needed are realistic hiring practices, a business-like approach to planning the company's future, a willingness to train the company's technical people so they can keep pace with technological advances, and a determination to tell the truth about job prospects, product performance, and the company's future.

Some electronics companies have already reached the point where they cannot hire good engineers because their reputations are so bad and they have trouble selling their products. Unchecked, the credibility gap can sink a company.

Electronics Newsletter

March 6, 1967

Litton plans two computers with MOS arrays

Litton Industries is designing two experimental computers based on large-scale arrays of metal oxide semiconductor integrated circuits. Both are in the early stages of development; the more advanced design has recently received financial support from the Air Force.

One machine is essentially a complex of digital differential analyzers that can perform such limited tasks as solving for trigonometric functions. **Designed for aircraft navigation, it could be applied to automatic tool control.** The other machine, planned as either a backup or replacement for the differential-analyzer unit, uses MOS arrays to perform logic and memory functions. **Its design, more advanced and more along the lines of a general-purpose computer, could be expanded to handle target recognition or fire control.**

Both designs depend heavily on the development of highly reliable, easily reproducible MOS arrays. Litton has asked Philco-Ford and General Instrument to prepare experimental circuits.

The two circuit makers are acting as consultants to Litton. Both received specifications for the production of a limited quantity of test arrays designed to be quickly tested with a single probe. Litton's plan is to determine quickly the expected yield (the number of usable functions on an array) that will result from the still-infant MOS technology.

For the more advanced machine, called a block-oriented computer, **Litton engineers haven't decided whether to use single or two-layer metalization to interconnect the circuits within the wafers.**

The major reason for turning to the MOS arrays is reduction in cost, size, and power needs. It's estimated that the price of a production-model MOS computer would be about a tenth the cost of a computer using bipolar devices; the size would be reduced by a factor of 5 to 10 and the power needs would be cut by a factor of from 100 to 1,000.

Scr's power rises but prices hold

The power-handling capability of low-cost silicon controlled rectifiers is continuing to rise, making them more attractive for use in consumer appliance. Motorola Semiconductor Products has just introduced an 8-ampere, 600-volt scr—one of a series of four plastic-encapsulated types. The scr's, 2N4441 through 2N4444, **are rated at 8 amperes root-mean-square forward current and have blocking voltages ranging from 50 to 600 volts.** Typical gate current is 10 milliamps. In quantities over 100, they cost from 80 cents to $3. General Electric's C106 series of plastic-encapsulated scr's cost about the same. However, the highest power unit in GE's line, which has probably had the giant share of the consumer scr market, is rated at 2 amperes, 300 volts.

Patent reform hits a snag in court

Just as the Administration's patent reform bill was being sent to Congress late last month, **a Federal court handed down a ruling that threatens to stir up a new controversy over patent jurisdiction.**

The bill, containing sweeping proposals to end the long and costly court battles, calls for ultimate jurisdiction by a regional court. But the U.S. Court of Claims, ruling in behalf of Technograph Printed Electronics, said a patent judged invalid in one court case can be brought up in another case.

Technograph, whose main business is to exploit its patents and licenses, had lost its battle for back royalties on printed circuits from Bendix [Electronics, Nov. 2, 1964, p. 23]. Now the firm has been given the green light to sue the Government, as purchaser of circuits, and others over the same patents as in the Bendix case. **Outlook: the controversy is likely to embroil the Supreme Court as well as Congress.**

Peak laser pulses top billion watts

Peak powers greater than a billion watts have been achieved with an experimental two-stage Raman-effect laser that uses reverse pumping. The work, done at Gaithersburg, Md., by the International Business Machines' Federal Systems division, has produced pulses as short as ⅓ nanosecond. Although the in-house effort is a long way from application, IBM believes an optical system based on the development could enable precise tracking of orbiting spacecraft.

FAA will test "inexpensive" anticollision unit

A new proximity-warning system, designed by the National Co. of Melrose, Mass., will be flight-tested this spring by the Federal Aviation Administration. **The system is being considered for use by planes flying the North Atlantic routes.**

National's design is hardly a full-fledged collision-avoidance system, but it can warn a pilot if another aircraft comes within 60 nautical miles in any horizontal direction and within 1,500 feet in either vertical direction. **It'll cost considerably less than the estimated $50,000 unit price of a collision-avoidance system,** which would use either cooperating ground stations or highly accurate time-frequency techniques.

With an expected accuracy of within 1 mile, the National system is adequate to maintain safe separation between planes flying over the ocean. For the dense overland routes, better accuracy is needed.

Production woes beset Philco-Ford

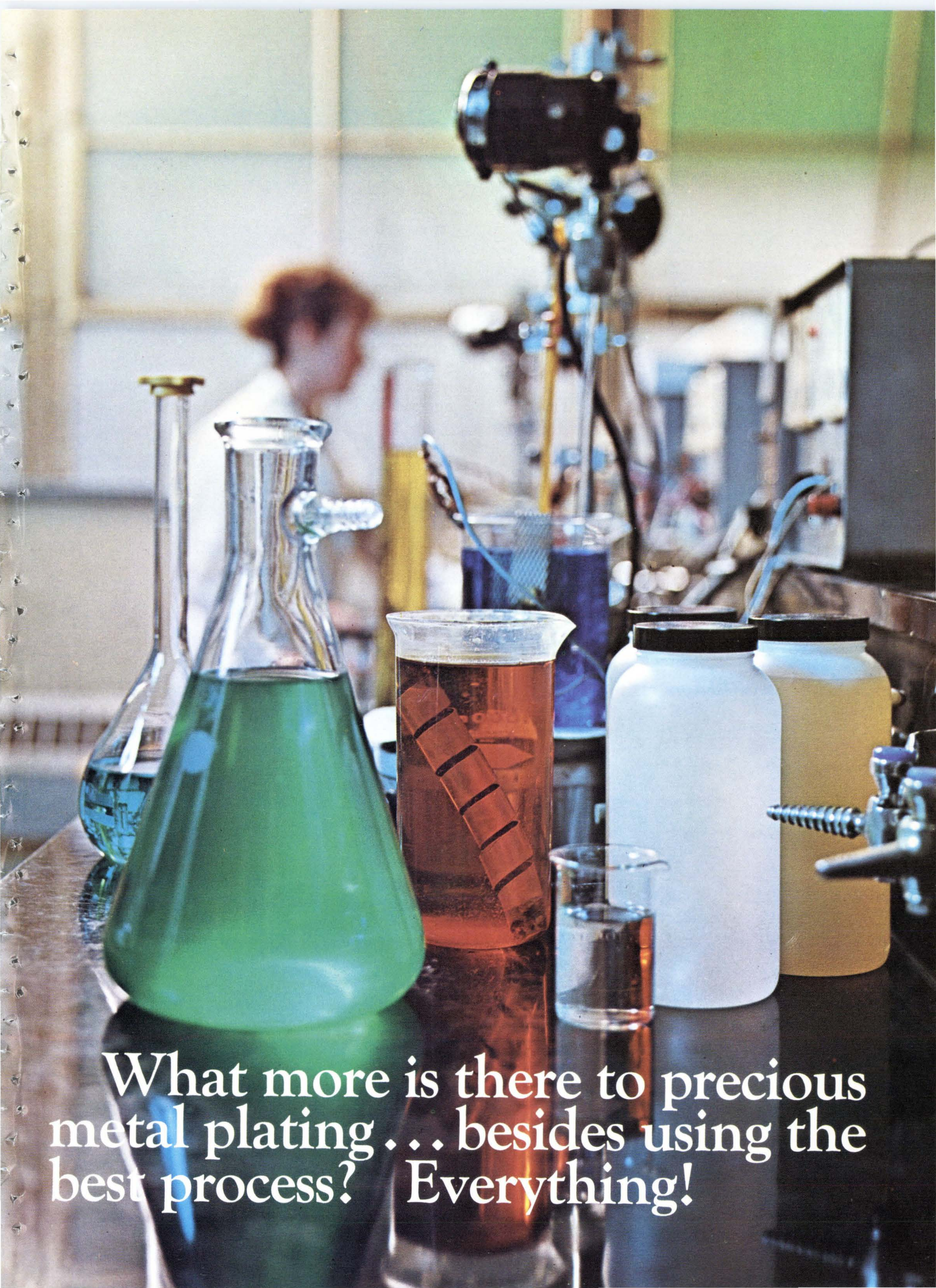
Though it is not yet out of trouble with its integrated-circuit calculator (see story on p. 31), the Santa Clara, Calif., operation of the Philco-Ford Corp.'s Microelectronics division **has a new worry with one of its major programs in bipolar integrated circuits.** Because of production difficulties, the plant has been temporarily suspended as a qualified source on the National Security Agency's classified R-13 program. Santa Clara was making milliwatt resistor-transistor logic for the project. **According to insiders, unless the suspension is lifted, the plant will have to lay off a large percentage of its 1,200 employees.** Although Philco-Ford executives have admitted having a problem, **they say no layoff** is now planned. Nearly 60% of Santa Clara's output is in bipolar IC's.

The troubles are in the deposition of aluminum metalization. **If the suspension on the Santa Clara plant continues, Philco-Ford will shift all its bipolar production to a sister plant in Lansdale, Pa.,** which currently is also producing circuits for the security agency project. Ironically, Philco had wanted to switch bipolar production there a year ago, but the agency opposed the idea.

Transit bids

The Westinghouse Electric Co. was the apparent low bidder for the train control and communications portion of the San Francisco area's rapid-transit system. The bid, for $26.2 million, must now be studied to make sure it meets specifications. Official word is expected March 23.

Circle 27 on reader service card→



What more is there to precious metal plating . . . besides using the best process? Everything!

"We don't disappear once we sell you the process."

If precious metal electroplating could be learned from a set of textbook rules, half the need for service would vanish.

But since electroplating is a dynamic, living thing, a blend of skill and science, optimum results depend on more than just a process.

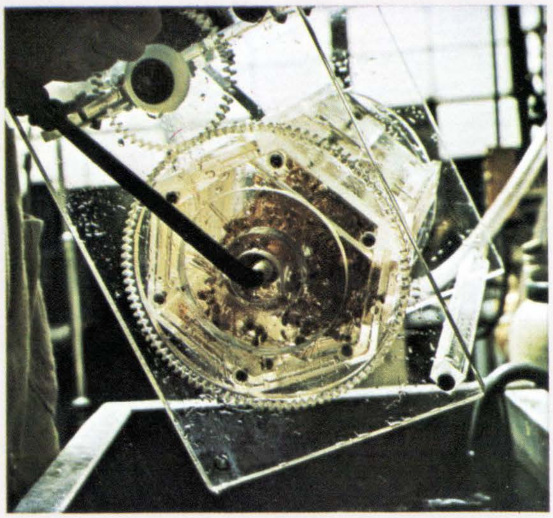
That's why Sel-Rex offers a "total approach". One that guarantees consistent reliability. Maximum production.

Such an approach *starts out with* the best process for your product. (Sel-Rex probably has the best process for you because Sel-Rex has the greatest number of precious metal electroplating processes.)

And if we don't have a process that's just right for you, we'll develop one.

You'd expect that from the company that developed the first bright gold, the first acid gold, and the first non-cyanide gold processes for industry.

Prototype Plating Service



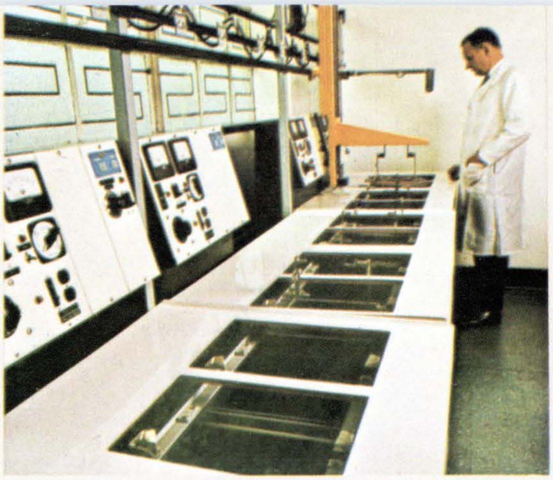
Bring us your product, and we'll conduct process studies for you aimed at satisfying your specifications. (Last year we were involved in evaluating *over 5000* high-reliability electroplating applications.)

Whether you have an in-plant plating operation or a job shop, we'll help you select a process and we'll run a sufficient number of samples to prove out the process.

We'll recommend the proper type of plating equipment, supply it if you need it, provide information on plating procedure and process control, and offer technical information on the maintenance of the bath.

If you've re-designed a product and it's not going through the cycle properly, our prototype plating service will check it out for you.

Or if your product can't be plated with standard equipment, we'll help design new equipment for you—just as we designed the special type of plating barrel that made transistor plating a routine operation.

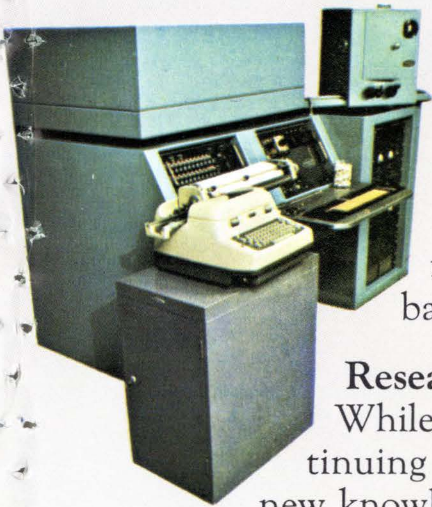


Matter of fact, the Meaker Company (a Sel-Rex subsidiary), is responsible for many widely-accepted advances in rectifier and control circuitry, and in manual and automatic equipment design. A number of these are still exclusive with us.

Preventive Maintenance

Once you're set up and running, we'll help you continue running properly—with preventive maintenance.

We'll backstop your control procedures in our analytical labs.



Every month we'll double-check samples from your plating baths with our direct emission spectrograph *and* our X-ray spectrograph. (In about 2½ minutes we obtain analyses of 22 elements in your sample.) We also check for non-metallic constituents, efficiency and other physical values.

Within 48 hours of receipt of your sample, we'll put our analysis in the mail to you. If the sample reveals less than optimum conditions, we'll offer recommendations for improving the bath's plating performance.

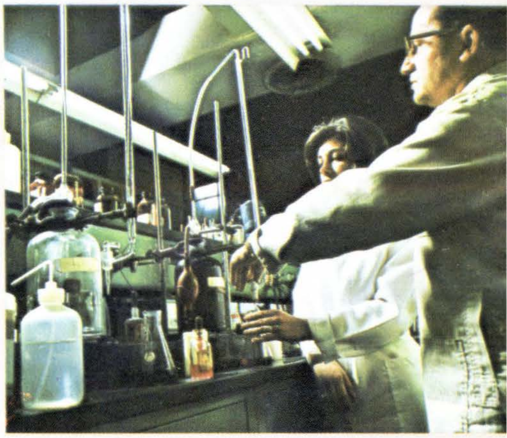
Research for your needs

While all this is going on, we'll also serve you indirectly through continuing research; and we'll make available to you the results of our new knowledge.

Our research spans the full spectrum from extremely high purity gold deposits to the relatively unexplored areas of low karat gold.

For example, we've developed several low karat gold alloy processes that perform the same functions, at lower cost, in certain applications, as high-karat deposits.

And though we're best known for our work in gold, we've made and continue to make significant contributions in rhodium, silver, platinum and palladium plating.



The final step

One other thing. If you use precious metal, you are bound to generate scrap. When we handle your scrap salvage, you can be sure of a complete refinery service with full technical facilities. Including, under one roof, a fire assay laboratory, instrumentation laboratory, and laboratory facilities for wet chemical analysis and electrolytic methods of analysis.

Fact is, when it comes to research and technical service, Sel-Rex has more people involved than anyone else in the field.

Any questions?

We keep some powerful experiments quiet.

Fuel cells don't have to be noisy.

We developed one for the Army that you can't hear only 100 feet away. This 300-watt cell should produce 28 VDC for more than 1000 hours without special attention.

Yet, complete with cell stack, blower, pump, starter and voltage regulator, it weighs only 30 lbs.

Fuel cells are the lightest, most effective, non-mechanical devices yet discovered for generating electric power.

We make them in all sizes.

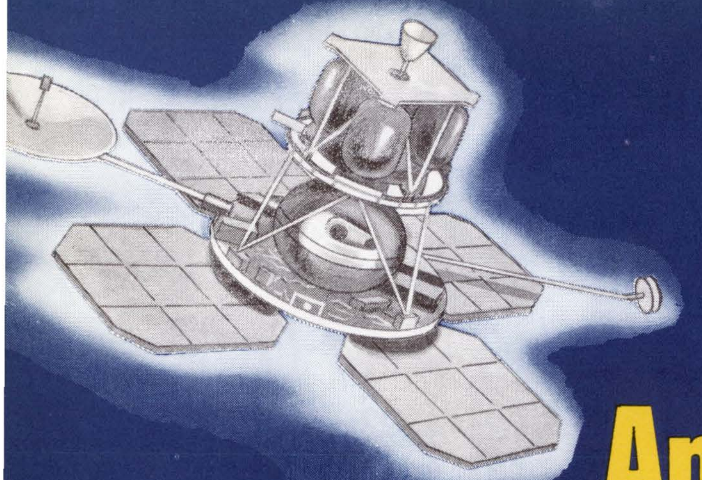
But fuel cells are only one of the activities that keep Union Carbide up front, on the frontiers of electronics. For instance, among other things, we're leaders in research, development and production of single crystals and crystal products; solid tantalum and foil-film capacitors; laser systems and accessories; solid state devices.

These are among the reasons to think of Union Carbide for help before your projects get beyond the talking stage.

UNION CARBIDE
ELECTRONICS

Union Carbide Corporation, Electronics Division, 270 Park Avenue, New York 10017.

Circle 31 on reader service card



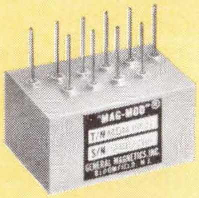
G/M COMPONENTS have proven to be superior in function and reliability of operation in thousands of military, space and commercial applications, including aircraft automatic flight control, guidance, weapon systems, fire control, missile and space vehicle flight and stabilization control, pressure-volume-temperature control of gases and liquids.

They conform to MIL-T-27 and MIL-E-5400 specifications, and provide a ready solution to problems involving solid state—integrated or micro circuit—analog computer design. Call or write for Bulletins.

Analog Computing

Magnetic Division Modules

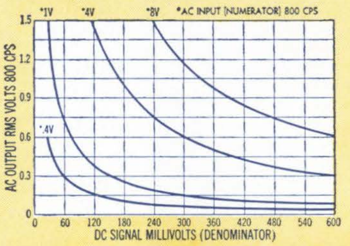
ACCURACY OF 1% OR BETTER!



These Analog Division Modules employ a concept which eliminates high gain operational amplifiers and logarithmic circuitry used in electronic dividers. The result is fewer components, excellent stability, micro-miniature size, lower cost. The combination of magnetic and semiconductor circuitry results in analog division accuracy of 1% or better.

FEATURES:

Micro-miniature Size
Completely Solid State
Low Power Consumption
Wide Numerator and Denominator Ranges

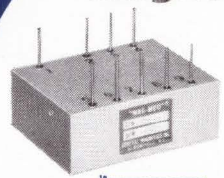


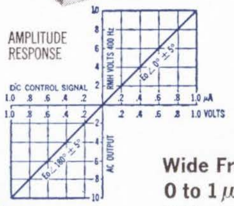
REQUEST BULLETIN MM 110

NANO AMP LEVEL

Current Sensing Magnetic Modulator

ULTRA LOW LEVEL—HIGH STABILITY!





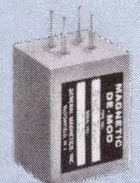
This G/M extremely low level signal current magnetic modulator operates from 0 to ±1 μa DC full scale with a frequency response of 0 to 100 cps minimum for a carrier excitation of 400 cycles. Excellent zero point, amplitude and phase angle stability with respect to line voltage, frequency and temperature range.

FEATURES:

Wide Frequency Response (over 100 cps)
0 to 1 μa DC Full Scale Input
Drift: Less than 10 Nanoamps referred to Input Terminal
Input Resistance 1 Megohm
Complete Solid State Magnetic
Rugged, Unlimited Life

Magnetic Demodulators

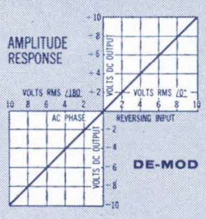
HIGH RELIABILITY—SMALL SIZE!



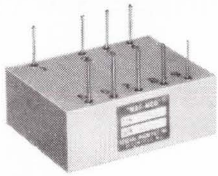
The new G/M Magnetic Demodulator is a solid state circuit for converting phase reversing AC signal voltages into phase detected polarity reversing DC voltages. The amplitude and polarity of the DC output are directly proportional to the phase and amplitude of the AC signal. High reference impedance results in very small reference power requirements.

FEATURES:

Output as High as ± 10 v. DC in Present Units
Very Low DC Offset Null Voltages (As low as 0.1% of full scale)
Operation Over Wide Environmental Conditions
Completely Solid State—No Moving Parts



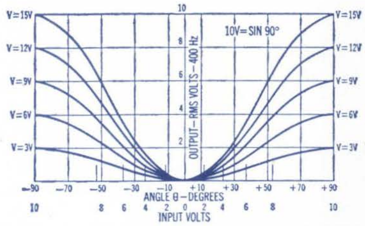
REQUEST BULLETIN MM 108



$E_o = V \sin^2\Theta$

EQUATION SOLUTION ACCURACY—2% fs

A micro magnetic multiplier and squaring block assembled with appropriate semiconductor-transfer gain to solve the indicated expression. Micro miniature, solid state microblock design features high accuracy, extremely stable operation through the application of micro magnetic stages in cascade circuitry.



FEATURES:

Operates over Wide Environmental Ranges
Unlimited Life, Low Milliwatt Power Level
Wide Frequency Range
Wide Dynamic Computing Range

REQUEST DESCRIPTIVE LITERATURE

THERE IS NO SUBSTITUTE FOR RELIABILITY

GM INC.

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THE NEW IN ELECTRONICS IS MUCH MORE THAN PRODUCT

IDEA

It's the right electronic component plus a trained and experienced marketing man working on your team

Straight talk! The new idea in electronics starts with a man—a man with a unique orientation to the special needs of your business.

He's more than a salesman. He's an expert oriented to your markets and to your business problems. He's not just looking for ways to replace the old with a new component; his responsibility is to find new ways electronically to do things for your business. He's business oriented. He's new idea oriented. He's new product oriented. He's customer oriented.

He's backed by General Electric's total electronic capability—in-depth technical backup assistance and the biggest (by far) product market basket in the world. You name it, and it's available through this one man. To mention just a few of the component types he offers:

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- epoxy transistors
- general purpose motors
- full-line receiving tubes
- aluminum electrolytic capacitors
- silicon, selenium, germanium rectifiers and stacks
- Volt-Pac* variable transformers
- microwave ceramic tubes
- foil and wet slug tantalum capacitors
- integrated circuits
- sealed relays
- five-star military tubes
- signal diodes
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He's your Electronic Components Sales Operation District Sales Manager—your single source for almost any electronic component requirement. He's located in every major market area.

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ELECTRONIC COMPONENTS SALES OPERATION

GENERAL ELECTRIC

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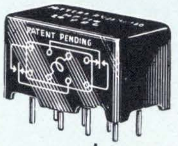
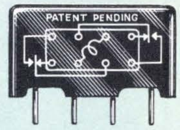
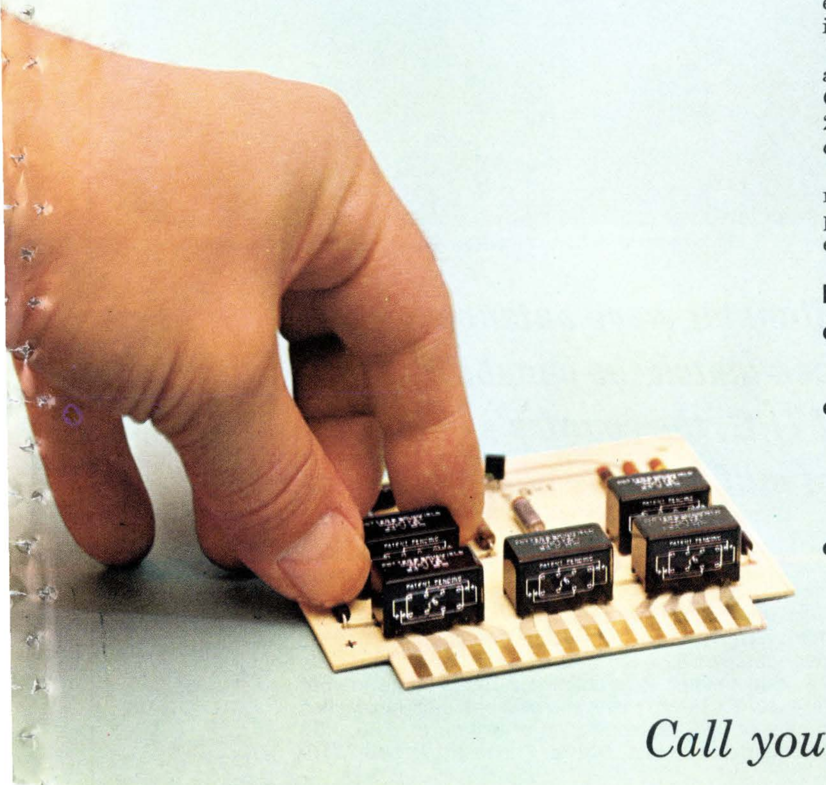
Circle 35 on reader service card

 Circle 36 on reader service card

Circle 37 on reader service card →

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



High density relay packaging becomes a reality with the low profile HP Series. Only one-fifth of a cubic inch is required for each relay. Seated height in socket or printed circuit board is 0.49″. Mechanical life is placed at 10 million operations.

The DPDT contacts are rated from low level to 2 amperes at 30V DC resistive or 0.5 ampere maximum at 120V AC. Coil voltages range from 6V to 48V DC . . . with 12- and 24-volt models available from authorized electronic parts distributors.

These microminiature relays are direct descendants of our military, aero/space designs and have been engineered to perform with singular reliability in modern commercial equipment.

HP SPECIFICATIONS

GENERAL:
- **Temperature Range:** −45°C to +70°C.
- **Dimensions:** 0.49″ x 0.88″ x 0.48″ max.

CONTACTS:
- **Arrangement:** DPDT, 2 Form C.
- **Rating:** Low level to 2 amps @ 30V DC, resistive; 0.5 amps max. @120V AC.
- **Contact Resistance:** 50 milliohms before life measured at maximum rated load.

COILS:
- **Power:** Approximately .662 watts nominal @ 25°C. 1.0 watts max. @ 25°C.
- **Duty:** Continuous.
- **Pick-up:** 75% of nominal @ 25°C.
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Call your electronic parts distributor

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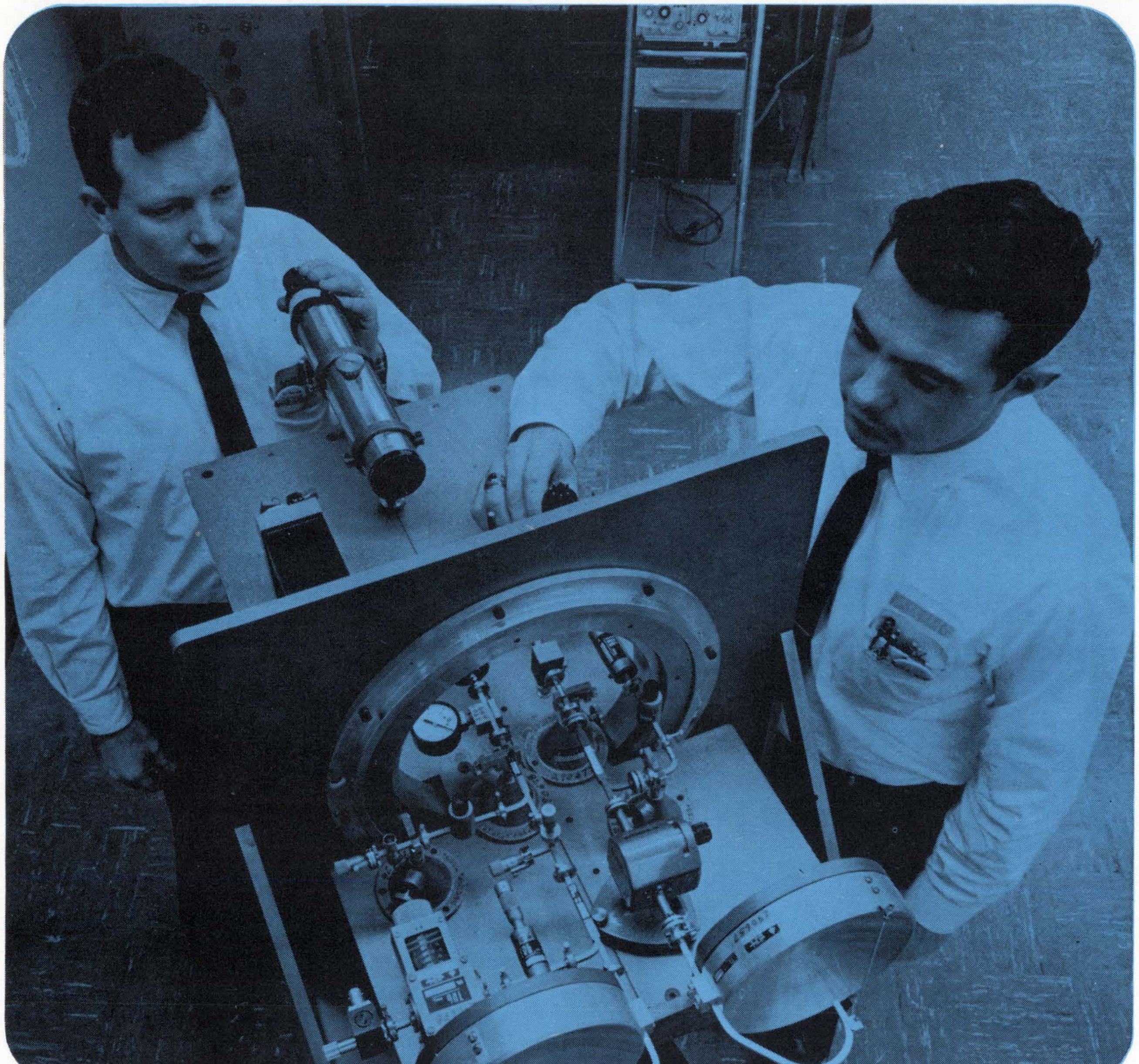
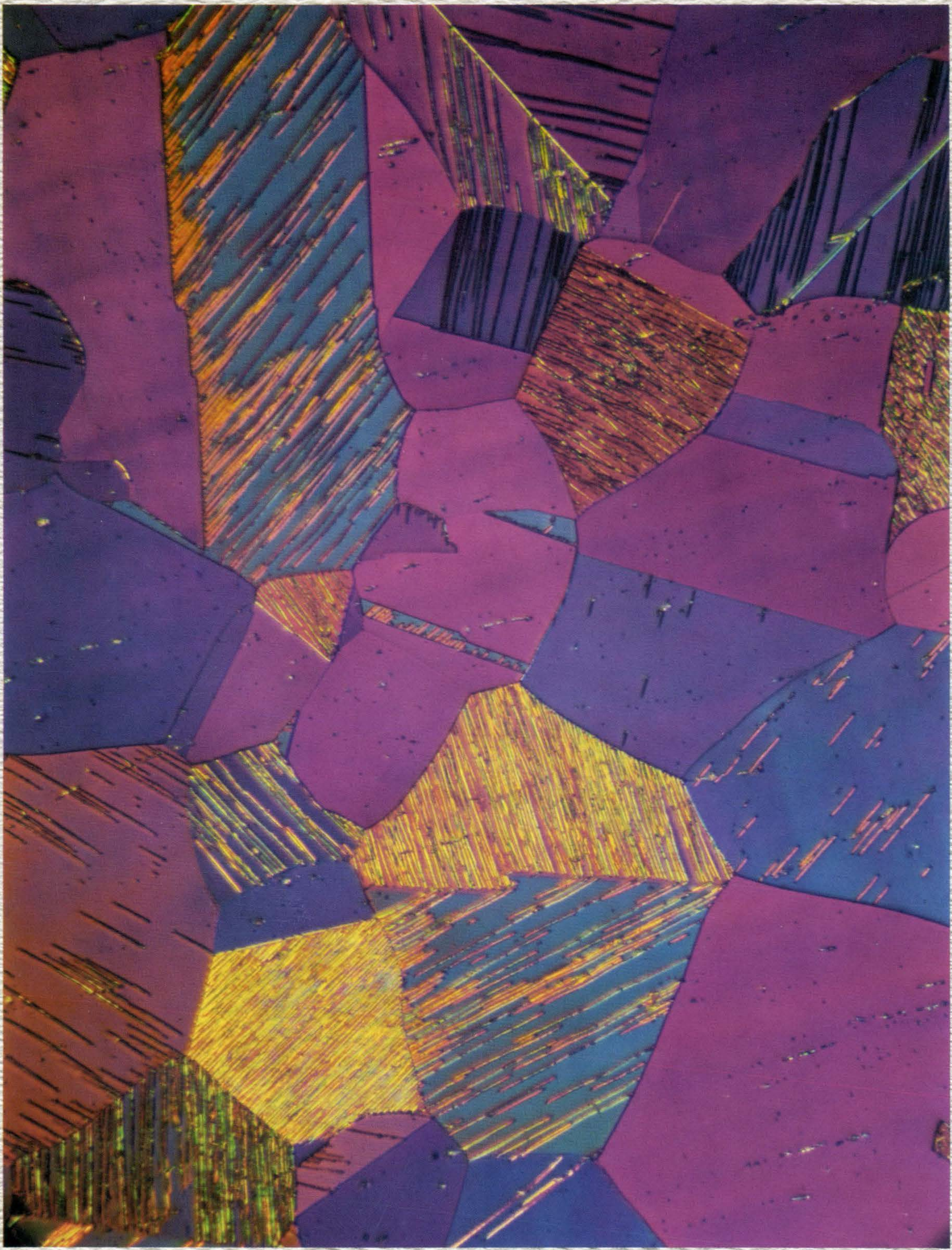


3.2-mm 10-Kw Pulsed Radar System For Target Analysis Studies — Photo courtesy of North American Aviation, Inc., Columbus Division

Please be seated...

BAUSCH & LOMB



Specimen: Austenite (6% manganese, 1% carbon, 93% iron).
Rolled, quenched in brine from 2000°F. Etched with Vilella's reagent.
Original magnification: 100×.

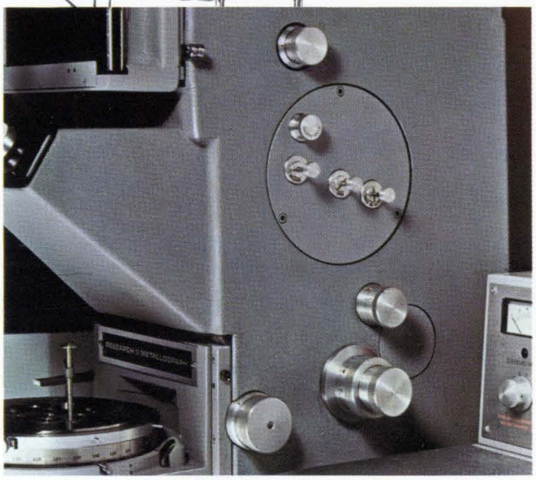
Specimen prepared by and photographed on the new Research II Metallograph by Prof. Joseph R. Vilella, Department of Metallurgical Engineering, School of Mines, University of Pittsburgh.

BAUSCH & LOMB

...and create

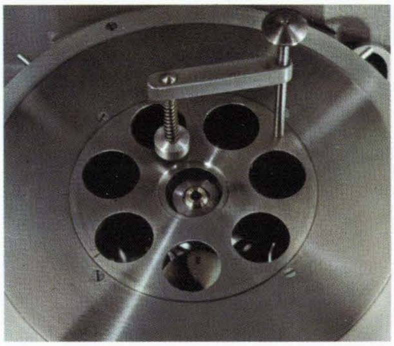
outstanding photomicrographs like this on the

NEW BAUSCH & LOMB RESEARCH II METALLOGRAPH



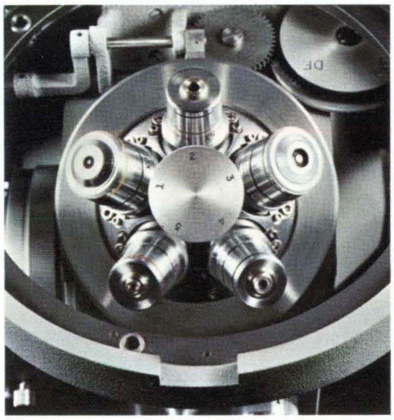
All features you want are built-in, at your fingertips. They can be used while you're comfortably seated. Conveniently reached control zone. Focusable stage. .5× -3× zooming variable magnification. Exclusive high-power stereo viewing. Visual observation, projection or photomicrography. Built-in shutter controls. Selector for transposable camera and viewing screen.

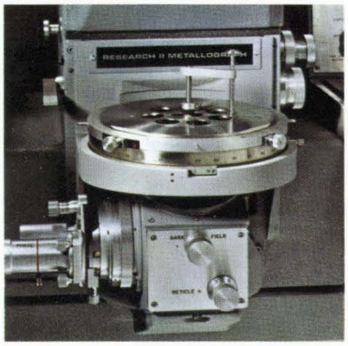
Close at hand . . . the quickly-interchangeable combination xenon-tungsten light source. Highest-intensity, long-life xenon, best for bright field, dark field, stereo, polarized light, sensitive tint and projection. Tungsten ideal for visual and photomicrographic work.



Everything is faster, easier, handier to use. Low-positioned inverted stage is at correct, table-top level. Operation of interchangeable stage plates and traversing controls is simple and effortless.

New flat field objectives for bright field, dark field, polarized light and phase contrast; give highest quality results. Individually-centered, parfocalized objectives selected by turning quintuple nosepiece. No handling of objectives—eliminates danger of dropping—smearing. Focus is automatic. Focus and resolution are uniform across entire field.



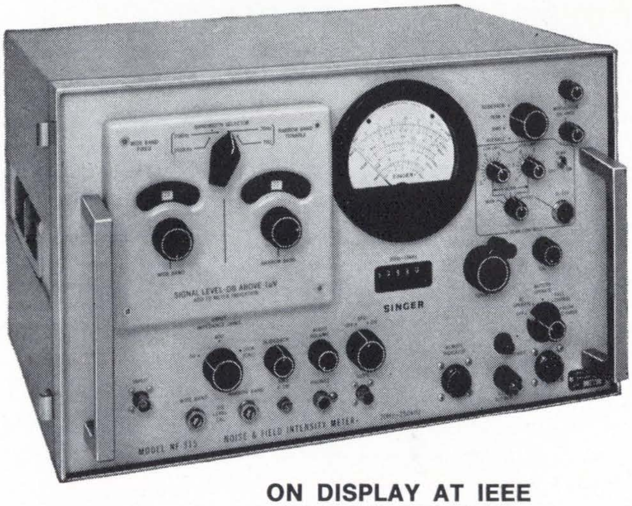


The exclusive Bausch & Lomb Foster Calcite Prism . . . your assurance of the finest results in polarized light . . . also provides vertical illumination for built-in bright field, sensitive tint, phase contrast and high power stereo viewing. A second prism produces an optimum level of dark field illumination.

An integral exposure meter removes guesswork—lets you turn every film into a properly exposed photomicrograph with optimum contrast, high resolution. Within arm's reach is the built-in desiccator cabinet—a moisture-free area for safe storage of normal size and most frequently used specimens.

AUTOMATIC SCANNING FOR EMI MEASUREMENTS from 20-15,000 Hz WITH THE APPROVED ONE

*EMPIRE** Noise and Field Intensity Meter



ON DISPLAY AT IEEE BOOTHS 2B25-2B30

Solid-State, Compact and Lightweight Model NF-315A is preferred by military and civilian government agencies, and major aerospace contractors for rapid and precise EMI measurements. Here's why:

- Three scanning modes: manual, sector, and single sweep over the complete frequency range
- Three separate calibrated scales — peak, average and RMS
- 180 db signal range
- 0.005 μv sensitivity
- 7 or 70 Hz bandwidth selection
- Reliable scanning at maximum sensitivity
- >70 db spurious response rejection
- Internal frequency and amplitude calibrators for on-the-spot checking without disconnecting signal input leads
- Highly stable circuits eliminate recalibration when tuning to new frequencies
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Write for complete technical data; better yet, call for a demonstration.

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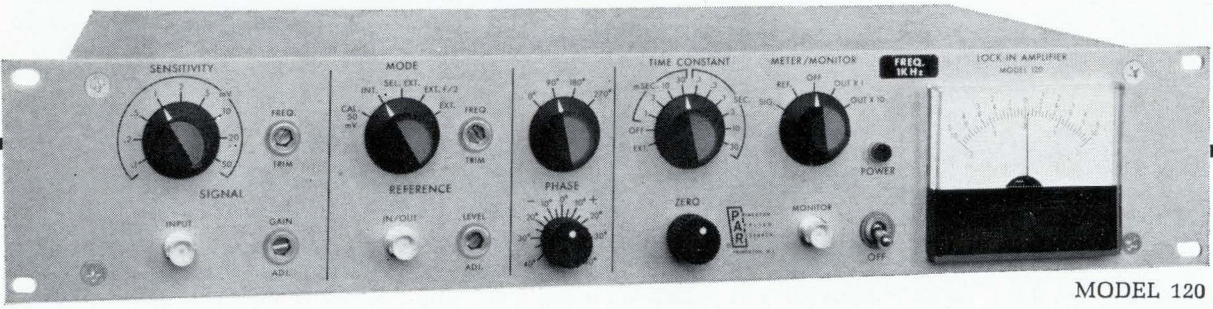
E-67-1

MODEL 121

New PAR Lock-In Amplifiers Recover Low-Level Signals from Noise



MODEL 120

Model 120 is a fixed frequency unit which allows the benefits of phase sensitive detection to be achieved at an economical price. Representative specifications are:

FREQUENCY RANGE: 5 Hz to 150 kHz. Frequency is determined by two plug-in circuit boards, each of which contains two or four (depending upon frequency) resistors and two capacitors. Plug-in frequency determining boards for any particular frequency in the above range can be ordered from PAR or the user can change frequency by changing the resistors and capacitors on the two plug-in circuit boards. A front panel vernier adjustment functions as a fine frequency control.

SIGNAL INPUT CHARACTERISTICS: Single-ended input of 10 Megohms shunted by 30 pF. Selectivity characteristic is that of a parallel resonant circuit with a Q of approximately 10.

SENSITIVITY: 100 μV to 50 mV rms full scale in a 1, 2, 5 sequence. Output X10 monitor position increases meter sensitivity by factor of 10 on any range.

FILTER TIME CONSTANT: 1 mS to 30 seconds in a 1, 3, 10 sequence and EXT position. 6 dB/octave roll-off rate.

OUTPUT: $\pm$ 10 volts full scale, single-ended with respect to ground.

PRICE: $765.00.

Export Prices approximately 5% higher, (except Canada).

Model 121 is continuously tunable throughout its entire operating frequency range. It provides the versatility required for use in many sophisticated research applications. Illustrative specifications are:

FREQUENCY RANGE: Continuously tunable from 1.5 Hz to 150 kHz in 5 ranges.

SIGNAL INPUT CHARACTERISTICS: Single-ended input of 10 Megohms, shunted by 20 pF. Adjustable Q from 5 to 25 over the entire frequency range.

SENSITIVITY: 10 μV to 500 mV in 1, 2, 5 sequence. Output X10 monitor position increases meter sensitivity by factor of ten on any range.

FILTER TIME CONSTANTS: 1 mS to 100 sec. in 1, 3, 10 sequence and EXT. position. 6 or 12 dB per octave roll-off.

OUTPUT: $\pm$ 10 volts full scale, single-ended with respect to ground.

VOLTMETER MODE: Internal demodulator reference signal derived from signal to be measured. Unit operates as average responding AC voltmeter with overall sensitivity unchanged.

PRICE: $1,600.00.

Export Prices approximately 5% higher, (except Canada).

For additional information write to Princeton Applied Research Corporation, Dept. D, P.O. Box 565, Princeton, New Jersey 08540. Telephone: (609) 924-6835.

PRINCETON APPLIED RESEARCH CORP.

Electronics Review

Volume 40
Number 5

Companies

Follow the leader

Even in a business as used to management raids as the semiconductor industry, the grabbing of five top executives of giant Fairchild Semiconductor by little National Semiconductor Corp. is startling.

In fact, National's chairman, Peter Sprague, seemed a bit overwhelmed after hiring Charles E. Sporck, former general manager of the Fairchild Camera & Instrument Corp., division, and naming him president. As an added windfall, four of Sporck's cohorts at Fairchild followed him to National. They are: Pierre Lamond, integrated circuit manager; Fred Bialek, director of international operations; Roger Smullen, IC manufacturing manager; and Floyd Kvamme, marketing product manager for IC's.

Fairchild wasted no time in trying to repair the damage, appointing Tom Bay, its Instrumentation division manager, to head the Semiconductor division.

Described by Sprague as the latest in a series of moves to strengthen and expand the Danbury, Conn., semiconductor firm, he said the addition of the Fairchild group is expected to have a negative effect on company earnings initially, but is part of a four-to-five-year growth plan. "Right now, we have a lot of chiefs and only a few Indians," Sprague commented.

Asked if the five Fairchild executives were hired as a group, Sprague noted that Sporck "is pretty much of a leader and when it became known that he was leaving, the others asked to come with him." He called their arrival late last month "somewhat of a surprise."

As to definite plans regarding the group, Sprague said they had not been accurately worked out as yet. But the additions do mean that National will expand its hybrid-integrated-circuit operations in Danbury and monolithic-IC work in Santa Clara much faster. After it firms up plans, National will seek new financing, Sprague said.

Other recent additions are Ken Davis, West Coast sales manager for Texas Instruments Incorporated; Ken Moyle, leader of an integrated circuit development group at the Hewlett-Packard Co.; and John F. Hughes, a financial vice president at the Perkin-Elmer Corp. Davis will become marketing manager of National, and Hughes will become chief financial vice president.

All of this talent, except for Hughes, is currently clustered at National's Santa Clara, Calif., operation at what used to be called Molectro, Corp., before National bought it year and a half ago. Molectro employs about 50 persons.

National's main business is in discrete components, although it recently introduced a line of its own linear IC's. The company holds licenses from Fairchild. "Our plans are not completed in terms of what circuits we will make," Sporck said. "Planning is our first step."

Jack F. Hegarty, National's president for the past six months, will take over Danbury operations and product marketing, according to Sprague.

Both Fairchild and Sporck said that the parting of the ways was friendly. "The reason we left," Sporck said, "was that the attraction of working with a small company was just too great."

Fairchild group vice president Robert N. Noyce says the loss of five top men won't hurt Fairchild's operations. "You ask me how I am and it's a little like 'aside from that, how did you like the play, Mrs. Lincoln," he grinned. "And to be honest, last week I did feel a little low. But Fairchild is not just a few people; we're not scraping the bottom of the barrel for talent."

Computers

Soft hardware

For years the Stanford Research Institute has been studying ways of organizing integrated circuits in standardized arrays that could be used as computer building blocks. Theory may soon become practice with a plan to program the functions of IC arrays by external electrical signals.

The institute is now seeking funds to fabricate experimental computers with arrays. A 64-cell model array was designed by Sven Wahlstrom of the institute's computer techniques lab. Each cell will have a working structure, or "base," of 13 logic gates, plus 13 flip-flops that will be switched on or off by programing signals to control data flow through the arrays and processing by the logic circuitry.

One cell, for example, might be set up as a NAND gate with any number of inputs up to seven. Several cells would then be combined to form a subsystem, such as an adder. The flip-flop could later be switched by a new program to form another type of logic function, or the other functions could be programed into duplicate arrays.

In the past, the institute's scientists have concentrated on cellular arrays organized by cutting or adding wiring, an approach that resembles the methods IC manufacturers are now using to make large-scale arrays. The institute has also studied such techniques for altering arrays as shining light through a mask onto photoconductive switches in the array. But the new design is the most flexible yet

—the array's function can be controlled through only two leads.

MOS for more cells. Wahlstrom and an associate, Bruce Clark, have decided to use metal-oxide-semiconductor circuitry. Layout is simple, Clark explains, and the small size of MOS devices allows large arrays—probably larger than 64 cells per chip in the future. Several semiconductor companies near the Menlo Park, Calif., lab have checked the design and found it feasible for production, Wahlstrom says. Clock cycle will be 2 megahertz, slower than most logic circuitry but fast enough for good computers.

Single-chip arrays are needed to fit the building-block concept. If mass-produced, the blocks would be far less expensive than custom arrays made with fixed wiring, Wahlstrom notes; custom arrays can cost as much as $30,000, depending on the number of computers made. Wahlstrom thinks the standardized arrays might cost as little as 5% as much as custom arrays, though over-all systems savings wouldn't be that great. If fewer than 500 computers were built in a production run, the savings would be significant, he says.

Programs for chips. Programing the building blocks would add little to system design costs, Wahlstrom believes. As the computer is designed, the logic designers would list cell logic functions and record them in code on magnetic tape. When the computer is turned on, the tape would be the initial input to the computer, setting up the functions.

Because logic IC's require power to retain switch positions, the program tape would have to be rerun each time the computer is turned off and on, or standby power would have to be provided by a battery during the time the computer is turned off.

The control circuits would operate like an X-Y switching matrix, using one set of input signals for X and another for Y. These signals would enter the array as serial bit streams and would be passed on to the cells by a cluster of input circuits at one corner of the chip.

They initially go to the cell in the corner of the chip farthest from the input. That cell decodes the signals that set its switches, and this decoding and switching process then works back, cell by cell, to the input. Clear paths for reprograming signals can be left in the array.

Communications

Phone-a-train

Before the year is out, rail travelers will be able to make telephone calls while zipping along at speeds of up to 160 miles an hour from New York City to Washington, D.C. Telephone booths are being installed on Budd Co.-built cars to be put into service by the Pennsylvania Railroad in the first test of advanced data links planned for rapid-transit systems [Electronics, Jan. 23, p. 59].

Expected to start in October, the test will be one in a year-long series of Northeast Corridor demonstrations sponsored by the Office of High-Speed Ground Transportation (soon to become part of the newly formed Department of Transportation). The Northeast Corridor is the high-traffic-density sector from Boston to Washington, where improved rail service is sought.

The Pennsy, prime contractor for the New York-to-Washington test run, will use 30 electric-powered parlor and snack-bar cars equipped for phone service — actually, a radio-telephone setup.

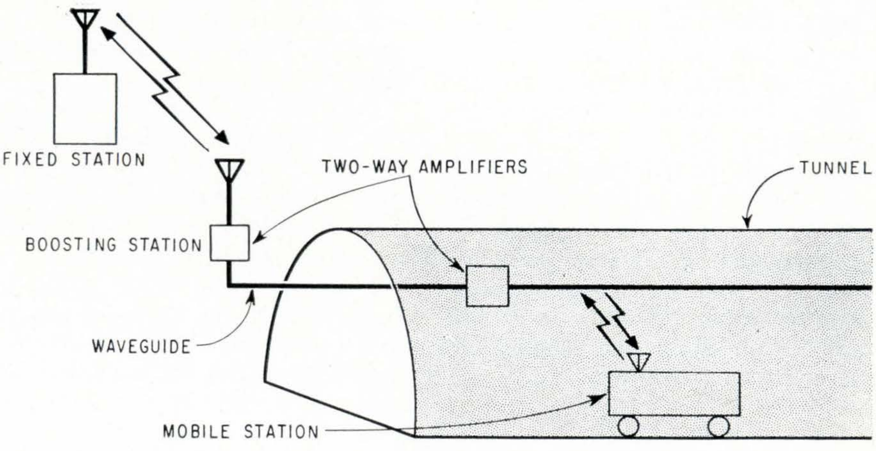
No cross talk. The American Telephone & Telegraph Co. will provide the radio-telephone service. Sixteen Government frequencies—8 mobile and 8 wayside—in the 400-megahertz band will be used. Each channel will be 100 kilohertz wide, and a 1-Mhz separation between transmit and receive bands will prevent cross-talk.

Fifty-watt transmitters and receivers will be included on the telephone-equipped cars. There will be nine wayside stations, each with a 300-watt transmitter, a receiver and an antenna. These stations will be from 35 to 40 miles apart and will link the mobile equipment with a central operator in Philadelphia.

Down the tracks. As a train nears the range limit of the wayside transmitter carrying a signal, a wayside coil—essentially a magnetic triggering device—will automatically shift the signal at the same frequency to the next wayside station.

The General Electric Co. is providing the mobile equipment and Motorola Inc. is making the wayside station gear, both as AT&T subcontractors. Bell Telephone Laboratories, an AT&T subsidiary, is to supply the amplifiers and waveguides to carry signals through the two tunnels near the Baltimore terminal.

A "leaky" waveguide consisting of two parallel wires is expected to overcome the problem of signal attenuation in the Baltimore tun-



Passengers will make phone calls from trains—even while under a tunnel.

nels. Two-way amplifiers may be placed along the waveguide as needed, and a two-way amplifier at the tunnel portals will boost the signal for relay either to the train or a wayside station.

A communications consultant estimates the cost of the mobile and wayside hardware at between $1 million and $1.5 million.

Routing. To make a call, a passenger deposits a coin in the pay phone to reach a Philadelphia operator who can connect him with any phone system in the country. Incoming calls will also be routed through the Philadelphia system.

Amplitude-modulated voice signals generated at the telephone handset are converted into frequency-modulated, single-sideband signals before reaching the train transmitter. The transmitter relays the signals to a wayside station; from there they go by land line to Philadelphia and are converted back to a-m at the switchboard. Similarly, incoming signals are converted to f-m at Philadelphia and sent by wire to a wayside station that beams them to a train. They are converted to a-m after reception.

Manufacturing

Testing on the run

Sylvania Electric Products Inc. is betting a half-million dollars that production volume of monolithic integrated circuits has reached a point where automatic in-line testing and sorting will pay off in reliability and orders.

Sylvania, a subsidiary of the General Telephone & Electronics Corp., has put the $500,000 into a computer-controlled system now undergoing final tests at its semiconductor division headquarters in Woburn, Mass. Two more systems are in the works—one is to be installed in May.

Called Mr. Atomic, for multiple rapid automatic test of monolithic integrated circuits, the Sylvania system is the industry's first automatic in-line tester-sorter. It will be used on Sylvania's entire circuit production output. Within the next month, the division will also install a commercially produced automatic probe for testing dice prior to assembly.

The market push. These are part of a quadrupling of Sylvania's IC facilities since August 1964, when Alvin B. Phillips left Motorola Inc. to become the general manager of the integrated circuit operation at Sylvania.

Phillips is setting his sights on third or fourth place in IC production within the next year. Presently, the company ranks about fifth or sixth. Phillips' optimism is based on the 100% testing of d-c parameters at four temperatures, plus a-c switching tests at room temperature. "This would be close to impossible without Mr. Atomic," he says.

Mr. Atomic's four temperature-controlled d-c test chambers and one switching test station are designed in-line with an automatic mechanical feed and regulated by a digital computer. An operator leads the circuits into plastic pallets, which take either TO-5's, flat packs or dual in-line plug-in packages. The dispensing rack presents a new circuit to the tester every 2.2 seconds. It takes a circuit 25 minutes to go through the entire system. During that time, 60 d-c characteristics are probed in each of the temperature chambers and 20 a-c tests are made at room temperature, for a total of 260 tests.

Circuit warmer. As each circuit enters the first chamber, with a 75° C ambient temperature, it is automatically inserted into a wheel-type holding device, designed in such a way that the circuit travels 180° to the test position. The time required to reach this point insures that the chip, case, and junction will have stabilized at the test temperature. Two probes contact each of the 14 leads on the package, one is the test probe and the other a sensor to signal the system that electrical contact has been established. A circuit that fails this contact-sensing test is automatically sorted into a bin for future reinsertion.

The circuits move on to other chambers of 125°C and —55°C. The computer memory stores the results obtained at each temperature.

After completion of d-c tests, the IC is moved to the fifth test station for the switching tests. Here, as in d-c testing, the circuit is "worse case" tested. Rise time, fall time, turn-on delay, and turn-off delay are all verified to each circuit's specification.

After the switching test, the circuit's performance is reviewed by the computer and a decision is made on its limits. The circuit then goes into one of 20 sorting bins where it is stored until removed by the machine operator.

Because the system can't handle all the a-c tests, some tests are made off-line. This is particularly true for J-K flip-flops, where from 30 to 35 a-c tests are required. According to John C. Blackie, engineer in charge of test equipment, as much as 25% of all a-c testing is done off-line.

In the system, 700 circuits at a time are run through the machine and each is allocated a slot in the computer memory. To reduce the amount of information the computer has to retain, the test limits are divided into performance bands. The memory keeps track of the bands and sorts the circuits accordingly into groups of devices that are suited for specific applications.

Computer control. "The bands are adequate for sorting," says Blackie, "but the computer keeps other quality-control types of information that can be read out."

The second Mr. Atomic will be a copy of the first. But No. 3 is being designed with a different concept: to test functions instead of circuit parameters. "It will ripple through a truth table in maybe 100 microseconds," says Blackie, "moving through all possible logic combinations."

Parameter testing, he points out, is limited. But a simple gate can have as many as 250 possible logic combinations. "We'll hit the circuit with most all of them, and any leakage is bound to show up," says Blackie.

Functional tests will require

about 100 microseconds per circuit, compared with 16 milliseconds per second on the first-generation Mr. Atomic.

Hot tip on IC's

Even a nimble-fingered girl has trouble soldering the tiny leads of integrated circuits on a cordwood package. If she holds the soldering-iron tip to the lead too long she'll get broiled IC's. The Ryan Aeronautical Co. of San Diego found that in one project—a package for the radar altimeter that will be used on Apollo's lunar excursion module—it was getting a defect rate as high as 30%. And the major reason was either bad soldering connections or broiled IC's. D.A. George, manufacturing director of the package, decided to try soldering the interconnections while most of the cordwood package was in an inert liquid. The result of using this liquid heat-sink technique, says George, was a drop in the rejection rate to 1%.

Circuit bath. What George did was to bathe the entire bottom half of the cordwood package in a fluorochemical, produced by the 3M Co., while the soldering operation was going on. As soon as the upper surface was soldered, the entire package was flipped over, and the other half was done.

To make it easy for the girls on the assembly line to handle the package in the fluid, he devised a small metal frame that holds it and suspends it in the bath. The level of the fluid is just short of touching the surface of the package being soldered.

Not only did the girls cut down on the number of connection failures, they did the soldering job about 25% faster.

Meetings

By invitation only

In response to a crescendo of dissatisfaction, the technical sessions at the 1967 convention of the Institute of Electrical and Electronics Engineers will have a new, and possibly improved, look. Over 90% of the 312 papers scheduled for presentation at the four-day meeting, which opens March 20 in New York City, were invited.

In years past, a blanket call for papers was standard operating procedure. This shotgun approach produced anywhere from 700 to 800 papers of varying quality and relevance from which about 300 were chosen for spots on the program.

Unfortunately, a number of drawbacks attended that procedure. For one thing, the institute's planners tended to spotlight established techniques rather than advanced technology. For another, standing technical groups husbanded the more significant presentations for their own symposiums and local conferences. Predictably, the result was a series of pitiful performances at what could, and should, have been the industry's annual showcase.

Reform. This year, however, the technical program committee has taken a different tack. According to the promotional material that has been flowing from the institute's offices since last summer, the 1967 meeting "has been designed to provide insights of [sic] some of the advances, during the past year, within the technology of particular interest to IEEE members. Emphasis is on broad, state-of-the-art coverage rather than either the highly specialized report or the tutorial presentation of previous years. The sessions are being organized independently by the sponsoring IEEE committees . . . and groups, thus assuring variety, timeliness, and spontaneity while retaining relevance to the impact of these technologies on modern society."

What this rhetoric boils down to is that the technical program committee chose session topics that it hoped would combine to make the best program. Sponsoring groups then sought technical papers from the top men in these several selected fields.

It remains to be proved whether the drive to select rather than settle can deliver on its promise. But a careful check of the convention prospectus suggests that a giant step has been taken in the right direction.

Copping a plea. In partial extenuation of the low standards of previous technical sessions, an institute staffer says the upgrading process has been necessarily slow since most of the work is done by volunteers. This source admits that quality was a casualty of the confusion prevailing after the merger of the IEEE's two ancestor organizations—the International Radio Engineers and the American Institute of Electrical Engineers. For example, AIEE members were preoccupied with standards while IRE groups were more concerned with communications. It was difficult to resolve their biases. "But," he says, "the groups are squared away now and all working together."

Medical electronics

Magnified X rays

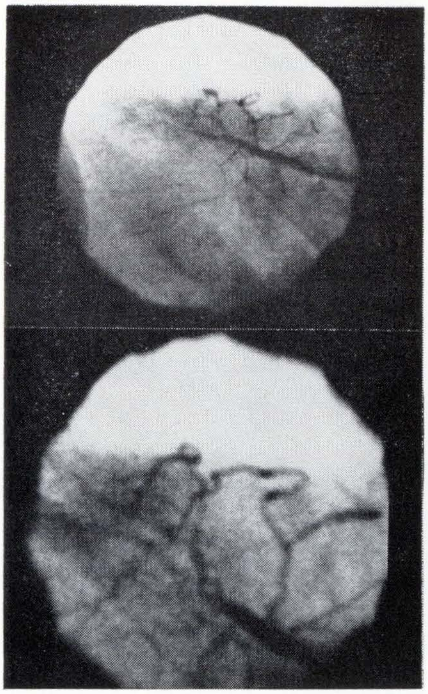
A pulsed X-ray technique has been developed that allows high-resolution motion pictures of a patient's heart and blood vessels to be taken at three times their actual size—twice the magnification level that's possible with present methods.

The technique, using very square-shaped X-ray pulses to boost the beam's density (and as a result, resolution), was devised by the Picker X-ray Corp. in cooperation with St. Vincent Charity Hospital in Cleveland.

Dr. Henry Zimmerman, director of the hospital's cardiovascular lab, says the method "gives us the ability to spot small difficulties or lesions that might otherwise be overlooked."

It's the first time, according to Herman Vahjan, Picker's medical products manager, that a pulsed X-ray tube, an image intensifier, and a 35-millimeter cinecamera with a zoom lens have been combined in one system.

Off and on. Picker employs an electronically pulsed X-ray tube. Usually tubes are pulsed by turn-



Researchers study X-ray motion picture taken with new Picker equipment. Image, of main trunk of a coronary artery, is magnified three times (photo on left). Top photo shows same section enlarged only 1½ times, the best that could be achieved previously.

ing on and off the primary or secondary power but Picker uses a grid effect. A grid control turns the electron stream on and off with square-wave pulses, resulting in a higher-energy X ray leading to shorter exposure times. In fact, says Vahjan, the exposure time can be as low as 0.5 millisecond.

The X-ray's square-wave control is pulse-width modulated. To operate, the set is adjusted for the density required on the film. The amount of tissue to be penetrated by the X rays determines the exposure time and therefore the total energy of the beam. This closed-loop control provides a uniform density on the film independent of the patient or his position.

The next step, says Dr. Zimmerman, will be to perfect the equipment so surgeons will be able to take X rays as they operate and get an almost instantaneous view of their work.

Employment

Raiding the Pentagon

Back in the 1950's, the Defense Department and the high-paying "think factories" it employs raided college campuses for gifted professors. The lure was money. But in recent years the pendulum has swung the other way. Using the same bait—money—the nation's colleges have been busy raiding the Pentagon and its "think tanks."

Faculty pay scales have risen sharply in the past few years and, as an added incentive, lucrative consultant positions for moonlighting professors have been on the upswing. The result: a professor earning $25,000 a year—which is on a par with a top-rated think-tank researcher—is almost sure to be able to pick up another $15,000 to $20,000 as a consultant.

Eye for an eye. Among the first to feel the squeeze are the same defense agencies and semi-independent research groups which raided the campuses a decade ago. And those most difficult to keep are the personnel trained in systems analysis and computer technology.

Although the greatest competition is coming from colleges, industry and other Government agencies—where the systems approach is becoming increasingly fashionable—also are grabbing their share of scientists whom the Pentagon once had merely for the asking.

Examples of what has been happening:

- The deputy directorship of the Pentagon's Advanced Research Projects Agency—hardly a sinecure or a dead-end to a scientific career—went unfilled for six months before the Pentagon latched on to Peter Franken, a laser expert, last month.
- The Institute for Defense Analyses reports that top scientists and engineers are rejecting its job offers 30% to 40% more often than was the case a year ago.

Says Gordon MacDonald, the institute's vice president for research: "We're finding an increased reluctance on the part of first-rate people to commit themselves to defense problems, at a time when we very badly need their help on major systems decisions being made."

Among the institute's projects are antiballistic missile defense and the new generation of intercontinental ballistic missiles.

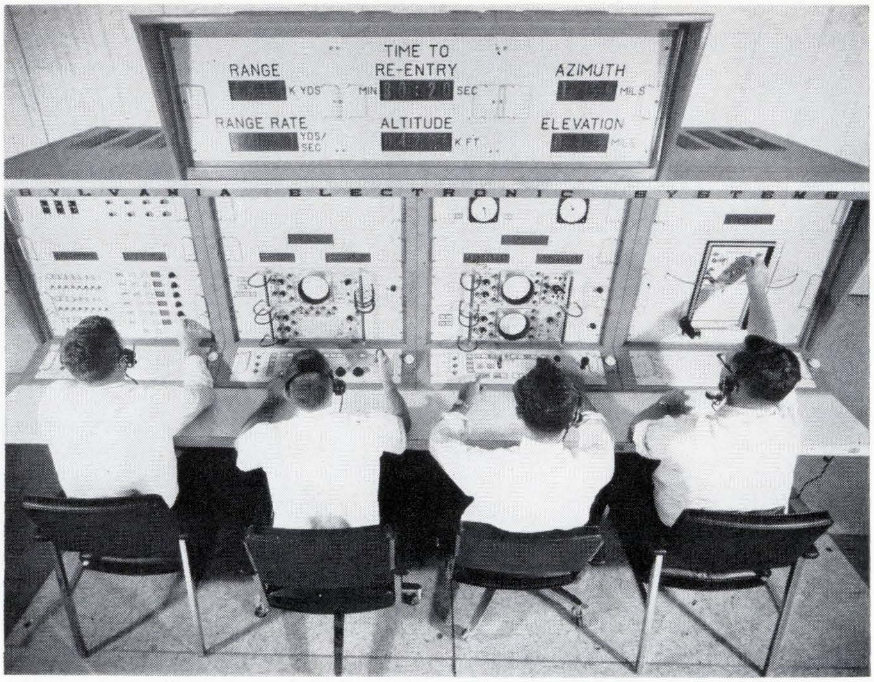
MacDonald and Lawrence J. Henderson Jr., vice president in charge of the Rand Corp.'s Washington office, cheer the keen competition from universities even though it poses problems. They feel those returning to the campuses from defense and the think tanks will show the schools the need to train more systems men, thus eventually raising the supply to meet the demand.

Moral stand. Do their objections

to the Vietnam war cause a significant number of scientists to shy away from the Pentagon? MacDonald, for one, doubts it. He says it might affect a small minority, but that's all.

One Pentagon official says the shortage of scientists and engineers is running into the hundreds. He emphasizes that the jobs can be filled, but not with men of the desired caliber. As he put it:

"I can get 50 applications for any job at any time, but too often not one from the type of man we had in mind. It's getting so you have to go out and beg for him on your hands and knees."



Keeping track of missiles. Sylvania Electric Products is shipping new electronic hardware for missile defense to the Marshall Islands. The equipment is part of the military's Project Defender Program.

Military electronics

Know your enemy

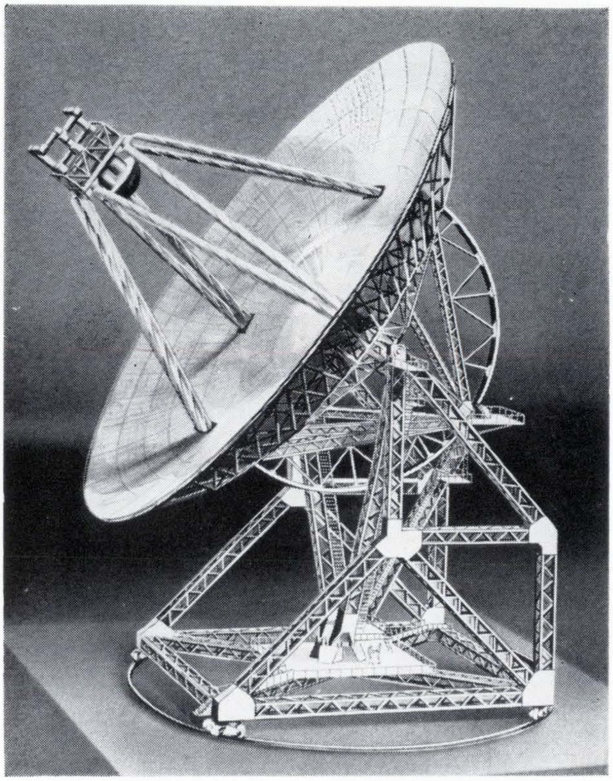
Although the U.S. has not yet decided whether to proceed with deployment of an antimissile defense system, it is researching the key problem: how to distinguish the lethal reentry vehicle from the penetration aids.

En route to the Marshall Islands in the Pacific is a new radar system that will improve this discrimination capability.

But how significant an improvement, military officials will not disclose.

Among other things, the new radar will gather "signatures" of orbital vehicles as well as reentering missiles. Also, its wider range of frequencies and fast maneuverability will aid in tracking the next-generation of missiles, which will no doubt have multiple, individually guided reentry bodies instead of ballistic warheads.

Part of Project Defender, the $25-million radar system is sponsored by the Advanced Research Projects Agency of the Defense Department. It's designated Altair, for ARPA long-range tracking and instrumentation radar.



Model of new 150-foot dish. New unit, called Altair, may eventually replace Tradex, the long-range defense system that's now in operation in the Pacific.

Latest step. Altair will be installed on Roi-Namur Island, part of the Kwajalein Atoll far down the Western Test Range. The site, now under construction by the Army Corps of Engineers, is near the first-generation radar, which it may replace. The earlier system is called Tradex, for target resolution and discrimination experiment radar.

Like Tradex, Altair will locate a reentry vehicle for other sensors and then record a vast amount of data for analysis in the Press (Pacific range electromagnetic signature studies) program. Press is op-

erated by the Lincoln Laboratory of the Massachusetts Institute of Technology [Electronics, Dec. 27, 1965, p. 106].

"Altair will mean increased sensitivity, higher resolution, more precise range and range-rate data, and other benefits," says Alfred Y. Harper, chief of the Altair office at the Army Missile Command, Redstone Arsenal, Huntsville, Ala.

High-resolution Altair will obtain data on both missiles and orbital vehicles at very-high and ultrahigh frequencies. Tradex, an adaptation of the radar developed for the ballistic missile early warning system, operates at uhf and L band.

According to Harper, no decision has yet been made on shutting down Tradex, which has been operating five years. "It will depend on the success of Altair," he says. In one mode, Altair can be slaved to Tradex.

State of the art. The new radar was designed as a data-collecting instrument, not a test bed. "We have stayed away from new developments," says William Wisnowski, deputy program manager for the prime contractor, Sylvania Electronic Systems, a division of the Sylvania Electric Products Inc. Sylvania has a $17.2-million contract for Altair, which does not include the site work on Roi-Namur and some logistic support.

When completed, Altair will be turned over to the Lincoln Laboratory for the Press program.

According to Harper, the steerable parabolic antenna will provide more precise measurements than would a phased array, and for less cost. "If it had to deal with widely separated multiple targets, the job would better be done with a phased array. But Altair will look at multiple targets within its beamwidth," says Harper.

Altair will scan 0° to 90° in elevation ±200° in azimuth. It will rotate on azimuth thrust bearings, built like railroad tracks.

The system consists basically of a 150-foot diameter antenna using an elevation-over-azimuth mount and a focal-point feed, low-noise receivers with radio-frequency preamplification, pulse expansion and compression, and a real-time control system using a small general-purpose computer. The system can perform closed-loop tracking with a monopulse receiving system in the vhf band; it can perform programed tracking, or it can be slaved to target tracking data provided by the Press computer.

Selected widths. To increase the amount of reflection data and doppler shift information, Altair will have higher pulse-repetition frequencies than required in systems where range determination is unambiguous. The pulse ratios and transmitted pulse widths can be selected to allow removal of range ambiguity and blind spots caused when the transmitter pulse or clutter obliterates the target return pulse.

A burst mode of transmission is also available, to obtain high effective pulse-repetition frequencies at reduced average transmitted power.

Pulse compression will be used as needed for longer-range tracking in order to transmit relatively high-energy pulses without degrading range resolution. With Altair, it will be possible to track incoming targets with a long expanded pulse first, then to change to an intermediate-length expanded pulse, and finally to track with a narrow constant-frequency pulse. The video pulses at the receiver output will be essentially the same length under all these conditions, thus providing constant range resolution.

. . . do you read me?

When two engineering teams come out of the jungles of Thailand later this year they will bring with them precise data on how jungle foliage attenuates radio communications.

It's an old problem—first faced by troops on the Pacific islands during World War II—now cropping up in Vietnam. The Army has attempted everything—from tying antennas to rocks and tossing them high into trees, to launching antennas by balloons—in its war with the jungle that absorbs and deflects transmissions from man-pack radio sets [Electronics, Sept. 7, 1964, p. 114].

The Atlantic Research Corp. and Stanford Research Institute will wind up their studies in December for the Pentagon's Advanced Research Projects Agency. After spending three years in the jungle to gather empirical data, the teams are expected to come up with jungle environmental factors that radio designers never had—the effects of soil, climate, terrain, vegetation, and ambient noise on radio transmissions. With a mathematical model of jungle environments, designers could identify the best frequencies, antenna polarization patterns, wave path techniques, and deployment methods.

The possibilities. Thus far, the studies indicate some possible ways of improving jungle communications other than by brute force techniques. Horizontally polarized antennas may be more effective than the vertically polarized antennas now used. But since they are very wide, they are virtually impossible to carry in the jungle. One possible trick would be to put a hinge on a whip dipole antenna, thus converting it from a vertically polarized antenna to one that's horizontally polarized.

Another possible solution could be using what Atlantic Research calls the "treetop" or "up, over, and down" signal transmission path. Instead of a wave that goes through the jungle in a direct path to a receiver, a radio could utilize a path that takes the signal above the heavy foliage; the signal could radiate up from the transmitter over the treetops, then through the air to a point over the receiver and then down.

The long-range solution appears to be directional antennas. Currently these are impractical because the extensive direction-finding equipment needed would be unwieldy for jungle use.

Advanced technology

Standard volt

An experimental technique developed at the University of Pennsyl-

vania may allow a company to calibrate its voltage equipment to within 6 parts per million without periodically sending its standard voltage cells to the National Bureau of Standards in Washington.

Using the a-c Josephson superconducting tunneling effect, scientists have measured a fundamental physical constant—the ratio of electronic charge to Planck's constant—and related it to standard voltage in a relatively simple, easily duplicated experiment.

In the a-c Josephson effect, two superconductors separated by a thin insulator are coupled by an a-c current, the frequency of which is proportional to the voltage across the sandwich. If the frequency and d-c voltage are measured, the constant, 2e/h, can be calculated. Alternatively, if the constant is known and the frequency is measured, the voltage can be calculated to an uncertainty of a few ppm. In the Pennsylvania experiments, scientists measured the constant to about 6 ppm with 70% confidence. Foreseeable improvements in the system can reduce the uncertainty to the 1-ppm level, according to the researchers.

Two structures. The scientists, William Parker and Donald Langenberg of the University of Pennsylvania, and Barry Taylor, now with the Radio Corp. of America's laboratories in Princeton, N.J., used two structures in making the measurement: a sandwich consisting of two superconducting tin films separated by a thin insulating oxide layer, and a point-contact device consisting of a superconducting wire with a fine point pressed onto a flat superconducting plate.

The structures were mounted in an X-band waveguide and inserted in a liquid helium dewar. When they were subjected to microwave radiation, the a-c Josephson current produced a d-c sideband, zero-beat frequency that was measured by a newly available nanovolt potentiometer produced by the Julie Research Laboratories, New York.

Part of the over-all uncertainty is due to the 4-ppm uncertainty in the relationship between the absolute volt and the volt as set by the NBS, since the measurements were carried out in terms of the NBS standard.

World effect. The effect can thus be used to compare standards internationally, since it depends only on the physical constants e and h and on the microwave frequency, which can be precisely measured with available equipment. The NBS, for example, could measure 2e/h with its own standard cell and publish the measuring frequency and the value of the constant. Other countries could then duplicate the measuring frequency and calculate their own standard voltages from the published value of 2e/h.

Industrial calibration laboratories would similarly be able to correlate the voltages of their standard cells with the NBS standards. The NBS now uses the gyromagnetic ratio of a proton to determine the constancy of its standard voltage, but this is a difficult experiment for outside laboratories to duplicate.

Single frequency

While many companies seem to be concerned primarily with getting more power out of carbon dioxide lasers, the Hughes Aircraft Co. has come up with a continuous-wave CO_2 laser that puts out only 5 watts, but which operates on a single frequency and single wavelength—vital requirements for use in communications and radar.

Developed partly with company and partly with military funding, the laser operates at 10.59 microns —a wavelength that can penetrate the atmosphere with relatively little attenuation. It is a sealed-off system (as opposed to flowing gas) and is water cooled, employing a quartz or Invar cavity. The laser cavity is 50 centimeters long and one centimeter in diameter.

Growth potential. Having achieved the single-frequency objective, Hughes is now building a laser system one meter long and one centimeter in diameter. Scheduled for completion in June, it too will be a sealed-off system and will put out 10 to 15 watts.

"We may be able to extend our single-frequency, single-wavelength techniques for lasers up to 4 meters long and with over 100 watts power output," says Peter Clark, a researcher at the Hughes Research Laboratories, Malibu, Calif., who developed the unit.

Hughes has delivered several to military customers for evaluation in communications and ranging applications and some have gone to a commercial customer. Clark declines to identify the customers or applications.

When it operates at a single wavelength the CO_2 laser is almost as efficient as it is in a multiwavelength mode. Clark points out that other c-w gas lasers lose efficiency when operated at a single wavelength. Also, the CO_2 laser has a narrow transition line width (the frequency margin in which it operates) of only about 60 to 80 megahertz and only one frequency per wavelength. Other gas lasers, such as argon ion lasers, have a transition line width of about 4,000 megahertz, with many frequencies at the same wavelength.

Isolation problems. A major problem with a CO_2 laser is that several wavelengths can oscillate at the same time. These are so close together it is difficult to isolate them but Hughes is able to suppress all but one wavelength without using a dispersive element, such as rock salt, by:

- Adjusting the cavity length to favor oscillation on one transition and suppress oscillation on neighboring transitions.
- Increasing the helium pressure in the laser to obtain faster transfer of energy from one transition to another.
- Adjusting the output coupling (the mirror from which radiation comes) to achieve single wavelength operation.

Clark notes that by making a short, narrow laser with an optimum resonator design, Hughes was able to ensure a stable cavity and to obtain a single longitudinal mode and a single transverse mode.

Cold-cathode emitters

Rather than being replaced by solid state devices, microwave tubes of the future may have semiconduc-

Circle 55 on reader service card→

tors working inside the tube envelope, according to scientists at the Stanford Research Institute. A new cold-cathode tube developed there can be pulsed quickly with low voltages, simplifying the pulse-forming circuitry now used to drive conventional microwave tubes. The cathodes may also benefit infrared sensors because they require far less energy than present hot-cathode sensors. The new cathodes lend themselves to batch fabrication with integrated-circuits technology.

The new device, called the transverse field emitter (TFE), has run 6,000 hours without a mishap, according to Burnell V. Dore, senior research engineer at Stanford. Conventional cold-cathode emitters have a considerably shorter life.

Four layers. In assembling the cathode, an n^+ (heavily doped) silicon substrate is first coated with a 1-micron layer of silicon dioxide and then a layer of aluminum is deposited on the oxide to form a three-layer sandwich of silicon, silicon dioxide, and aluminum. An aluminum ohmic contact is deposited on the underside of the silicon. Next, a hole is etched into the upper-surface aluminum, cutting down through the oxide, into the silicon substrate. Contact is then made to the two conducting layers and the assembly is placed in a vacuum envelope. A thin layer of semiconducting barium oxide then is deposited over the top aluminum contact, coating the walls of the hole.

When 50 to 100 volts is applied across the conductors, electrons flow to the edge of the silicon through the barium-oxide film. Some acquire enough energy to fly off into the surrounding vacuum, where they are collected on an anode. Thus, the tube is pulsed with the relatively low voltage of 100 volts, in contrast to the 5,000 volts needed to pulse conventional microwave tubes. In a microwave tube, the transverse-field emitter would operate without cooling, but would operate at a higher noise level than conventional thermal cathodes.

There are some other problems, though Dore believes they are not insoluble:

The TFE is also noisier than conventional cold-cathode tubes because the electrons are not moving at the same speed. The effect of residual poisonous gases, such as fluorides resulting from hydrofluoric acid cleaning, may kill the cathode reaction. The thickness of the barium-oxide layer is also difficult to control. A large-scale emitter has not been built yet, but an optimum structure, according to Dore, would be a substrate with an array of emitting holes 1 micron in diameter spaced on 2-micron centers.

More efficient. However, Dore says the TFE is more efficient than two other types of cold-cathode emitters, the field emitter and the tunnel cathode. The field emitter, manufactured for electron microscopes by the Field Emission Corp., McMinnville, Ore., uses a strong electrostatic field to pull electrons from the sharp tip of a magnesium wire, causing the tip to wear off. The tip must be continually reformed. The device thus has limited life, since eventually the whole tip wears out.

The tunnel cathode, which is still being developed, uses a thin insulator between two conductors. When a high-voltage is applied, the electrons tunnel through the insulator and the hot electrons leave the surface and enter the surrounding vacuum. The film must be uniformly thin, (about 50 angstroms), however, to support the high field and weak spots in the insulator cause burnouts.

Dore also sees the TFE being used as a compound photoconductor cathode for infrared sensing, where a photoconductive layer would be sandwiched into the structure. Another possible use would be in interplanetary vehicles powered by cesium-ion engines, where the TFE tube would drain off and neutralize the excess positive ions created by the engine.

For the record

Big dish. Four colleges have formed a consortium to build the

Tony DeBerardis likes green eyes, freckles and buck teeth...but he just can't stand crooked knees.

Tony will be the first to admit that not everybody likes buck teeth.

Freckles, yes. Green eyes? O.K. . . .

But buck teeth . . . ?

When it comes to knees, though, Tony likes them the same way you do. Because, when you're Product Assurance Manager at Unitrode you *know:* Either your diodes have sharp, crisp knees, or you simply don't have the ability that's built into every Unitrode to handle avalanche current, whether surge or continuous.

So Tony's got to be fussy. He knows controlled avalanche is just one of the qualities he's responsible for assuring. And when you're testing diodes that are designed to deliver an entirely new level of performance and reliability, you've got some "assuring" to do.

Of course, *entirely new* is the key phrase there. And it's easy enough to say. But when we say it, we mean just that.

Because the Unitrode diode was developed from the ground up. With entirely new design. With entirely new methods of construction. The metallurgical bond that joins the silicon between the two terminal pins is stronger than the silicon itself, so the silicon will break before the bond does. The entire unit is fused in hard glass at over 800°C. It's voidless, so all contaminants are excluded.

Because the pins are bonded over the full face of the silicon die, heat due to surge is carried away quickly from the silicon into the terminal pins. So even the smallest Unitrode diode can take a surge of 600 amps for one microsecond, and the big ones can take 4000 amps.

Nevertheless, we try not to ever forget that people like Tony DeBerardis are more important than any process. After all, they're the reason we can virtually guarantee: Unitrodes don't fail. Ever.

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biggest radio telescope in the U.S. To be installed on Peach Mountain, near Ann Arbor, Mich., the dish will be 328 feet in diameter—topping the 300-foot telescope at the National Astronomy Observatory in Greenbank, W.Va. The new telescope will operate at a wavelength of 6 centimeters, compared with Greenbank's 21 cm. The colleges banding together are the University of Michigan, California Institute of Technology, the University of California, and Stanford University.

Powerhouse. The Houston Lighting and Power Co. will have a computer-operated control center in operation by next winter. The center will monitor and control the electricity flow from the utility's generators to its customers. It will also perform trouble-shooting chores for the power-generating and distribution network. Two Sigma 5 computers—produced by Scientific Data Systems—will be used. Major contractors for the system are Leeds and Northrup Co. and the Philco-Ford Corp.

Microwave computer. The Army is supporting research on the use of microwave components for signal-processing techniques. A $68,882 contract was awarded to New York's Syracuse University Corp. for a preliminary study to determine whether hardware development is justified. The military believes recent advances in strip-line versions of Butler matrixes and latching ferrite phase shifters can produce faster memory units and correlators. The company, a research arm of Syracuse University, has developed a number of such components that could be used in computer operations, such as wideband couplers [Electronics, Aug. 22, 1966, p. 110] and switchable circulators for microwave integrated circuits.

Seeing with diodes. A television-camera tube designed with discrete photodiodes instead of a photoconductive surface has been developed by Bell Telephone Laboratories. Bell says the tube, called the Sidcon, is sensitive to both visible and infrared radiation. Further, the tube is said to have a life of several years—considerably longer than the conventional vidicon tube. The

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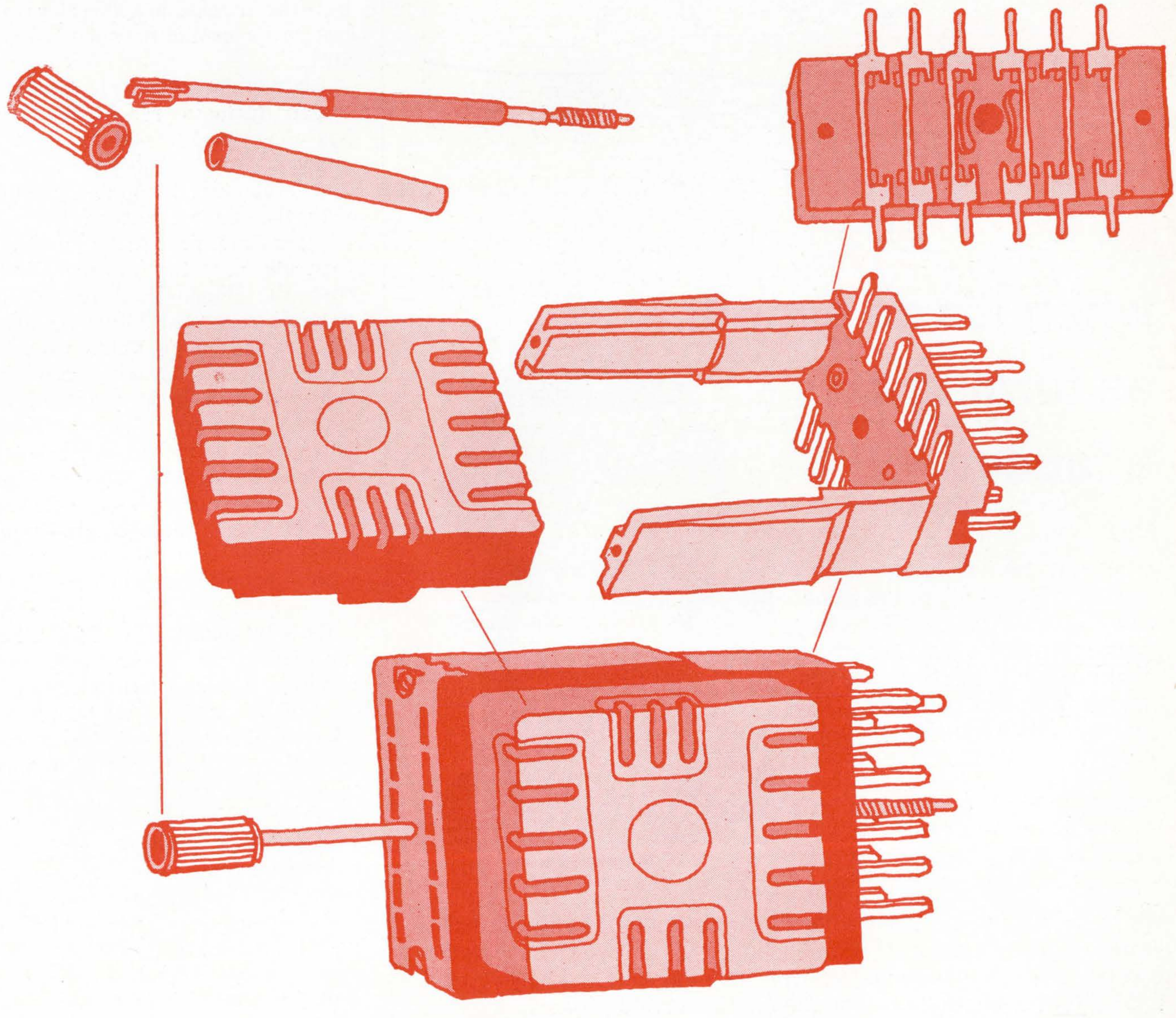

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Circle 59 on reader service card

light-sensitive diodes are produced by diffusing islands of boron into a substrate of n-type silicon. Neither intense light nor the impact of scanning electronics degrade their performance, according to Bell. The tube—1 inch in diameter and 7 inches long—has a resolution of about 400 tv lines over the target width.

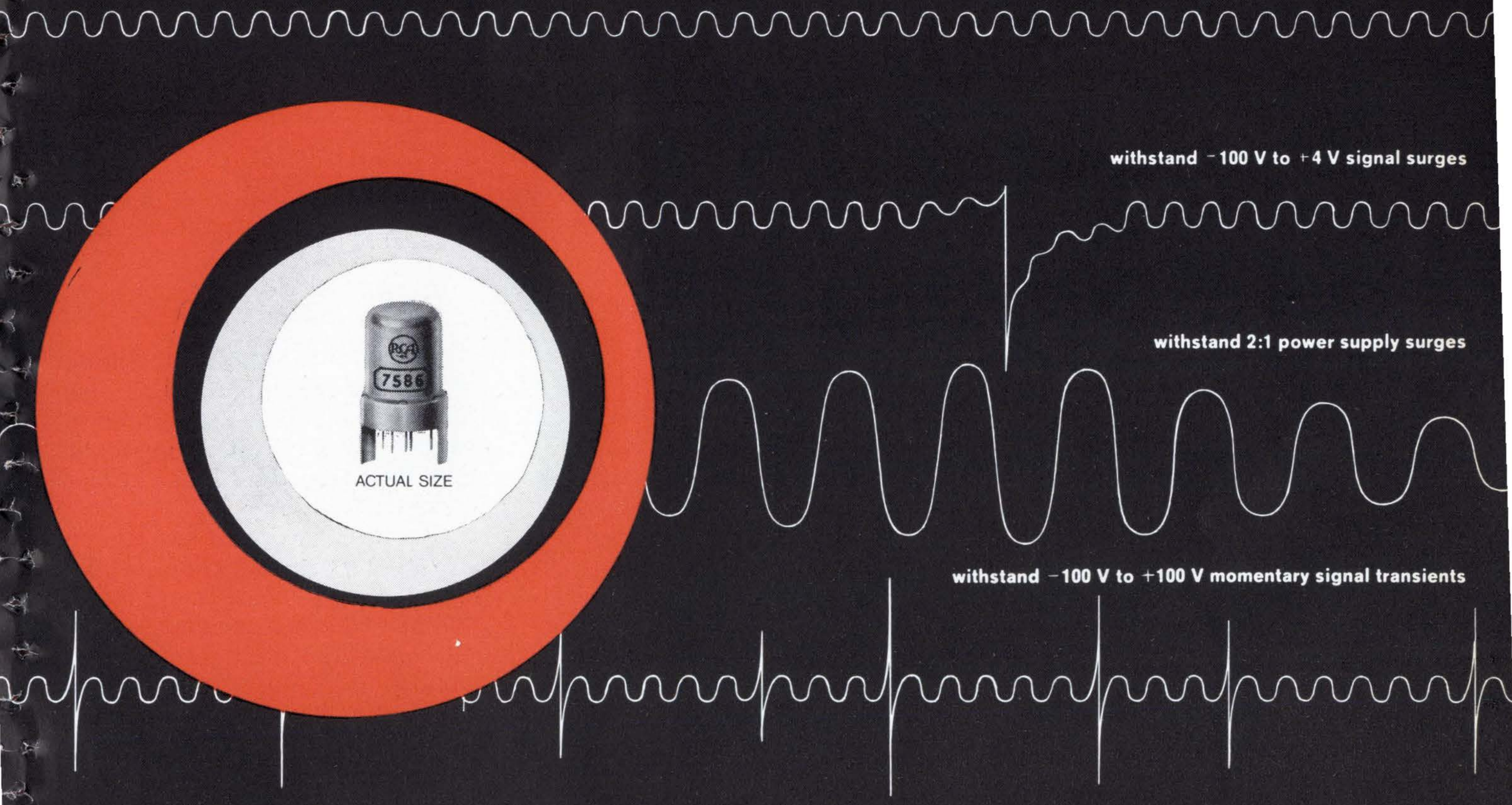
Profit rise. Texas Instruments Incorporated's 1966 earnings rose 28% from 1965 to a record $33.9 million. Sales climbed 33% to $580.3 million, also a high. P.E. Haggerty, chairman, says results in the current year aren't expected to match these rates of gain. He projects the increase in 1967 sales from last year's level at between 5% and 20%.

Germanium IC's. The International Business Machines Corp. has developed masking, etching, and protection methods for producing germanium integrated circuits with the planar process. Because of germanium's greater mobility than silicon, faster IC's can be built with the dimensional resolutions possible in present diffusion masks. Also, speeds comparable with today's silicon circuits can be achieved with greatly relaxed dimensional controls. The experimental circuits, described at the International Solid State Circuits Conference last month, have switching speeds of 350 picoseconds—much faster than is currently possible with silicon circuits three times smaller.

EKG by phone. The 3M Co. has introduced an electrocardiogram machine that can transmit signals to remote locations by telephone. The machine, model 1260, also contains a microfilm reader-printer for viewing enlarged images. The unit is able to provide copies of the EKG signals in triplicate.

First for MOL. The Douglas Aircraft Co. of Santa Monica, Calif. has announced its first major component subcontract for the Air Force's manned orbiting laboratory (MOL). Scientific Data Systems, also of Santa Monica, has the job of developing a computer system for an all-systems ground checkout for the MOL. The total contract is said to exceed $8 million.

No trace of overload problems



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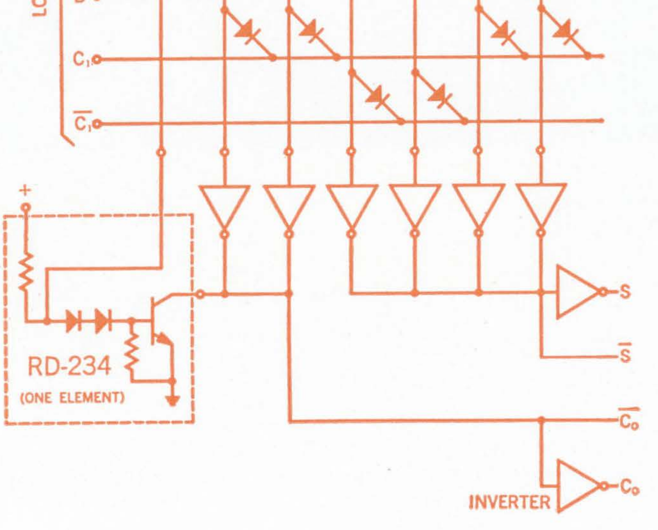
State of the monolithic art



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Design high speed, low cost full adders with Radiation 6 x 8 Diode Matrices

Radiation's Monolithic Diode Matrices are ideally suited for logic function generation as required in adders. These circuits, using Radiation Matrices, offer three major benefits:

Cost is reduced since low-volume special function circuits are eliminated. *High speed* is achieved through reduced levels of active gating. *Flexibility* in matrix sizes, in conjunction with Radiation's unique fuse link technique for "customizing" patterns, permits design freedom in the organization of an adder.

The binary full adder, schematic at left, requires only one Radiation RM-30 6 x 8 Monolithic Diode Matrix in addition to Radiation RD-220 Hex Inverters and RD-234 Interface Circuits. This full adder provides both complementary SUM and CARRY output. The logic equations and truth table are shown below.

$S = A\bar{B}\bar{C} + \bar{A}B\bar{C} + \bar{A}\bar{B}C + ABC$

$C_0 = AB + AC + BC$

TRUTH TABLE

A	1	1	0	1	0	0	1	0
B	1	0	1	0	1	0	1	0
C_1	0	1	1	0	0	1	1	0
C_0	1	1	1	0	0	0	1	0
S	0	0	0	1	1	1	1	0

Note: True logic positive.

Radiation's popular dielectrically isolated matrices provide an unusual degree of flexibility. (1) RM-30 Matrices contain 48 active devices per chip. (2) A fusible link in series with each diode permits unlimited matrix patterns to be formed. And (3), circuits can be combined to produce an almost infinite variety of size configurations.

In addition to flexibility, Radiation 6 x 8 Matrices offer the increased reliability of monolithic construction. Size and weight requirements are slashed through reduced package count. Further, cost of matching, testing and assembly of discrete diodes is eliminated.

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A new low-cost RM-134 design in a ceramic dual in-line package is available in volume at a unit price of less than $5.00—and can be supplied to any code configuration requested.

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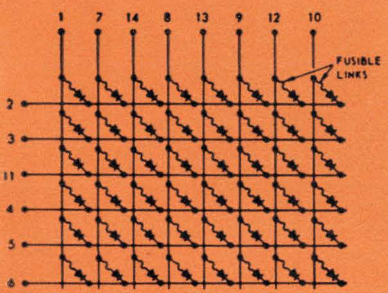

BEFORE "CUSTOMIZING"

Radiation 6 x 8 Monolithic Diode Matrices* (typical limits)

Characteristic	Symbol	RM-30	RM-31	RM-34 RM-134†	Unit	Test conditions ($T_A = +25°C$)
Forward drop	V_F	1.0 0.7	1.3 0.75	1.0 0.7	V	$I_F = 20$ mA $I_F = 1$ mA
Reverse breakdown	BV_R	60	60	50	V	$I_R = 100\,\mu A$
Reverse current	I_R	7	25	70	nA	$V_R = 25$ V
Reverse recovery	t_{rr}	7	11	30	ns	$I_F = 10$ mA to $I_R = 10$ mA
Crosspoint capacitance	C_{cp}	1.9	1.9	2.0	pF	$V_R = 5$ V; f = 1 MHz
Coupling coefficient	I_{CL}	20	20	20	μA	See data sheet

*Supplied in T0-84 packages. †Supplied in ceramic dual in-line package.

All Radiation integrated circuits are dielectrically isolated.

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MICROELECTRONICS DIVISION

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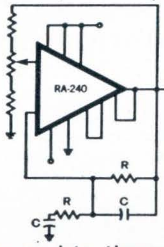
Circle 62 on reader service card

State of the design art

The flexibility of Radiation IC Operational Amplifiers is illustrated by the circuit below. Here, the RA-240 is used in the design of a highly stable, uncompensated Wien bridge oscillator which is virtually unaffected by temperature variations.



Using the RA-240, engineers may select a wide range of RC combinations without regard to the active element of the circuit. Frequency of oscillation (up to 500 kHz) is defined by:

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

Stability and versatility of our Radiation Operational Amplifiers is made possible through advanced dielectric isolation and thin film over oxide technology. Further information will appear in our ELECTRONIC DESIGN advertisement of March 15.

Radiation's line of IC operational amplifiers opens the door for integration of systems requiring high-performance analog circuitry. These amplifiers provide the ideal 6 dB per octave high frequency roll-off required for unconditional stability in operational feedback connections *without* use of external compensation . . . even in the critical unity gain configuration.

Three types are immediately available in T0-84 flat packages: general-purpose, broadband, and high-gain amplifiers.

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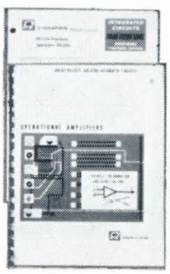

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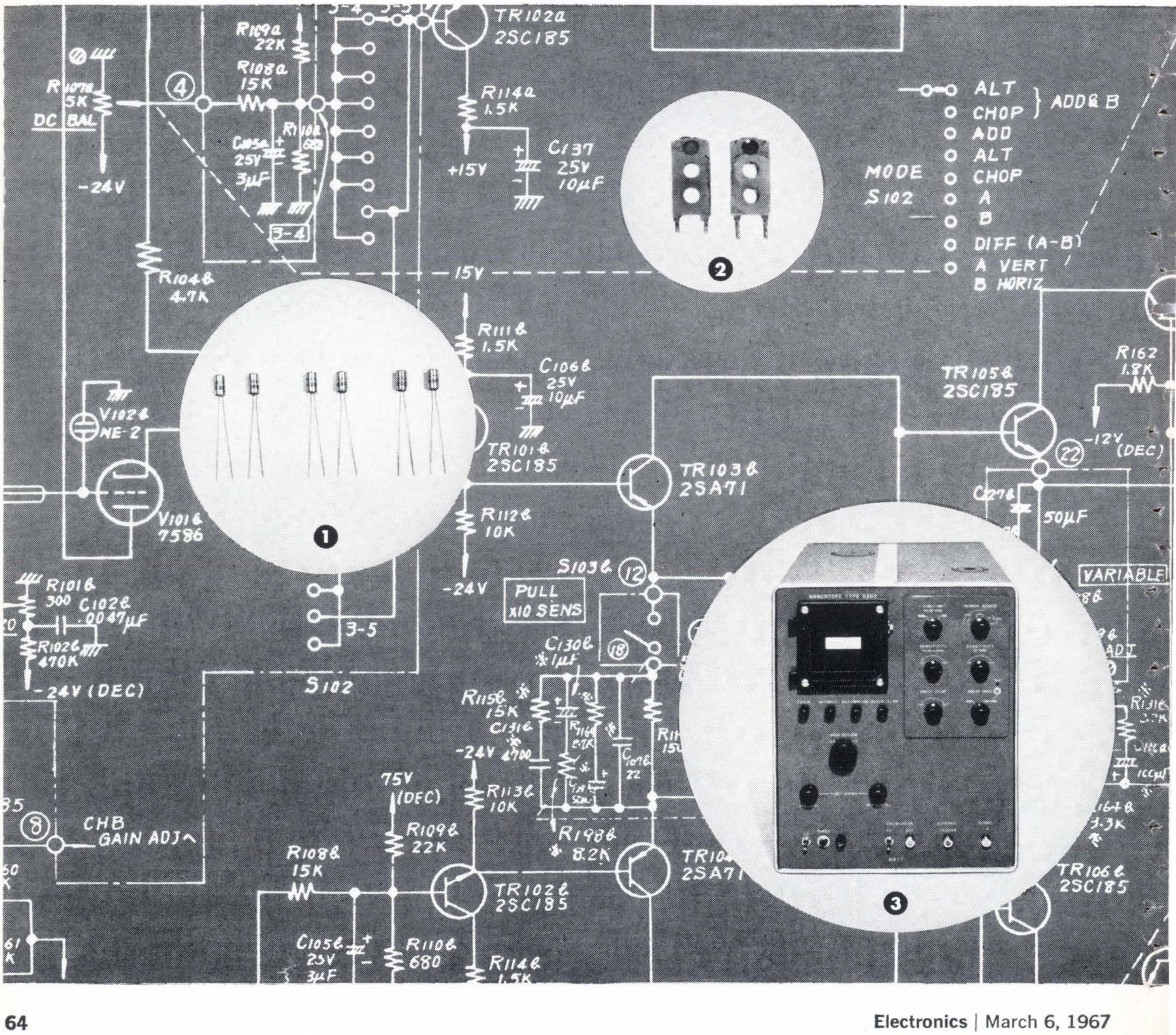

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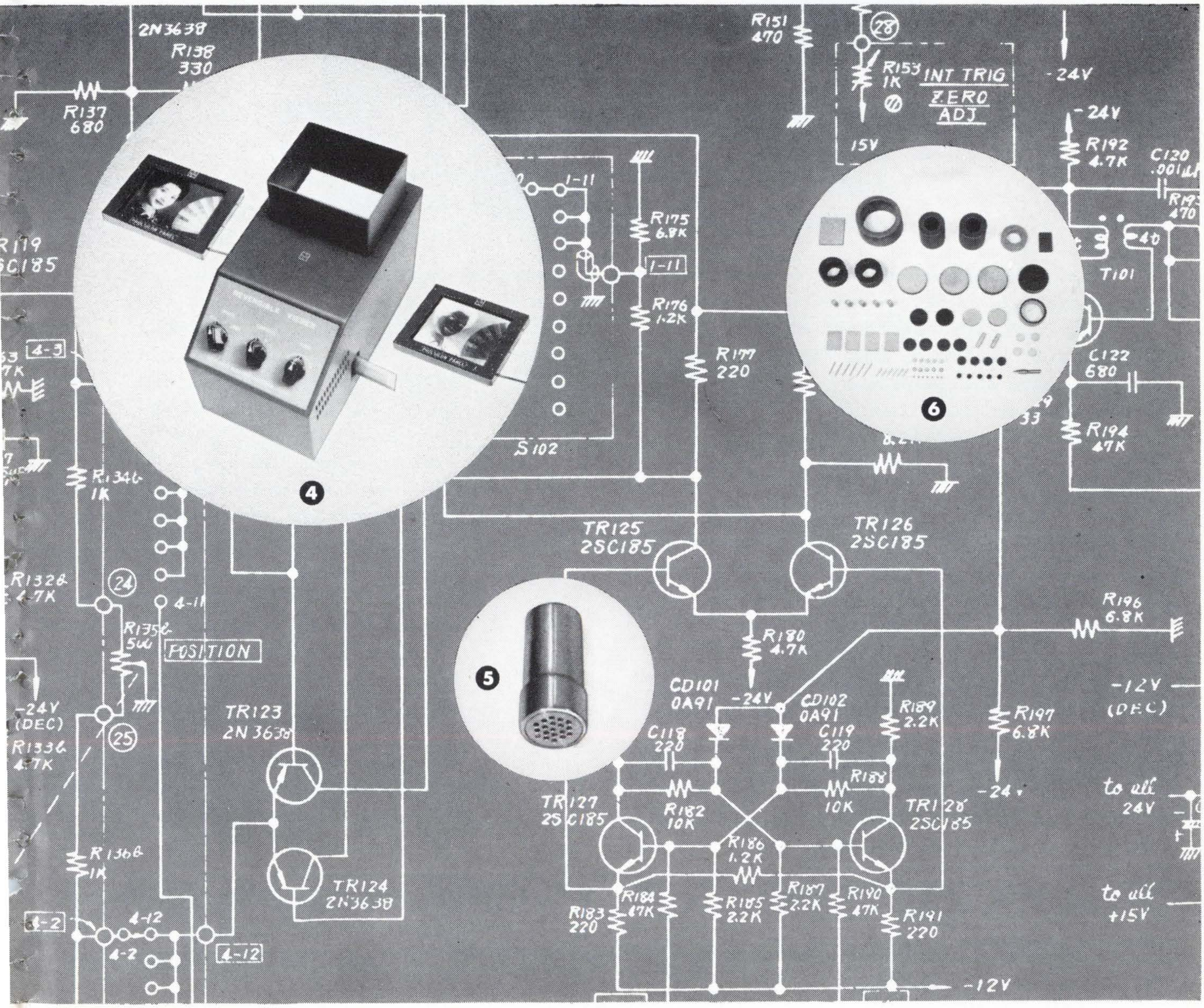

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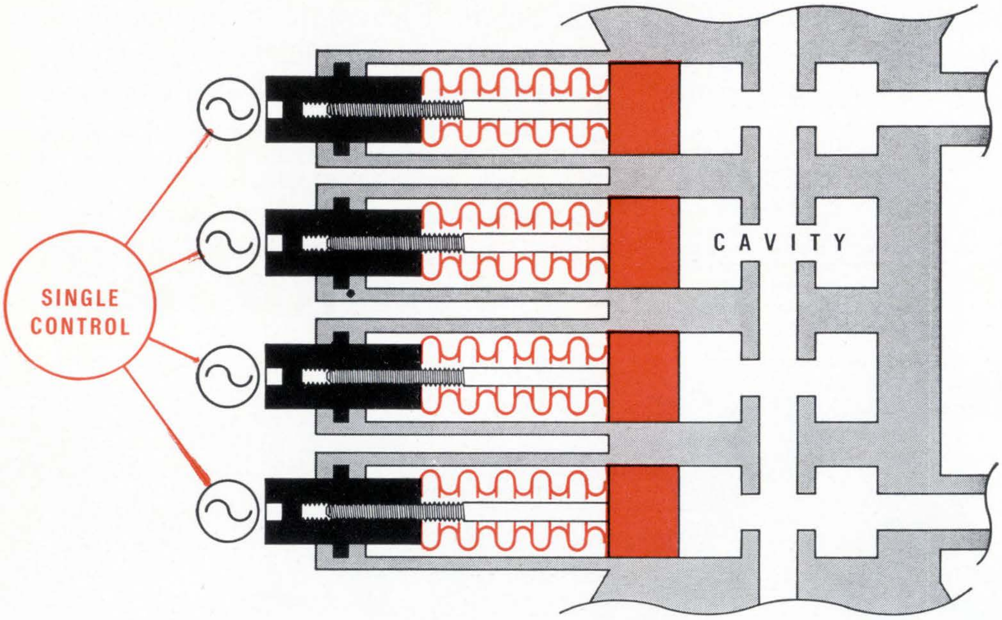
CALLING THE TUNE

Why so many system designers choose Sperry klystrons for communications applications



The secret of remarkable tunability for communication klystrons is Sperry's exclusive bellows-type tuner. Replacing the old-fashioned, short-life diaphragm, the bellows gives you longer tuner life and greater tuning accuracy. The bellows tuner, combined with remarkable tracking of the tube cavities, makes remote push-button or gang-mechanical tuning a reality.

Sperry's SAC-4062 is a good example. This C band amplifier delivers 15 kW CW with only 17 kV of beam voltage. Properly tuned, it can give you gain as high as 60 db, and even in the high efficiency mode, gain is 54 db. Electrical characteristics remain practically constant across the entire 600 Mc tuning range. The tube may be tuned at full operating power. There are no thermal detuning or sparking problems. Thus the SAC-4062 can meet both power and frequency requirements over all C band troposcatter frequencies.

The SAC-4062 is one of a complete klystron family that Sperry has built for communications work. In satellite systems, for example, Sperry's SAX-4700 series will deliver 6 to 10 kW over 7.9 to 8.4 Gc with a single tube. You can choose PM focusing with new air cooling, or electromagnetic focusing with liquid cooling. Both are tunable over 500 Mc, with Sperry's exclusive tuner which allows fast, accurate remote operation for mobile systems.

Find out how you can achieve more communications with less hardware. Get your free copy of a new technical paper describing Sperry progress in high-power CW klystrons for communication systems. Write today to Sperry Electronic Tube Division, Gainesville, Florida.

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Washington Newsletter

March 6, 1967

GE wins contract to develop a radar for Nike-X system

A contract to develop one of the five Nike-X antiballistic missile system radars has been won by the General Electric Co. **The award will be announced after price negotiations are completed between GE and the prime contractor, Western Electric Co., the manufacturing arm of AT&T.** GE will develop the phased-array perimeter-acquisition radar that will be used for long-range area defense if the antimissile system is deployed. The company already has a contract for the beam-forming subsystem of the Nike-X multifunction array radar.

GE edged out Bendix Corp.'s Radio division in the competition for the latest order, although Bendix was the only bidder to have built a prototype—the AN/FPS-85 at Eglin Air Force Base [Electronics, June 27, 1966, p. 133]. Bendix opted for the FPS-85 frequency in its bid, though Western Electric had asked for a different frequency. However, after GE was selected, Western Electric is said to have changed the perimeter-acquisition radar frequency to conform with the Bendix FPS-85.

Burroughs submits low bid for FAA's digitizer subsystem

Burroughs Corp. is the apparent winner of a contract to develop and build the common-digitizer portion of the Federal Aviation Administration's National Airspace System. **The company was low bidder for the radar and beacon processing subsystem for the semiautomated traffic control program,** a contract that will total either $16 million or $22 million, depending on the number of units initially ordered. The award, to be announced shortly by the FAA, will cover production of either 111 or 177 digitizers.

FCC will test use of tv frequencies by radio operators

The Federal Communications Commission will begin tests next month to see if it can assign commercial television frequencies to mobile-radio operators. The FCC is confident the feasibility trials will show that these new users can take over unused tv channels in the vhf area.

In the test, transmitters at various locations around Washington, D.C., will send 25-kilohertz-bandwidth signals over unused Channel 6 (82 to 88 megahertz). If the test transmissions don't interfere with tv reception on Channels 5 and 7, the FCC will be able to allocate the frequencies to mobile-radio users in Washington. In order to make similar assignments in other cities, however, the agency would have to hold new tests to gauge local conditions.

Television broadcasters oppose such sharing, maintaining that they were given exclusive use of the spectrum they were allocated.

IBM aims to make space-tv lasers of gallium arsenide

Researchers at IBM's Federal Systems division are working to develop arrays of gallium-arsenide injection lasers for a system to transmit real-time tv pictures from a spacecraft to earth at interplanetary distances. Other work on a laser link for NASA has incorporated such gas devices as the Hughes Aircraft Co.'s ionized argon laser and Sylvania Electric Products Inc.'s carbon-dioxide laser [Electronics, Feb. 20, 1967, p. 25].

IBM's quantum electronics department at Yorktown Heights, N.Y., has been studying ways to phase a number of gallium arsenide lasers to yield a 10-watt data link able to transmit a million bits per second. Researchers have succeeded in phasing the lasers—just how many IBM won't say—

but are having trouble achieving reproducibility—that is, getting the lasers to turn on and reach full power at the same time repeatedly. The company said it's confident, however, that it can solve this problem within a year. The advantages of the IBM laser over the CO_2 device are smaller size and higher efficiency (30% to 50% against about 15% for the CO_2). IBM's effort is being funded by NASA's Marshall Space Flight Center, Huntsville, Ala.

Navy awaits approval on Omega

Navy project officers expect a go-ahead from the Pentagon by April on construction of a worldwide very-low-frequency Omega navigation system. **A letter recommending full Omega deployment is now on the desk of Defense Secretary McNamara.** The Navy maintains that the 10-to-14 kilohertz hyperbolic system is "technically ready," though it has been asserted that Omega propagation data will be less stable as sunspot activity increases [Electronics, Oct. 17, 1966, p. 129]. The Navy admits that a continuing development program will be needed to improve the system, but says recent tests have proven Omega accurate for general-purpose navigation of surface ships, submarines, and subsonic aircraft.

Congress is ready to back full outlay for AEC project

Reflecting a shift in Congressional sentiment, the Joint Atomic Energy Committee is now expected to approve the full $10 million requested by the Atomic Energy Commission for fiscal 1968 work on a proton accelerator in Weston, Ill. **The Senate-House panel is reportedly anxious to get preliminary design work started on the project.**

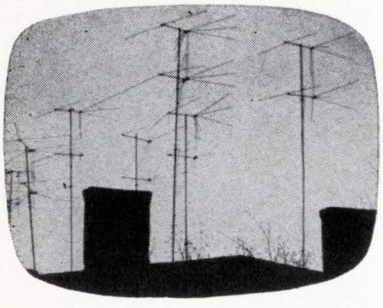
Originally, the AEC, together with the Budget Bureau, planned to construct the system in two phases to save money. The accelerator was to be designed to operate initially at 200 billion electron-volts and was later to be upgraded for 300-bev operation. **However, the joint committee believes it would be less costly to build a 300-bev accelerator, scale it down to 200 bev for early operations, and later upgrade it to 300 bev when additional money is available.**

Little hope is seen for 90% funding of defense orders

Despite a rising chorus of defense-contractor pleas, the chances appear slim that industry will succeed in persuading the Pentagon to increase its partial payments to 90% on military production orders. **Contractors say they are finding it increasingly difficult and costly in these times of tight money to borrow funds to support their burgeoning Vietnam war production.** The Aerospace Industries Association and the Defense Industry Advisory Council have proposed raising progress payments to 90% from the current 70%. The unofficial word, however, is that the Defense Department isn't likely to approve much, if any, increase in these payments because it believes the credit situation is easing.

Addenda

The FAA isn't entirely sure that the ground-based navigational aids and traffic control radar now serving commercial airliners will be adequate at the altitudes supersonic transports will fly in the 1970's. Beginning this summer, the FAA and the Air Force will make 100 joint transcontinental flights with instrumented aircraft to obtain test data. . . . **Congress is expected to approve $100,000** for development of a Coast Guard guidance system that would give ship positions under all weather conditions in channels serving U.S. ports.



Stackpole Ceramag® ferrite components have been the accepted standard of the Television Industry for over twenty years.

In 1965, Stackpole began supplying Automatic Pincushion Correction Cores, a major advance, for color television receivers. 1964 saw the introduction of Stackpole 90° color components including Flyback, Yoke and Convergence Cores. As far back as 1954, these same components were introduced for the 70° color Deflection Systems.

The list of contributions Stackpole engineering and production know-how has made to the growth of color in television is long and varied. This same capability has been applied to the continual improvement of black and white receiving equipment as well.

To be first with such items as Horizontal Output Transformer Cores and Automatic Pincushion Correction is not enough. Innovation must stand the test of performance. Stackpole Ceramag® components have, since 1947. Small wonder most manufacturers have come to depend so heavily on Stackpole's experience and quality. Stackpole Carbon Company, Electronic Components Division, St. Marys, Pennsylvania 15857. Phone: 814-781-8521. TWX: 510-693-4511.

Ceramag® Ferrite Components are Coloring the Entire Television Picture

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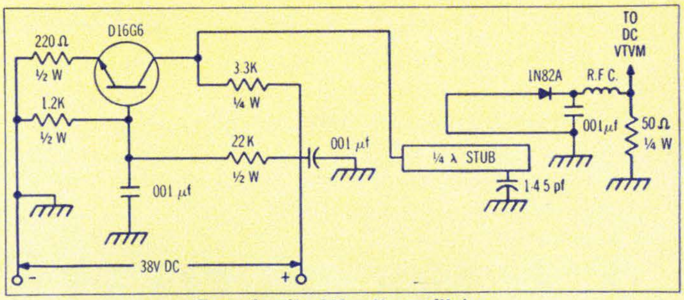
ELECTRONIC COMPONENTS DIVISION
"OUR 60th YEAR"

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

COMPONENT CAPSULES

New economy breakthrough for UHF TV oscillators

Just specify GE D16G6 silicon planar transistors —priced now at less than 25¢ in volume quantities. The D16G6 comes in GE's familiar T098 economy package and features an injection current of 0.5 ma at 940 mHz and low output capacitance of typically 1.2 pf. Circle **Number 90** for more details.



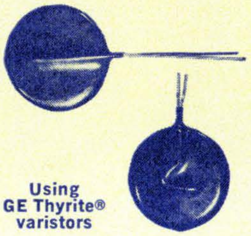
Test circuit—940 mHz oscillator

Out front . . . meeting more of your tube requirements

Look to the leader. General Electric is your number one supplier and number one innovator of tubes for entertainment-type products such as radio and TV. GE developed more than twice as many new tube types in 1966 as any other manufacturer. GE now offers over 125 different compactrons you can apply to reduce assembly time and related costs. Circle **Number 91** for more information on GE compactrons and other tube innovations.

Typical GE compactron

Automatic de-gaussing for color TV sets



Using GE Thyrite® varistors

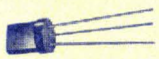
Used in conjunction with a thermistor, GE disk-type Thyrite varistors will develop, automatically, an ideal de-gaussing waveform in your color television receivers. Many have hailed this as one of the most important circuit developments in the TV industry, since it can eliminate so many costly service calls. Contact General Electric for these and all other varistor and thermistor requirements. Circle **Number 92** on the Reader's Service Card.

Rechargeable nickel cadmium batteries last so much longer

Available types—suitable for many commercial applications—include sealed, pressure relieved, and vented cells nominally rated from 0.5 amp-hours to 160 amp-hours at the one hour rate. Shock-resistant GE nickel cadmium batteries operate over a wide temperature range and have a high discharge rate capability with constant voltage output. Custom designs are also available. Circle **Number 93** for more facts.

Can last hundreds of times longer

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



Actual size

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

**In lots of 1,000 and up*

WE MAY NOT OFFER EVERYTHING YOU WANT FROM ONE COMPONENTS SUPPLIER. BUT WE DO COME A LITTLE CLOSER THAN ANYONE ELSE.

285-17

GENERAL ELECTRIC

SCIENCE/SCOPE

Commercial communications service to the Far East was inaugurated January 26 over COMSAT's Intelsat IIB. New satellite, launched January 11 and put into synchronous orbit over the Pacific, is relaying telephone, TV, Teletype, and data between the U.S. and Hawaii, Japan, and Australia on a round-the-clock basis, and will also be used by NASA in support of the Apollo program. It has three times more transmitter power, five times greater bandwidth, substantially greater antenna-beam coverage than COMSAT's Early Bird, also built by Hughes. COMSAT operates it for the International Telecommunications Consortium.

Contract for a vast NATO air defense system has been awarded to a six-company European consortium led by Hughes. Known as the NADGE (for NATO Air Defense Ground Environment) system, it's the largest military electronics project ever undertaken in Europe. NADGE will identify all aircraft crossing NATO borders, decide if they're unfriendly, warn the military within seconds, and advise them what interceptors and missiles are available and which should be dispatched.

Instant moon shelters from ordinary gelatin have been developed by Hughes research chemists under an Air Force study contract. Shelters would be prefabricated of fiber glass cloth, impregnated with gelatin, sealed in airtight containers. Opened and unfolded on the moon, they'd harden into rigid, lightweight shelters as the water evaporated from the gelatin in the vacuum of space.

Rapid expansion of several advanced programs at Hughes has created important and immediate assignments for electro-optical, microcircuit, space systems, information processing, circuit design, and communication/radar systems engineers. If you have an accredited engineering or scientific degree, have at least two years of applicable experience, and are a U.S. citizen, please send your resume to: Mr. J. C. Cox, Hughes Aircraft Company, Culver City, California. Hughes is an equal opportunity employer.

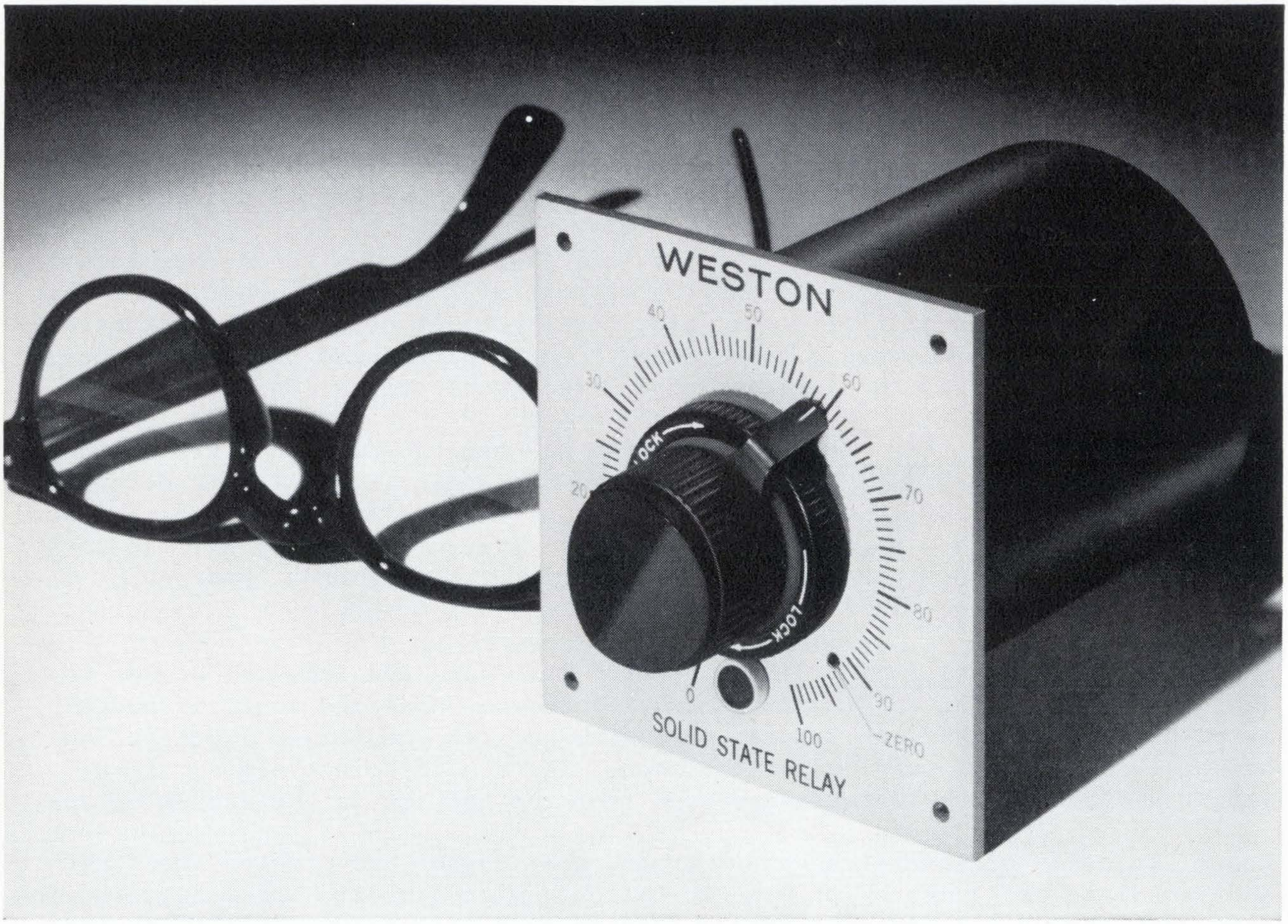
The Army's new Missile Mentors, computer systems developed by Hughes to coordinate the firing of Nike Hercules and Hawk missiles, now provide major U.S. cities with air defense umbrellas. Systems detect and track all aircraft in the defense areas, give commanders more data for split-second battle decisions than ever before. Missile Mentors, with solid-state circuitry, cost about 1/10 as much as the tube-circuitry systems they replace, can be operated and maintained by 50 men compared with 200. Basic systems are carried in two mobile vans, which operate as a single command post. A third van, designated RRIS, can be added to collect remote radar inputs.

A color camera for NASA's ATS-C satellite, scheduled for launch in December, is being developed by Santa Barbara Research Center (a Hughes subsidiary). ATS-C will be spin-stabilized in a synchronous orbit over the Atlantic. New camera's data will consist of simultaneous blue, green, and red video channels, from which full-color photos can be processed. SBRC also built the spin-scan camera that has been sending back high-resolution black-and-white photos of the earth's cloud cover from ATS-1, now in geostationary orbit over the Pacific.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY


WESTON
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SOLID STATE RELAY

When even the Best Carbon or Wirewound Pots won't do...

CTS Cermet Pots Offer a Solution

6 WEEKS DELIVERY...NEW LOWER PRICES...

due to CTS automated production techniques and the industry's biggest output.

Consider these CTS Cermet Pot characteristics:

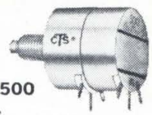
1. 20 Ω to 5 megohms resistance range.
2. Greater power/size ratio. (See captions.)
3. The environmental stability & higher wattage rating of wirewound.
4. The wide resistance range & infinite resolution of carbon.
5. Extremely high temperature capabilities.
6. Stability under extreme humidity.
7. No catastrophic failures.
8. Low noise. Long life.
9. Exceed MIL-R-23285 (Navy) metal film; far exceed MIL-R-94B.

Series 400
1-3/64" dia.
3 watts @85°C

Series 500
3/4" dia.
1-1/2 watts @85°C

Series 600
1/2" dia.
3/4 watt @85°C

Series 550
3/4" dia.
2 watts @70°C

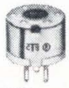


Series 2-500
3/4 " dia.
1-1/2 watts @85°C
Tandem Series 500

Series 385
11/32" dia.
1/8 watt @125°C
For P.C. applications

Series 600PC
1/2" dia.
3/4 watt @85°C
For P.C. applications

Series 660
3/8" dia.
1/4 watt @125°C



Series 630
1/2" dia.
1/2 watt @85°C

Specify from the broadest line of thick film controls available.

New low prices begin at $1.35 each in large quantities.

Request Cermet Catalog.

Founded 1896

CTS OF BERNE, INC.

BERNE, INDIANA

Subsidiary of CTS Corporation, Elkhart, Indiana

Amazingly quick and accurate response!
FUJITSU ELECTRIC AND ELECTROHYDRAULIC
PULSE MOTORS

EPM Model 109 | EPM Model 110 | EHPM Model 1/2-SSS | EHPM Model 1-SSS

Electric Pulse Motors (EPM's) Models 109, 110 and 111 are stepper motors of excellent qualifications based on originality of both construction and drive circuit. In particular, newly introduced Models 110 and 111 feature large output torque sufficient to directly drive small size machine tools, various machines with relatively small load, etc.

Outstanding features of FUJITSU EPM's:

☐ Original 5-phase pulse motor ☐ Minimized magnetic flux leakage insures high magnetic efficiency ☐ Large output torque due unique rotor/stator construction ☐ Output torque maintains practical level despite high pulse rates ☐ Unique driving method eliminates resistors connected to Stator-coils in series, thus minimizing power consumption

Specifications of EPM's

Item \ Model		109	110	111
Angular increment per pulse	deg	2.25	1.5	
Max. starting pulse rate	pps	2000	1500	1000
Max. pulse rate	pps	8000		2000
Output: Torque at max. pulse rate	kg-cm	0.6	20	150
Max. power	hp	0.025	0.56	1.05
Allowable max. load inertia	kg-cm-sec²	2×10^{-5}	2×10^{-3}	2×10^{-2}
Max. static torque	kg/cm	2.5	50	300
Max. power consumption for driving	VA	42	940	1750
Weight	kg	1.5	20	50

Electrohydraulic Pulse Motors (EHPM's) consist of an electric pulsemotor as a digital-to-analog (D-A) converter and a hydraulic servomechanism for power amplification combined in a single unit. In the EHPM's the rotating angle is proportional to the number of input pulses applied and the rotating speed to the pulse rate of the input pulse train.

Outstanding features of FUJITSU EHPM's:

☐ Need no external digital-to-analog converter ☐ Position without external feedback loop ☐ Simplify positioning and speed control ☐ Give quick response and have large torque ☐ Can be controlled with very small electric pulse input ☐ Make possible highly accurate digital control ☐ Make control device extremely economical

Specifications of EHPM's

Item \ Model		1/5-SSS	1/2-SSS	1-SSS	3-SSS
Angular increment per pulse	deg	1.5			
Max. starting pulse rate	pps	2000			
Max. pulse rate	pps	8000			4000
Output (at 70kg/cm² hydraulic pressure): Torque at 2,000 pps	kg-cm	35	103	195	6000
Max. power	hp	0.8	2	4	6
Allowable max. load inertia	kg-cm-sec²	1×10^{-3}	5×10^{-3}	1.5×10^{-2}	1×10^{-1}
Max. supply pressure	kg/cm²	70			
Displacement per revolution	cm³	4	14	27	75
Weight	kg	6	14	18	30

For more detailed information, write FUJITSU EXPORT DEPT. or:

FUJITSU LIMITED NEW YORK OFFICE
680 Fifth Ave.
New York, N.Y. 10019
Phone: CO 5-5360

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FUJITSU LIMITED
Communications and Electronics
Marunouchi, Tokyo, Japan

TEST BOARD BEFORE...

AND AFTER SOLUTEC PROCESSING

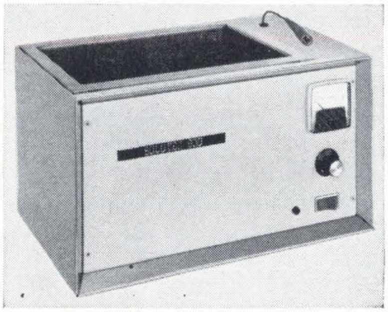
New Solutec system cleans PCB's faster, more economically than ultrasonics or vapor degreasing

You can improve your productivity, cut your investment in cleaning equipment and get more uniform results by switching to the Solutec method of printed circuit board cleaning. It's a simple process, requiring only one cleaning solution and generating no fumes, films or toxicity problems.

If it takes you more than three minutes to clean a board — whether you use ultrasonic, vapor degreasing or manual methods — you need more information about the Solutec "hydrogen scrubbing" system! It removes tenacious contaminants by generating hydrogen bubbles on or near the surfaces of parts being cleaned. In the presence of "Hydrochemex," a proprietary activated alkaline detergent, the bubbles actually scrub surfaces clean.

How clean? Clean enough to accept electroless copper plating after less than three minutes of processing. The Solutec system also gives you excellent wetting action for subsequent soldering operations.

In addition to the scrubber and its detergent solution, Solutec offers a complete line of board processing chemicals — deoxidizers, strippers and electroless copper solutions. Start cutting your board cleaning time and cost today: send this coupon for more information.



THE SOLUTEC Model 900 is a bench-type hydrogen scrubber. The device is also available in larger capacities for production line use.

SOLUTEC

SOLUTEC CORPORATION
5903 Seminole Boulevard
Largo, Florida 33540 • Phone 813/392-4268

☐ Please send me more information about the Solutec PCB cleaning system.

☐ Please have your representative call me to arrange a demonstration.

NAME__________ TITLE__________

COMPANY__________

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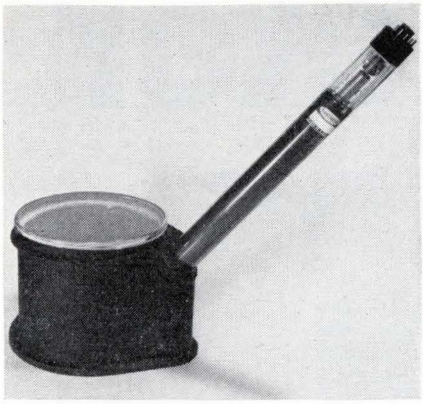
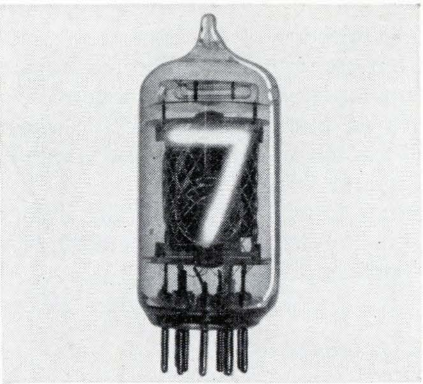
CITY__________ STATE__________ ZIP__________



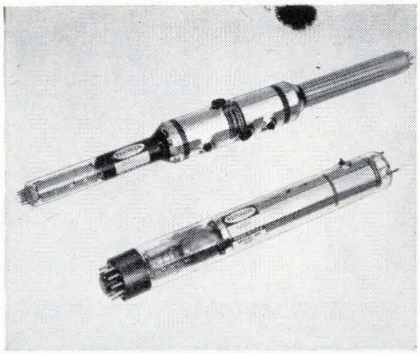
New Raytheon Projectoray* Tube produces more than double the light output of standard projection-type cathode ray tubes. The tube's light output is 30,000 foot lamberts, which results in a light level of 15-foot lamberts on a 3′ x 4′ lenticular screen.

The tube's expected minimum operating life is 500 hours — 20 times the life of a standard projection tube.

The Projectoray's high light output and long life are due to its novel design. The design incorporates liquid cooling of the phosphor backplate. This allows the phosphor to be energized with a very intense electron beam. At high beam levels, very high peak light output is obtained. The light image is projected through a 5″ optical window in the face of the tube. The electron gun is set at an angle to the phosphor and the deflection system compensates for keystone effects.



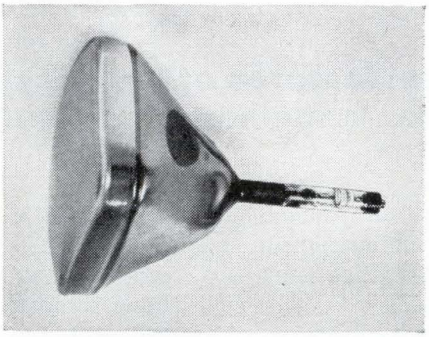
Datavue* Side-View Tubes. New Type CK8650, with numerals close to the front, permits wide-angle viewing. These side-view, in-line visual readout tubes display single numerals 0 through 9 or preselected symbols such as + and − signs. Their 5/8″-high characters are easily read from a distance of 30 feet. Less than $5 each in 500 lots, they also cost less to use because the bezel and filter assembly can be eliminated and because their mating sockets are inexpensive.



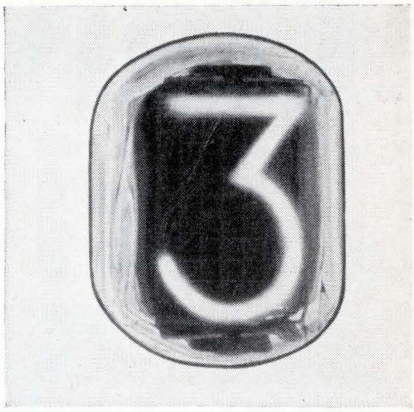
Recording Storage Tubes. The miniature tubes shown here are Raytheon's single-gun (CK1516) and dual-gun (CK1519). They provide high resolution, long storage, and fast erase capability.

Raytheon electronic input-output storage devices feature the above capabilities and immediate readout. Information can be written and stored by sequential techniques or by random-access writing. Complete, gradual or selective erasure is possible.

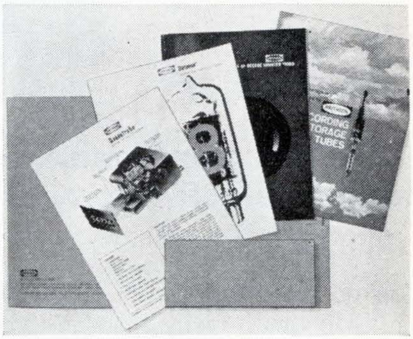
Raytheon storage tubes are readily available for applications in radar scan conversion, slow-down video, signal processing, signal enhancement, time delay, and stop motion.



Dataray* Cathode Ray Tubes. Raytheon makes a wide range of industrial CRTs —including special types—in screen sizes from 7″ to 24″. Electrostatic, magnetic, and combination deflection types are available for writing alphanumeric characters while raster scanning. All standard phosphors are available and specific design requirements can be met. Combination deflection or "diddle plate" types include CK1395P (24″ rectangular tube), CK1400P (21″ rectangular), and CK1406P (17″ rectangular).



Datavue* End-View Tubes. These tubes are easily read in high ambient light — do not wash out like other displays. Erroneous readings due to segment failure do **not** occur because the characters are fully formed. Raytheon Datavue End-View Tubes fit existing sockets and conform to EIA ratings. Models include round (CK8421) and rectangular (CK8422). Ultra-long-life types are designed for 200,000 hours or more of dynamic operation.



Send Reader Service Card for literature on the:

Symbolray CRT	491
Projectoray CRT	492
Datavue Indicator Tubes	493
Recording Storage Tubes	494
Dataray CRTs	495

Or call your Raytheon regional sales office. Or write to *Raytheon Company, Components Division, Quincy, Mass 02169.*

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Industrial Components Operation—A single source for Circuit Modules/Control Knobs/Display Devices/Filters/Hybrid Thick-Film Circuits/Industrial Tubes/Optoelectronic Devices/Panel Hardware

Galvanometer with brains

ESI has combined the best features of the classic galvanometer and the modern electronic voltmeter in the new Model 900 Nanovolt Galvanometer.

How do you create a galvanometer with true nanovolt sensitivity that is really *practical* to use . . . an instrument that doesn't require hours of delicate dial twiddling, trapdoor adjustments or experimental hook-ups?

You give it brains. Brains in the form of feedback circuits that automatically control speed of response and damping for each of its 12 calibrated ranges. *It operates from any source resistance without changes in speed of response or damping characteristics.* Noise is less than 2 nanovolts regardless of the source impedance. With all this working for you, it's easy to make effective use of the extreme sensitivity of our Model 900 Nanovolt Galvanometer.

The instrument consists of *two* units—the control unit shown above, which is the brains of the outfit, and a galvanometer unit. The Model 900 is ideal for use with high-accuracy and high-resolution potentiometers and bridges; for the calibration of thermo-couples, strain gauges, thermopiles, standard cells and the like. It also has myriad applications in the measurement of tiny voltages or currents in experimental chemistry, physics, biology or medicine. A fixed input resistance of 1 kilohm allows calibrated ranges for *both* voltages and current.

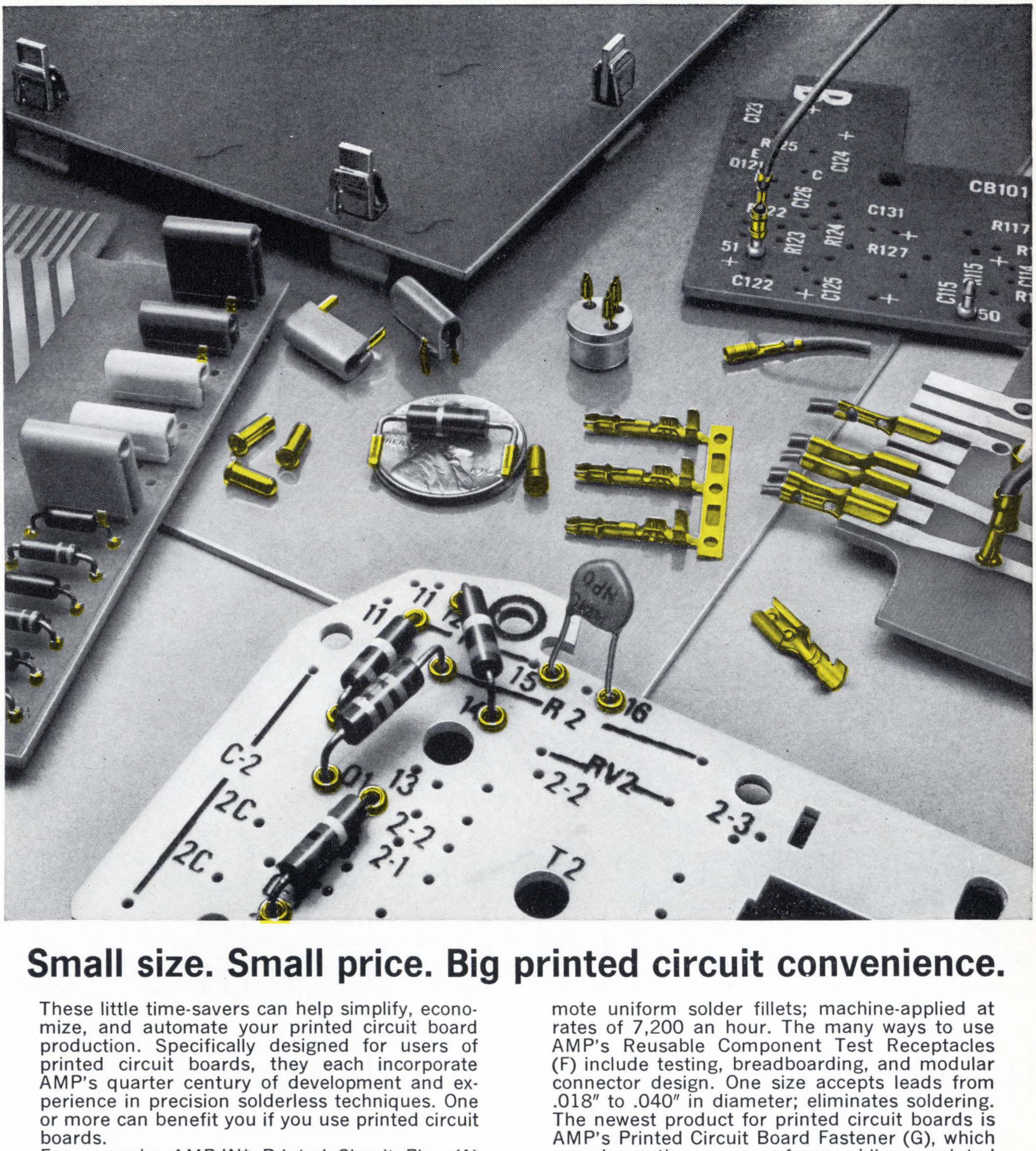
Through solid state circuitry, we've been able to combine the best of two worlds in the Model 900. It has the high sensitivity and ac rejection of mechanical galvanometers. But it also has the multiple calibrated ranges, meter readout, and operation simplicity of modern electronic voltmeters. It's an honest nanovoltmeter whose high sensitivity and complete guarding also simplify measurements in the microvolt area.

You'll have more time to use your own brains if your galvanometer has some of its own. ESI, 13900 NW Science Park Drive, Portland, Oregon 97229.

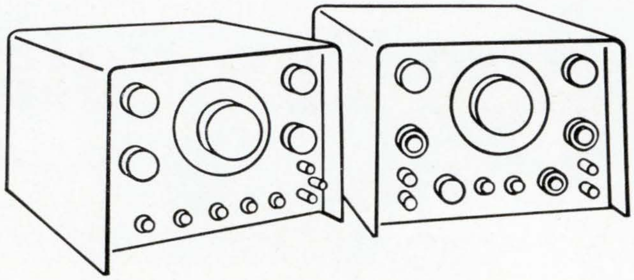
Model 900 Nanovolt Galvanometer
Ranges: 10nV (10pA) end scale to 3mV (3μA) end scale on zero-centered meter; 12 overlapping ranges in 1, 3, 10 sequence.
Accuracy: 2% of end scale for voltage and current.
Input Resistance: 1kΩ on all ranges.
Minimum Detectable Signal: Less than 2nV or 2pA.
Superimposed AC Rejection: Greater than 120 db (Infinite common mode rejection).
Noise: Less than 2nV or (2pA) peak-to-peak for all source resistances.
Damping: Slightly less than critically damped for all source resistances (adjustable).
Zero shift with source resistance change: None.
Price: $1975.

Electro Scientific Industries, Inc. esi®

IEEE BOOTH NOS. 2A02-4-6


CB101
C131
R127
C122
R117
C-2
2C
R 2
RV2
T2

See the little boxes.



See what they can do.
Sine, square, triangle, ramp, tone burst, trigger, sweep, sine^2, phase lock, VCG, plus analog & digital control of frequency & amplitude.

See the little boxes work at IEEE, booth 2A18.

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Here's A PNP Silicon RF Transistor That's Going To Change The Polarity of A Lot of Present Designs!

TO-72

3.0 dB max. Noise Figure } @ 450 MHz
17 dB min. Power Gain }
1200 MHz min f_T

An easy modification of the bias arrangement of your NPN circuit — by simply reversing dc polarity, or grounding the emitter circuit instead of collector circuit (or vice versa) — and you're ready to plug in the far superior performance of the new Motorola silicon PNP 2N4957-9 VHF/UHF transistors.

Take the 2N4957 — for true state of the art. Even at 1 GHz, the N.F. is only 5.0 dB and with a power gain of 13 dB! Other key advantages: breakdown voltage for the 2N4957-9 series is a relatively high 30 V, plus you benefit from low collector-base capacitance and resultant low feedback (C_{cb} = 0.4 pF typ).

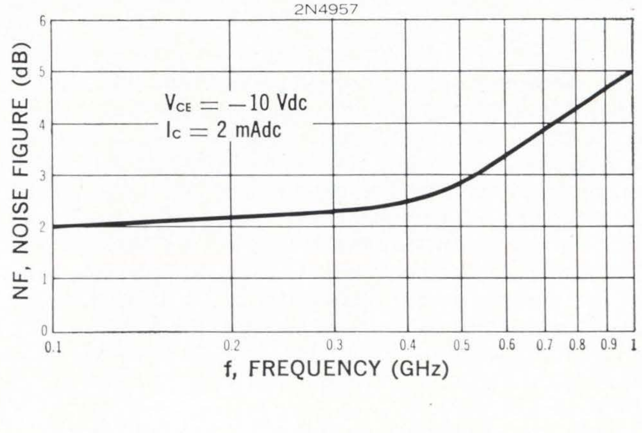
What's more, with these PNP devices you can have silicon noise figures that are comparable to low-noise PNP germanium at prices as low as $4.50 (100-up lots)! (Incidentally, Motorola also can supply NPN devices 2N2857 and 2N3839 if that's what you're presently using!)

These "state-of-the-art" devices are available at low prices, too:

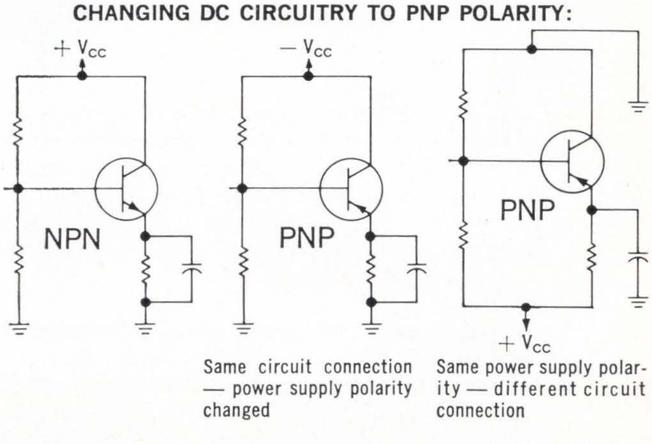
Type	100-up
2N4957	$13.50
2N4958	6.90
2N4959	4.50

For evaluation units and application information, see your Motorola sales representative. For detailed data sheets, write Motorola Semiconductor Products Inc., Box 955, Phoenix, Arizona 85001.

TYPICAL NOISE FIGURE vs. FREQUENCY



CHANGING DC CIRCUITRY TO PNP POLARITY:



Same circuit connection — power supply polarity changed

Same power supply polarity — different circuit connection

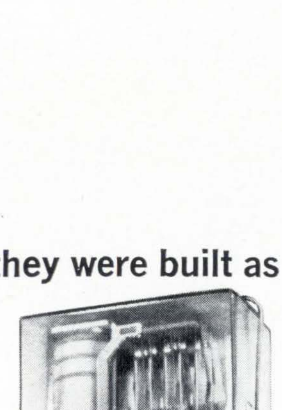
—where the priceless ingredient is care!

MOTOROLA
Semiconductors

Circle 83 on reader service card

OTHER 2, 4 AND 6 POLE 2 AMP RELAYS MIGHT BE AS GOOD AS THE NEW SIGMA SERIES 62.

If they were built as well.



Versatile, miniature Sigma Series 62 general purpose relays outperform their competitive counterparts because they are built better three ways:

Larger Contacts For Longer Life: The larger contacts (.093" & .058" dia.) used in the Series 62 assure superior thermal and electrical conductivity and a life expectancy of 1 million operations at rated load.

Thicker Base For Greater Contact Stability: The Series 62 base, in the terminal area, is twice as thick as competing types. This provides a much higher degree of mechanical support assuring long-term stability of the stationary contact members.

More Durable Lifter For Better Contact Action: The contact actuator of the Series 62 is made of fabric-filled phenolic rather than paper-based phenolic. It is extremely durable, rigid, and not subject to cracking even after extended use.

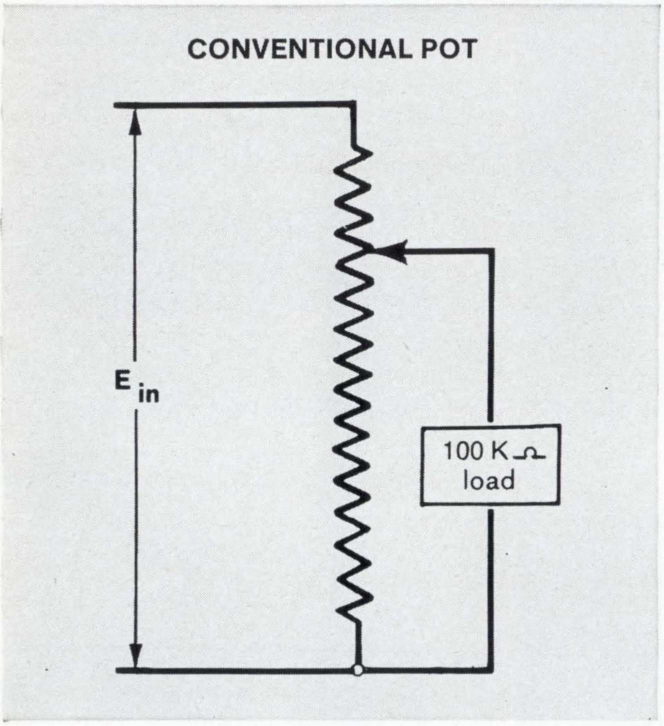
We'd like to give you a new Sigma Series 62—or any of our other standard relays. Test and compare it against the brand you may now be using. It's the best way we know to prove what we say about Sigma relay performance. Just circle our reader service number on the reader service card. We'll send you the new Sigma relay catalog and a "free relay" request form. Return the form to us and your Sigma representative will see that you get the relay you need.

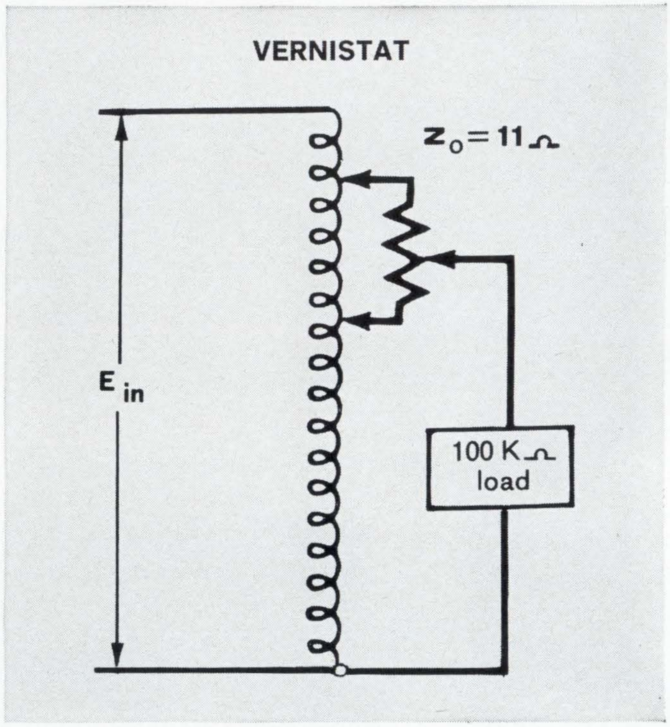
Need fast delivery? The Series 62 is available off-the-shelf from your Sigma distributor.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design / Braintree, Mass. 02185

Does the load make your linearity go to pot?





Conventional Pot		Vernistat
±0.05%	**Absolute linearity without load**	±0.05 %
0.60%	**Load error**	0.011%
±0.65%	**Absolute linearity with load**	±0.061%

Maybe your pot looks great when you test it under no-load conditions. But how does it perform in a real circuit?

You'd be surprised how a load can put a bend in an ordinary pot's linearity curve.

With today's accuracy requirements for systems, you can get an error that will break the back of your design even with loads that are generally considered trifling.

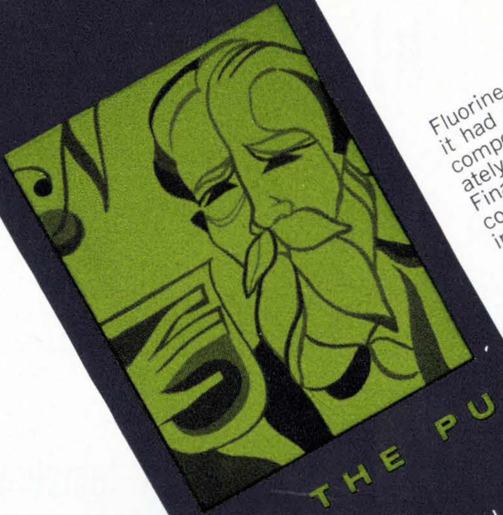
Take a conventional 4000 ohm pot and load it with 1 megohm. This load can contribute a greater error than the linearity of the pot under infinite loading. Drop the load to 100K and the loading error zooms upward.

Vernistat a.c. Potentiometers solve loading problems with no special measures. For instance, our Size 11 Model 446 contributes truly negligible loading error and still gives you the same high input impedance of 4000 ohms.

Vernistats meet other potentiometer design needs, too. Use Vernistats when you must have: • Reliability and long life • Low quadrature output • Negligible pickup of stray energy • Accurate non-linear functions • Continuous rotation in a multiturn unit.

How Vernistats straighten out loading errors and unburden the designer is explained in electric terms in a brochure we've prepared in case you asked. Do just that. Address: Electronic Products Division, Perkin-Elmer Corp., 131 Danbury Road, Wilton, Connecticut 06897.

PERKIN-ELMER



Fluorine is such an active element that, until 1886, it had never been successfully separated from its compounds. When isolated, it combines immediately with water, many metals and even glass. Finally Henri Moissan, a French chemist, fabricated containers of a platinum-iridium alloy, the most inert metals known. By cooling his equipment to slow down fluorine's activity, he managed to capture some free fluorine. In 1906, he received the Nobel prize in chemistry for his achievement.

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In 1957 Raychem pioneered a series of innovations in the field of radiation chemistry. Among the first was heat shrinkable tubing which has since become an accepted device throughout the aerospace, communication and commercial equipment industries. Today Raychem continues to be the world leader in the development of commercially irradiated products.

®**THERMOFIT NT** is one development of Raychem's experience in the field of radiation chemistry and heat-shrinkable materials. It is a flexible, abrasion resistant insulating tubing, manufactured from a specially formulated Neoprene which has been cross-linked by irradiation, resulting in a unique combination of properties, including elastic memory. Thermofit NT is primarily used as a jacketing material for cables and harnesses. It is a genuine improvement over conventional jacketing methods.

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Circle 87 on reader

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Adlake Mercury Wetted Relay — Application Data

Measurement of "Dynamic Contact Noise" for Low Level Signal Applications

Adlake AWCS 26000 Series Relay— 2 Switch Form C

In small signal applications, such as computers, telemetric systems, strain gauges, etc. generated emf. within the system's relays must be taken into account.

Dynamic Contact Noise is a "coined" phrase used to indicate an undesired generated emf. upon contact closure. It is the result of mechanical oscillation of the armature—caused by the impact of the armature on the stationary contacts — sweeping the coil flux.

Typical illustrations of this noise are shown in the oscillograms, with the relay being driven at nominal voltage in the test circuit shown below. The frequency and amplitude are integral functions of system bandwidth and coil drive conditions.

The slight ripple seen at the end of each trace is not noise, but due to resolution of test equipment and test circuit.*

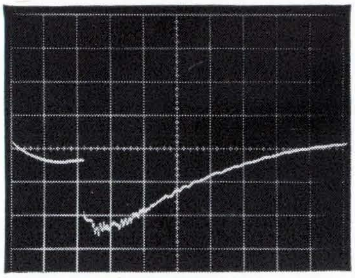


FIGURE 1

Horizontal Deflection	1.0 ms/cm
Vertical Deflection	20 μV/cm
Systems Bandwidth	.06—60 Hz.

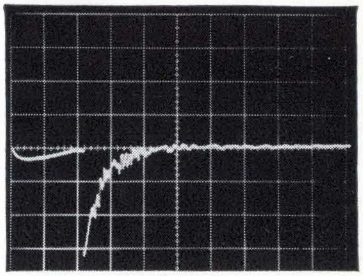


FIGURE 2

Horizontal Deflection	1.0 ms/cm
Vertical Deflection	100 μV/cm
Systems Bandwidth	.06—600 Hz.

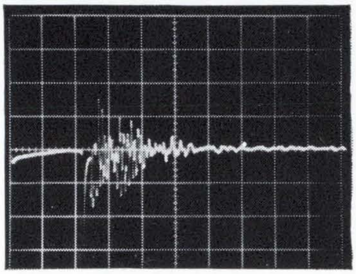


FIGURE 3

Horizontal Deflection	1.0 ms/cm
Vertical Deflection	200 μV/cm
Systems Bandwidth	.06—6K Hz.

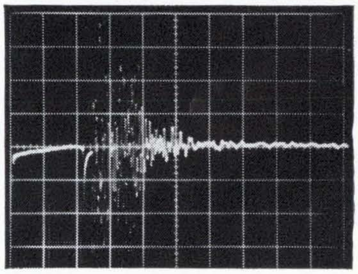
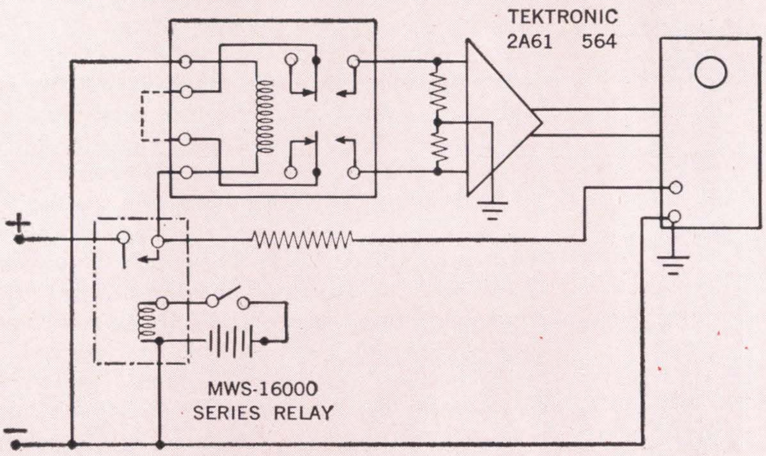


FIGURE 4

Horizontal Deflection	1.0 ms/cm
Vertical Deflection	200 μV/cm
Systems Bandwidth	.06—60K Hz.

TEST CIRCUIT



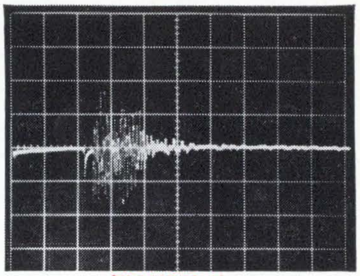


FIGURE 5

Horizontal Deflection	1.0 ms/cm
Vertical Deflection	500 μV/cm
Systems Bandwidth	.06—100K Hz.

* If you have a problem regarding relay applications to a particular system our engineering staff is ready to help you. Contact Mr. Le Roy Carlson, Chief Project Engineer.

Backed by sound research and disciplined engineering, Adlake applies the industry's broadest line of mercury displacement and mercury wetted relays to the creative solution of design circuit problems. However unique or special your application, Adlake can assist you in developing it. For prompt, personal and knowledgeable attention to your relay needs, contact the one source that is the complete source in the mercury relay field. Contact Adlake today for catalog and further information.

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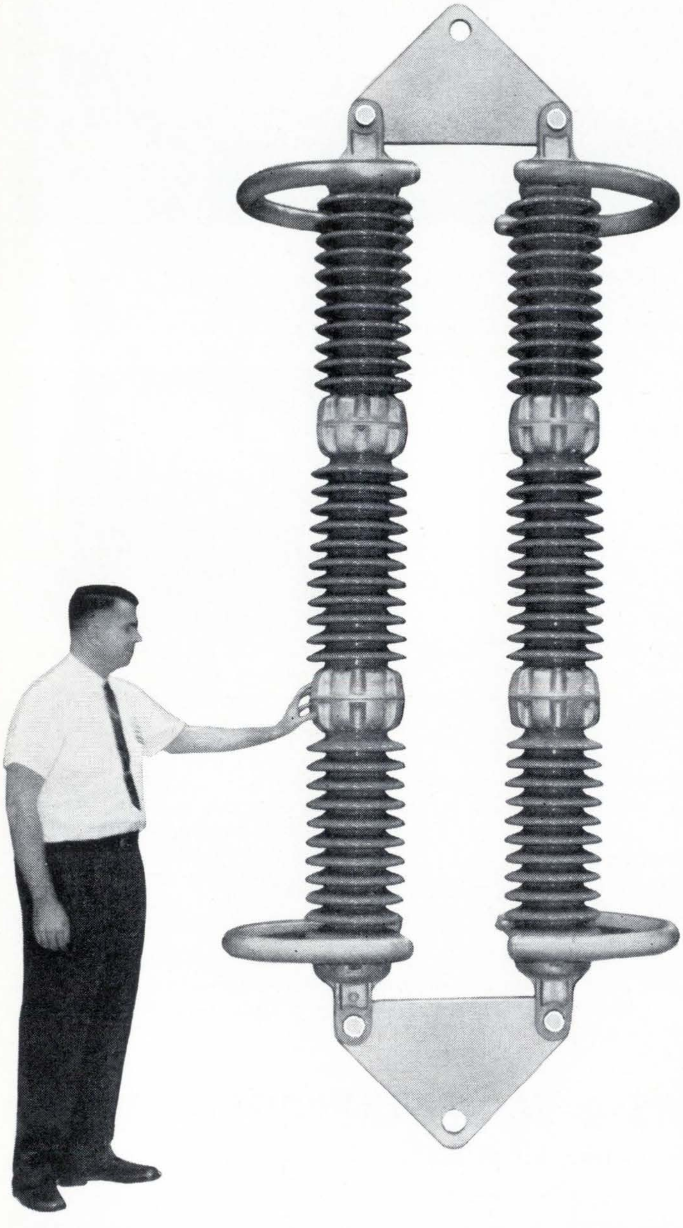
Antenna strain insulators of 240,000 lbs. ultimate strength?



Lapp designs and builds them.

The double-strain insulator assembly shown here tested to 240,000 lbs. ultimate strength. It isn't the biggest either. Already designed is a similar triple-strain insulator with a strength of 360,000 lbs. Lapp also has delivered compression cone guy insulators as high as 620,000 lbs. ultimate strength, and has designed them to 750,000 lbs. strength.

Lapp makes individual insulators, insulator assemblies, and complete insulator systems to handle most any electrical and mechanical requirement. Lapp does the complete job from drawing board, through testing, to delivery. We've been doing this work since "radio" was born. So, you can count on Lapp for knowledge, ingenuity, facility and quality.

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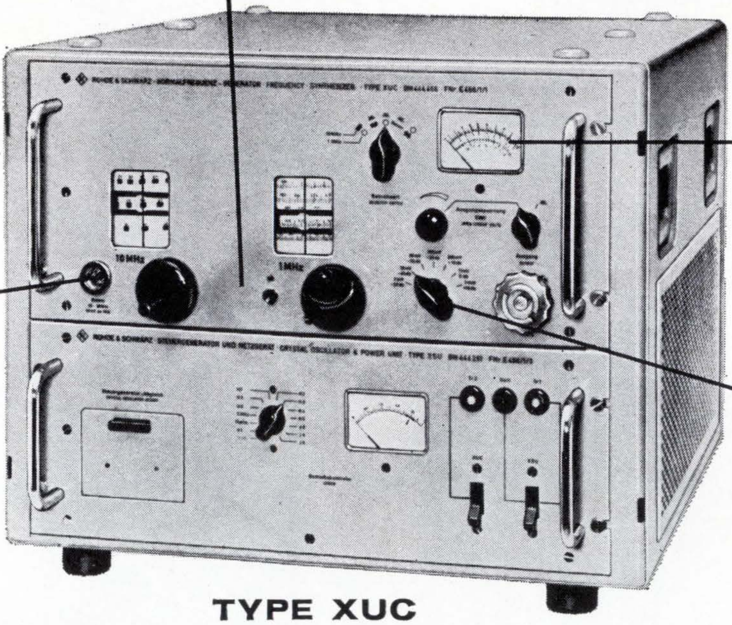

TYPE XUC

UHF FREQUENCY SYNTHESIZER

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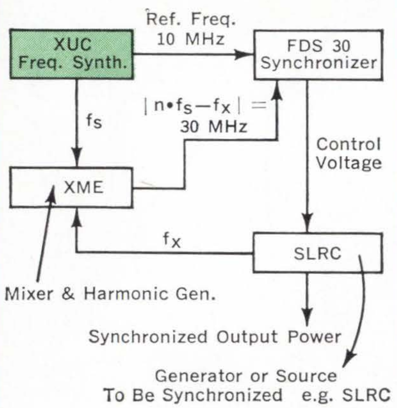
- Built-in 5 MHz crystal has proportional oven and 2 x 10^{-9} stability
- Spurious frequency suppression greater than 80 dB
- Fixed frequency outputs:
  100 kHz, 1 MHz, 10 MHz
- Solid State Design

TYPICAL SYNCHRONIZING SYSTEM



The Type XUC is the only true UHF-Synthesizer. It is the only single instrument to provide output frequencies to 1 GHz with 3V and 80 dB suppression of spurious. Generation of ultra-stable microwave frequencies is simplified and can be accomplished in two ways:

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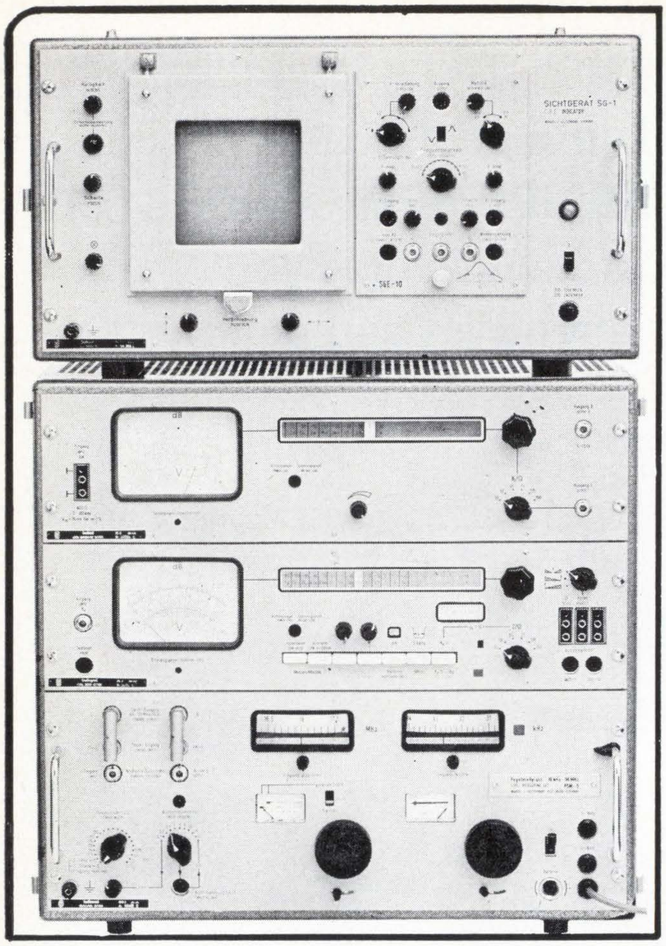

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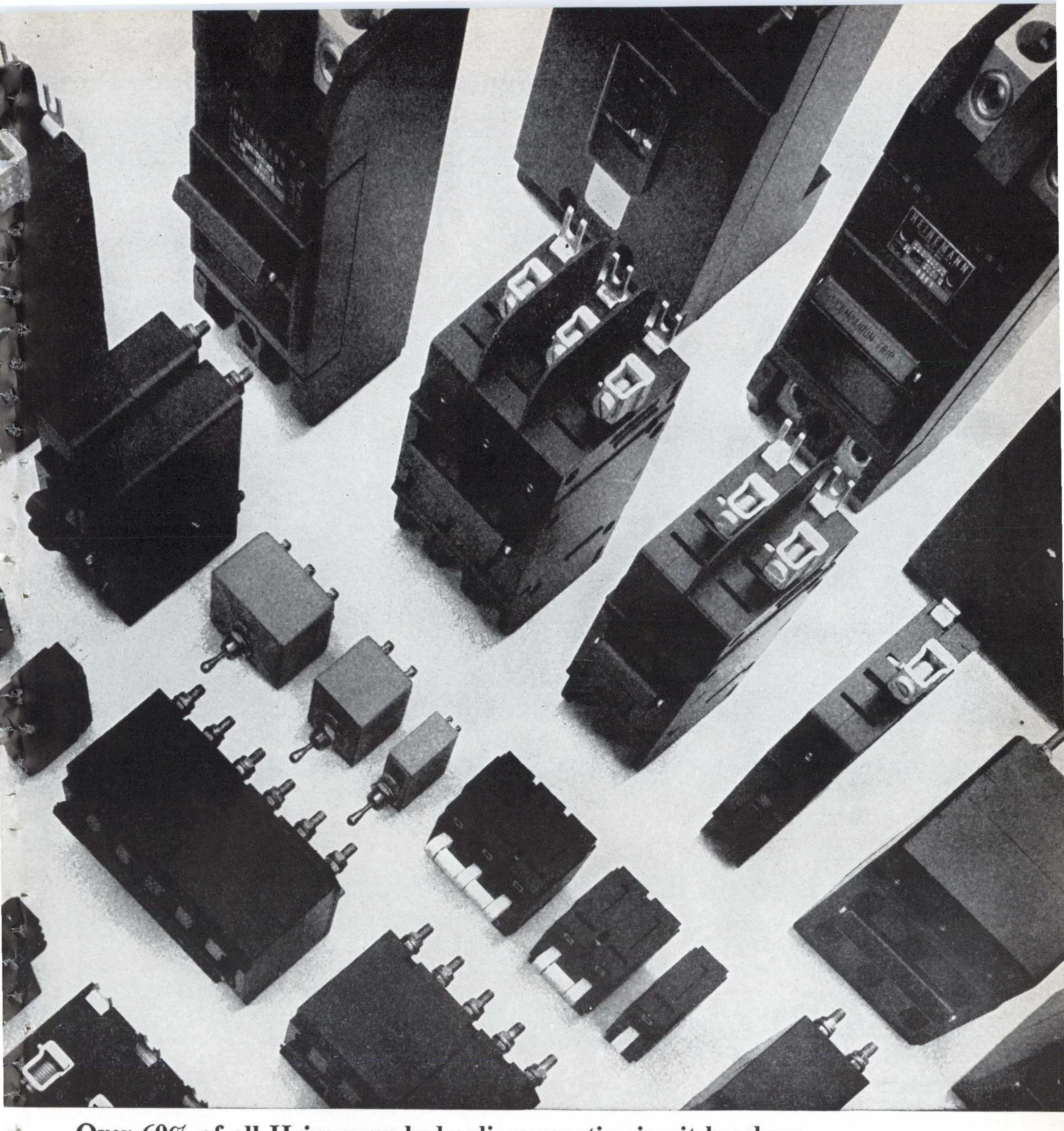

Over 60% of all Heinemann hydraulic-magnetic circuit breakers produced each year are rather odd in one way or another.

By the usual standards, at any rate. But for us the far-out is all in a day's work. We're tooled up to manufacture the out-of-the-ordinary as a matter of routine.

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If you've got a knotty protection requirement, get in touch with us. For a starter, try our Bulletin 302; it covers our entire line of breakers. We'll put a copy in the mail as soon as we hear from you. Heinemann Electric Company, 2626 Brunswick Pike, Trenton, N.J. 08602.

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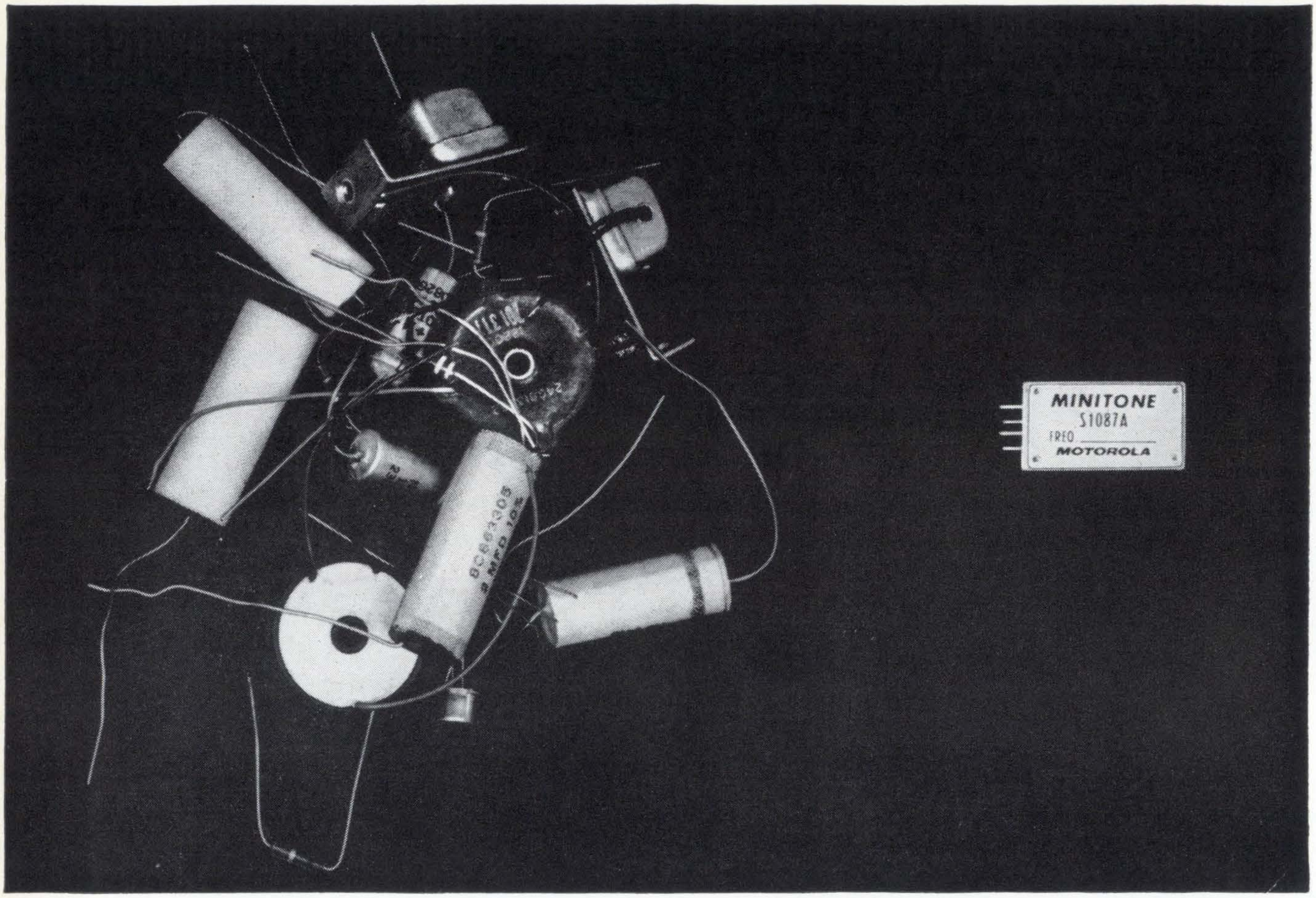
Circle 95 on reader service ...



Two ways to achieve selective signaling

The MINITONE reed on the right does it better

Motorola's new miniaturized resonant reed either generates a highly stable audio tone, or provides very selective decoding. It does the job better because it's small, has excellent stability, and contains no contacts to wear out. And the MINITONE resonant reed is more economical; it eliminates the expense of extra components and design time needed to build highly selective tone oscillators and associated compensating circuits. Take a look at these facts:

See it at Booth 3A05–6 at I.E.E.E.

SMALL SIZE: About ¼ of a cubic inch in volume. Measures only 1.11″ x 0.619″ x 0.393″.

LONG LIFE: No contacts to wear out or cause malfunctions; life comparable to solid-state devices. Plus 3-year warranty.

HIGH STABILITY: Frequency tolerance ±0.1%. Temperature stability better than ±0.001% per °C between −30°C and +100°C (25°C reference).

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QUICK DELIVERY: Over 200 standard frequencies available from stock.

RUGGED CONSTRUCTION: Exceeds E.I.A. standards for shock and vibration.

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FOR MORE INFORMATION contact your Motorola representative. Or write for bulletin TIC-3214.

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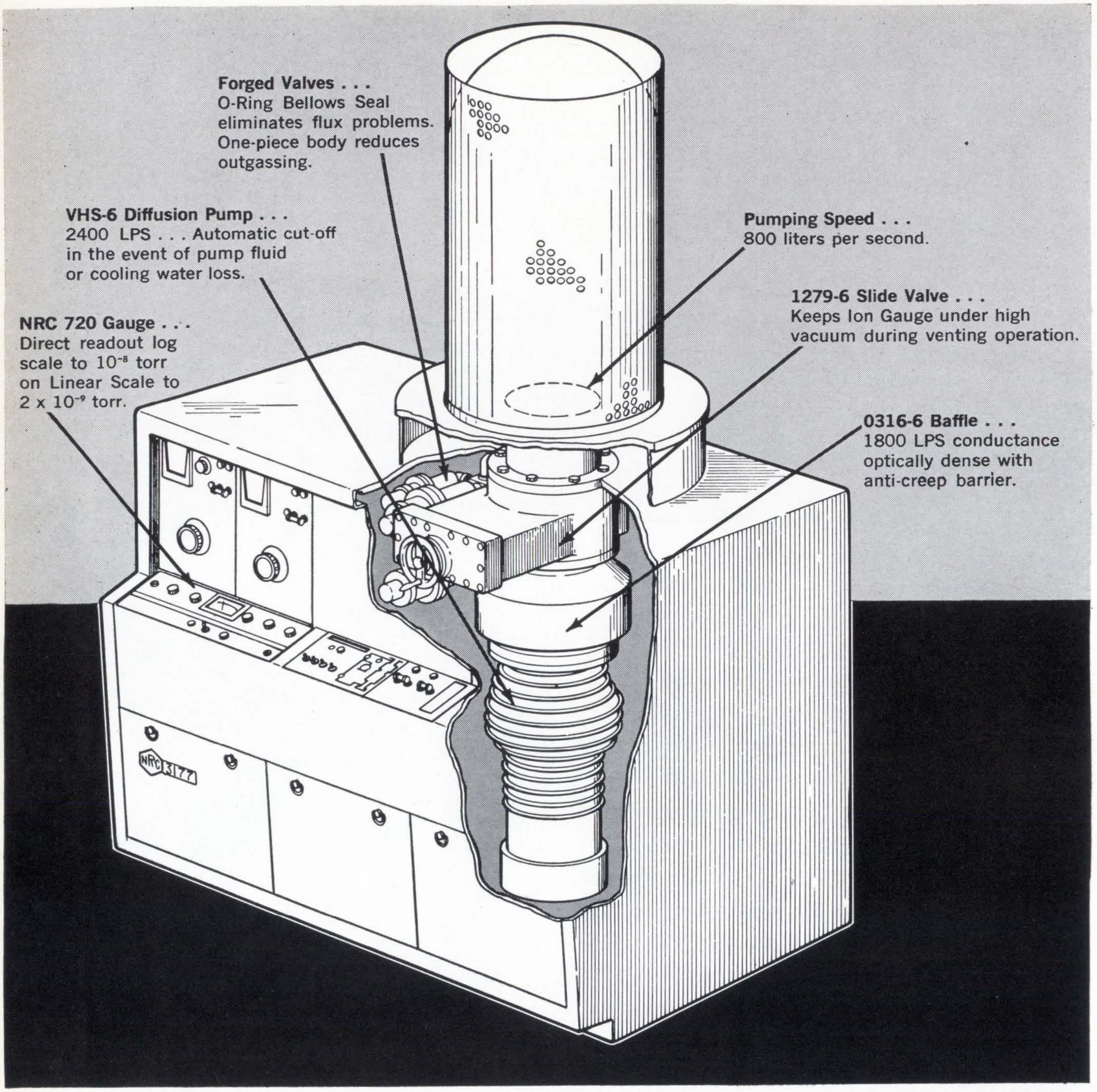

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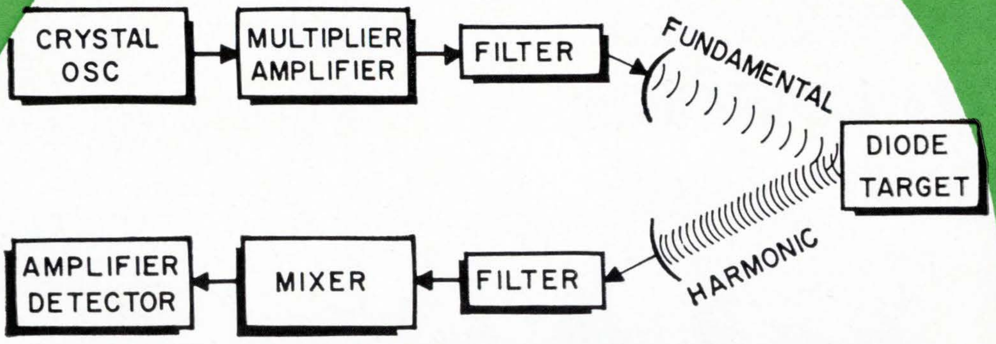

Can a diode in free space generate harmonics?

YES—and it's the basis of a new communications & navigation system from Microlab/FXR!

Everyone knows that diodes generate harmonics—in a circuit! But perhaps you didn't know that diodes can be made to do this in free space—without any attached circuitry or power source.

Microlab/FXR has applied this principle to a new Diode Interrogation, Communication and Navigation System*. This is a harmonic radar system, consisting of a Diode Exciter/Receiver plus a passive diode antenna—or a self-focusing phased array where increased range is required—either modulated or unmodulated.

This new Microlab/FXR system can thus detect and communicate with any object (or person) to which the diode is attached. Perhaps even more important, it can positively *single out and identify* any particular target from all others.

Microlab/FXR's new system can well be the answer to heretofore unyielding problems connected with air/sea navigation, flight traffic control, rescue and recovery operations, IFF systems, etc. In other areas, the system can be used for everything from automobile traffic control to aircraft blind landing systems; from bird and animal migratory studies to human medical diagnostics.

Maybe these applications whet your appetite – maybe they fit in neatly with a project you're working on– maybe they give you a new idea for something we haven't thought of. If so, you'll want more information. Just circle the Reader Service Card. Better still, write us directly, at Dept. E-61.

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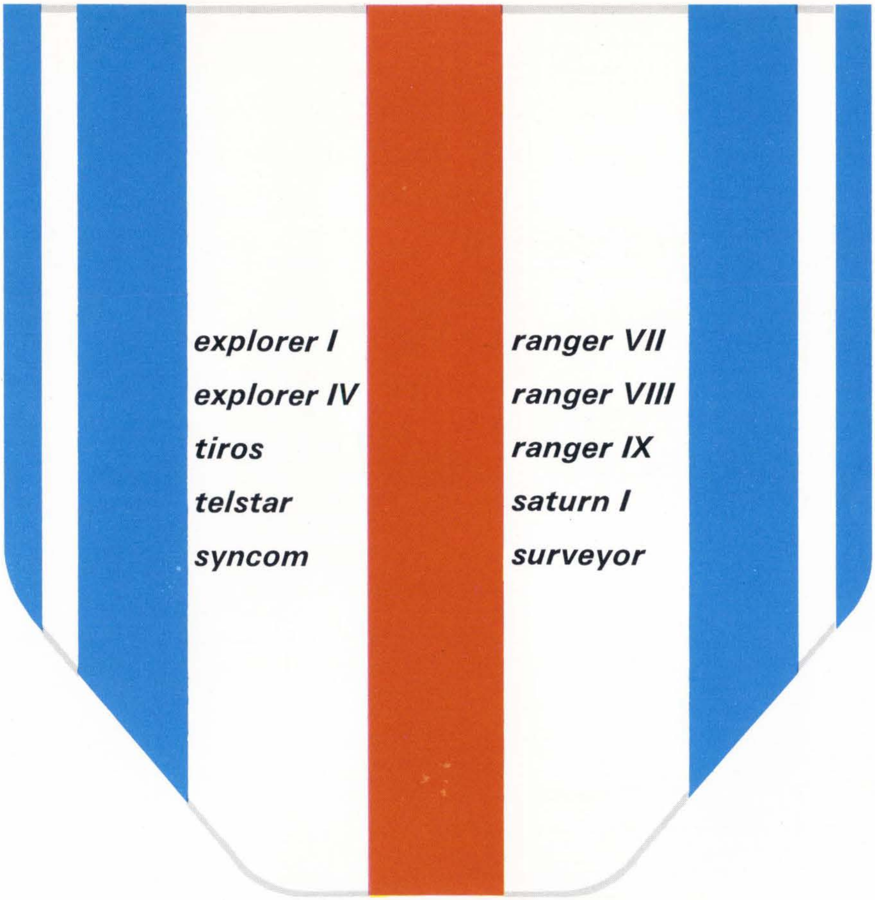
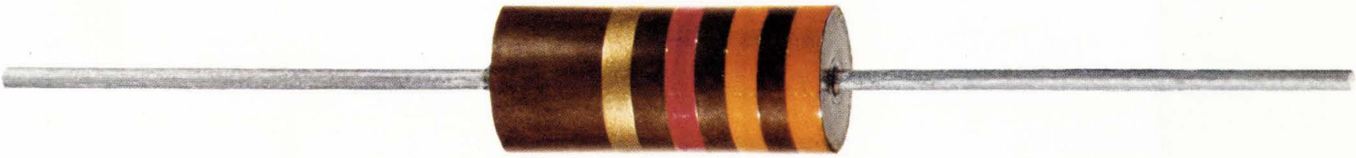




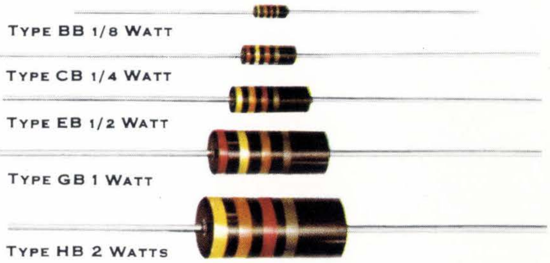
the most honored resistor in the Space Program

■ Allen-Bradley hot molded resistors were chosen to participate in these many history-making space projects for only one vital reason—a history of proven performance that dates back for more than a quarter of a century! A record more conclusive than any testing program could possibly provide!

The superiority of Allen-Bradley resistors is found in the exclusive hot molding process. Through the use of completely automatic machines—developed and used *only* by Allen-Bradley—there is obtained such uniformity of characteristics from resistor to resistor, year after year, that the resistors' long term performance can be accurately predicted. Furthermore, no Allen-Bradley hot molded resistor has ever been found to have failed catastrophically.

The widespread use of the Allen-Bradley hot molded resistors in these space programs should convince you that to include this plus value in the equipment which you produce gives it the mark of "extra quality." Let us tell you more about the complete line of Allen-Bradley electronic components. Please write for Publication 6024. Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Limited. Export Office: 630 Third Ave., N. Y., N. Y. U.S.A. 10017.

HOT MOLDED FIXED RESISTORS are available in all standard resistance values and tolerances, plus values above and below standard limits. **Shown actual size.**



ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

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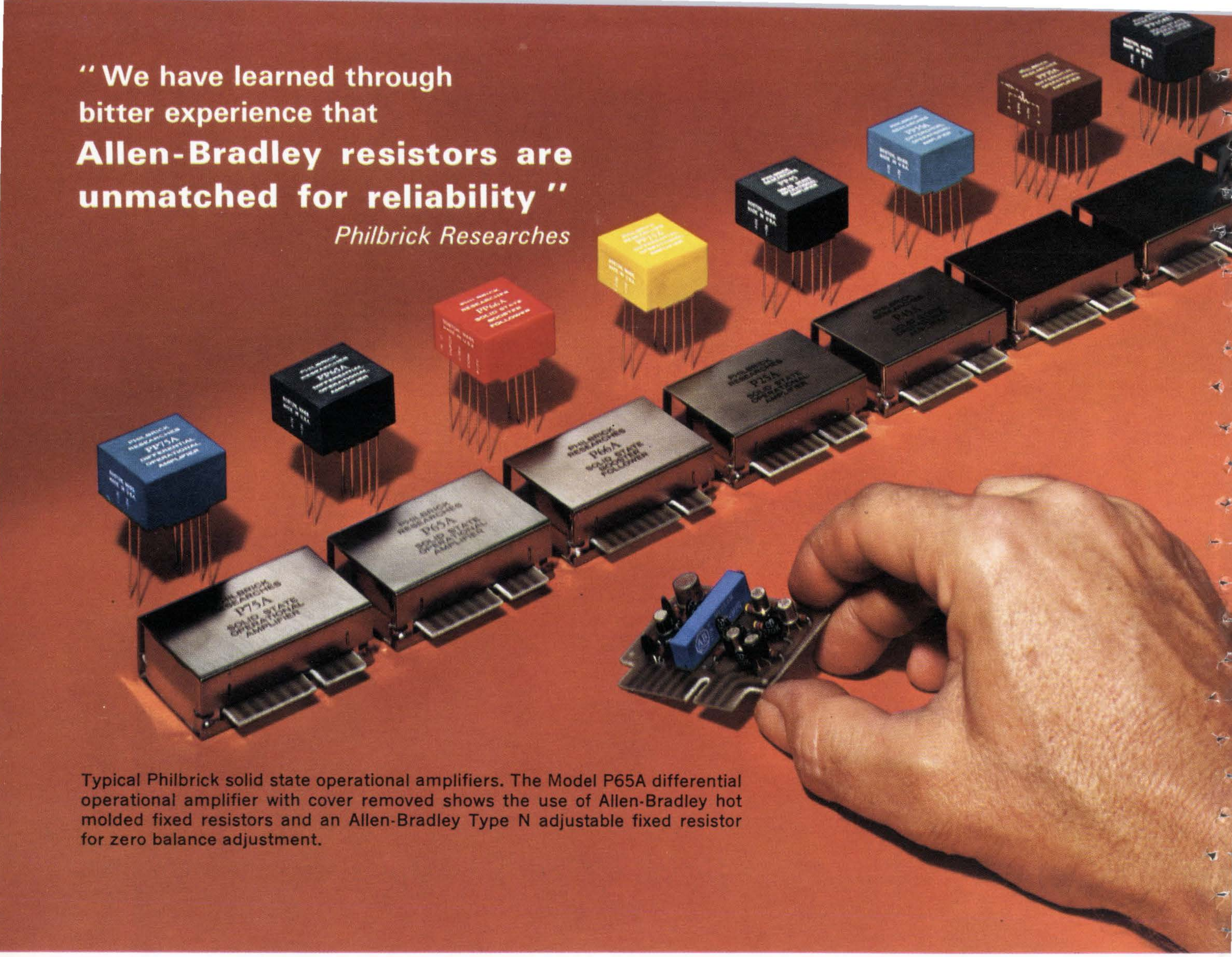
"We have learned through bitter experience that Allen-Bradley resistors are unmatched for reliability"

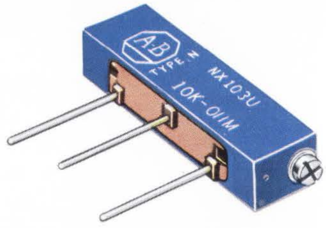
Philbrick Researches



Typical Philbrick solid state operational amplifiers. The Model P65A differential operational amplifier with cover removed shows the use of Allen-Bradley hot molded fixed resistors and an Allen-Bradley Type N adjustable fixed resistor for zero balance adjustment.

HOT MOLDED FIXED RESISTORS are available in all standard EIA and MIL-R-11 resistance values and tolerances, plus values above and below standard limits. Shown actual size.

The need for a yearly production capacity of well over a billion units is a testimonial to the uniformity and reliability of all Allen-Bradley hot molded resistors.



Type N hot molded adjustable fixed resistor rated ⅓ watt at 50°C ambient. Available with nominal resistance values from 100 ohms to 2.5 megohms with tolerances of ±10% and ±20%.

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Allen-Bradley Type N adjustable fixed resistors likewise use a solid hot molded resistance track. Adjustment is so smooth, it approaches infinite resolution—and settings remain fixed. Being noninductive, Type N controls can be used at high frequency, where wire-wound units would be completely unsatisfactory.

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A-B QUALITY

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

63-05-6E

Solitron announces

A MAJOR BREAKTHROUGH in Silicon Power Transistors:

ISOLTAXIAL T.M.

NPN SILICON TRANSISTORS

PAT. PENDING

Featuring

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- freedom from secondary breakdown
- flat gain curve
- 15 amp capabilities
- 145 Watts @ 25°C
- low output admittance
- low saturation voltages
- high reliability

Now — for the first time — a transistor has been developed with the characteristics of low-leakage planar units, combined with resistance to secondary breakdown offered by homogenous devices. The results are Solitron's ISOLTAXIAL NPN Silicon Power Transistors! The ISOLTAXIAL transistors have special construction innovations and processing techniques, and were developed with the high reliability standards associated with Solitron. A few of their many applications include power supplies, audio amplifiers, inverters, converters, relay drivers and series regulators. ISOLTAXIAL transistors are low-cost and packaged in TO-3 and T-61 cases.

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

ALL TYPES INCLUDE THE FOLLOWING SPECIFICATIONS:
Gain 20-60 @ 5 A
VCE (sat) 0.5 V Max. @ 5 A
VBE (sat) 1.2 V Max. @ 5 A
ft 1.0 MHz Min.

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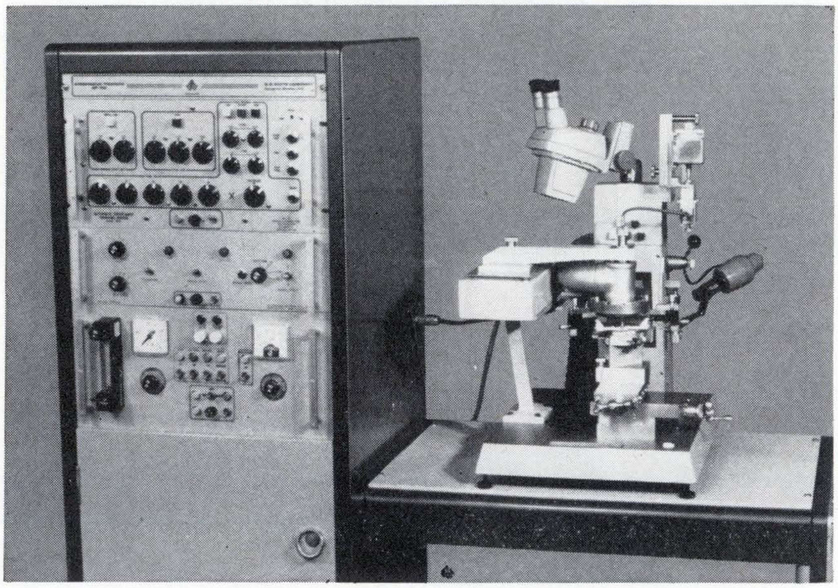
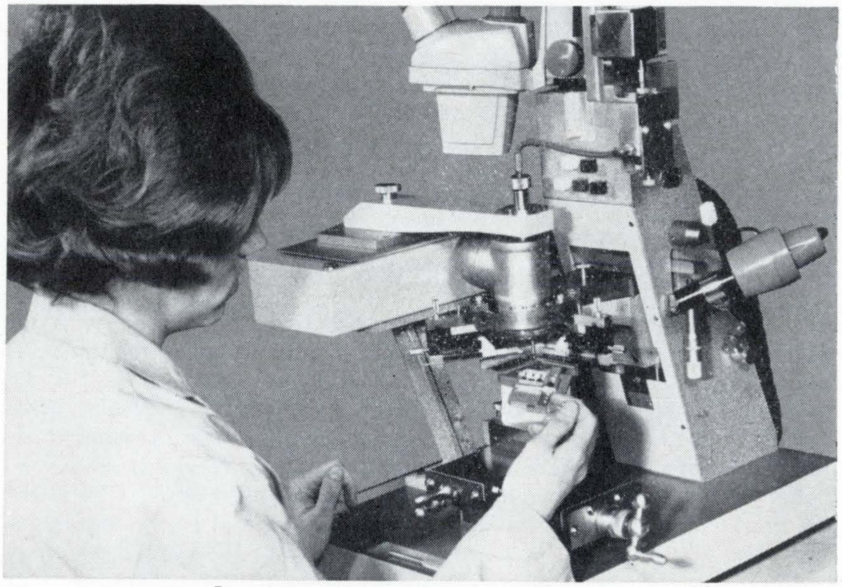
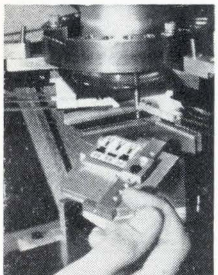


Airbrasive® Resistor Trimming System:



a complete system that adjusts IC resistors to 0.5% accuracy



Production rates of 600 trims per hour are attainable with this new, complete system which automatically trims and tests resistors to any specified value within 0.5%. Once operator has placed module in position, checking, trimming, and inspection are automatic. Complete cycle requires from one to three seconds, depending on programmed tolerance and the amount of material to be removed.

Final value tolerance limits may be programmed from 0% to 11% in increments of 0.1%. The machine increases production yield by holding programmed tolerance with great accuracy. Modules which cannot be trimmed to required value are rejected before further processing is done.

Trimming is accomplished by the proven Airbrasive method—a miniature abrasive jet of 27-μ aluminum oxide provides precise, cool, shockless abrading which does not affect substrates or electrical properties of resistance material. Machine may be programmed for a wide range of values, will trim resistors in any position, on any size module, with thick or thin film substrate.

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The Moseley 7005A lets you record on an 11"x17" chart for increased resolution. Five calibrated ranges each axis, 1 m V/in. to 10 V/in. High input impedance, floating and guarded input, 0.2% accuracy at full scale. Adjustable zero set each axis. Autogrip care-free electric paper holddown. Electric pen lift. Bench and rack mount model in one. Metric Model 7005AM is also available.

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BRIEF SPECIFICATIONS

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Input Resistance: Potentiometric—1 mV/in. range; 100K—10 mV/in.; 1 Megohm—0.1, 1, 10 V/in.

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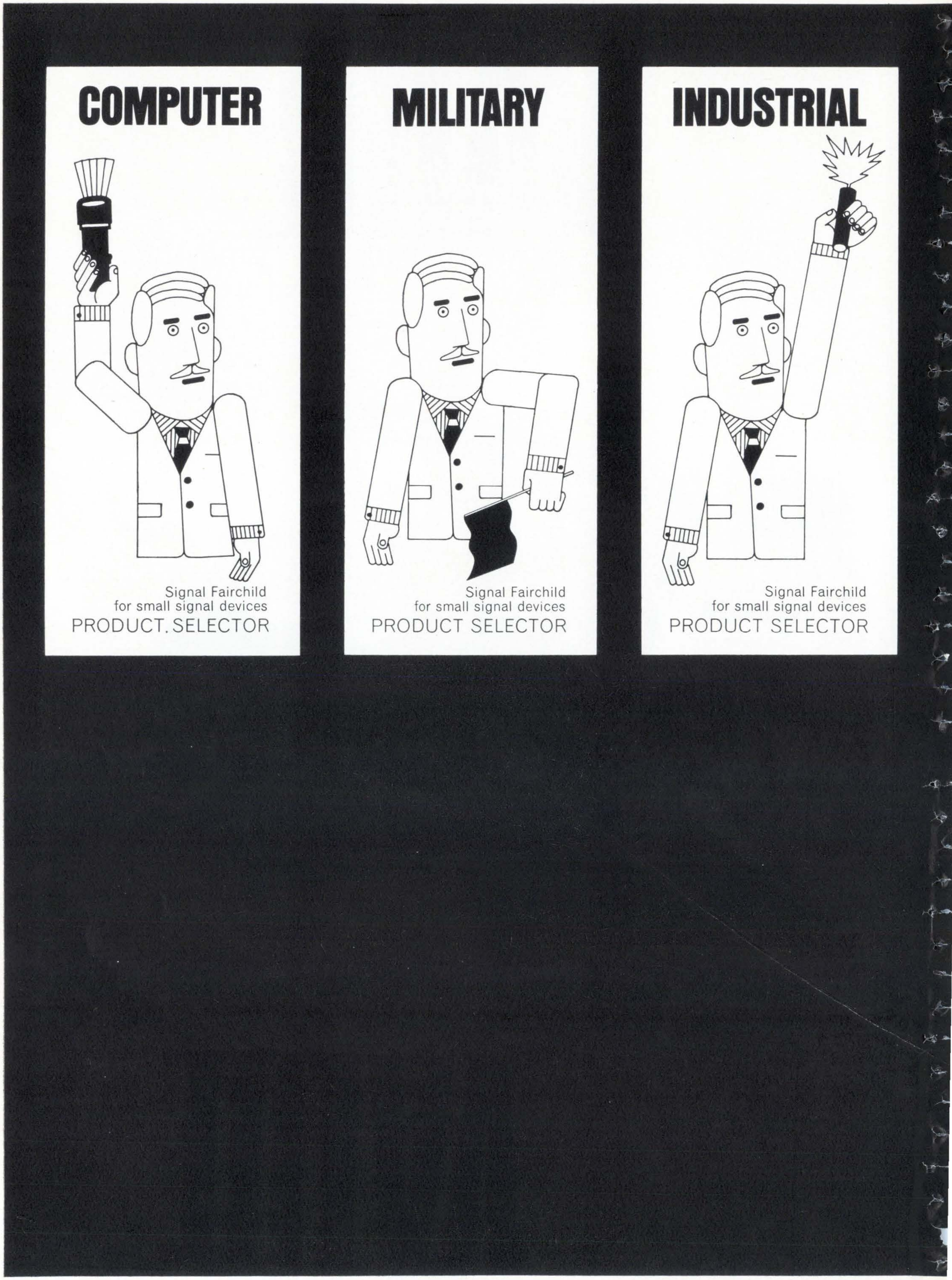
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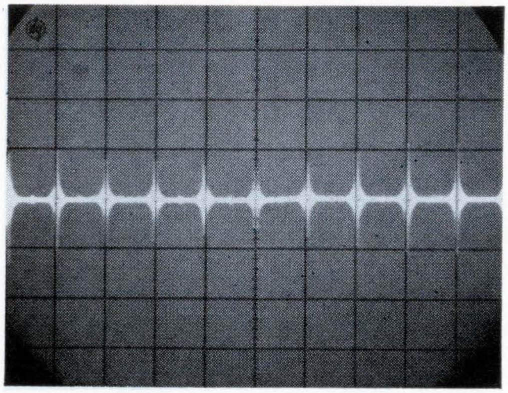
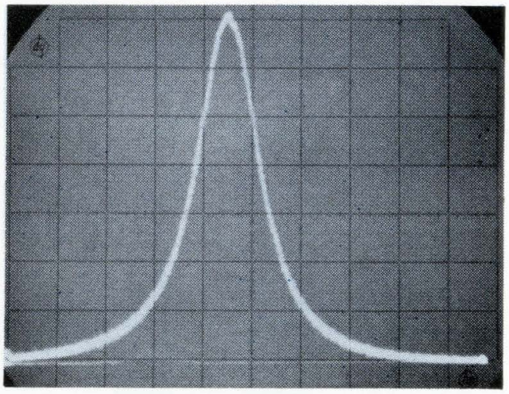
Wide and Narrow Sweeps with this



Oscillogram of a 10 to 110 MHz sweep with 10 MHz birdie markers added to show excellent sweep linearity. Specified 0.5% linearity and 1% frequency accuracy permit easy identification of intermediate sweep points, eliminating need for tedious pre-calibration.



With low residual FM and very linear sweeps, you can measure narrow-band characteristics easily. Shown here is the response of a 20 MHz crystal filter over narrow 100 kHz sweep width (10 kHz/cm.); just read the 10 kHz pass band directly from oscilloscope.

The Hewlett-Packard 8690A/8698A Sweep Oscillator (0.1 to 110 MHz) offers all the performance and operating conveniences you've been looking for in an RF sweeper:

- **Two independent broadband sweeps, each with 1% end-point frequency accuracy and 0.5% linearity.**
- **Calibrated ΔF sweeps (sweeps 0 to 10% of frequency range) for narrow sweeps, maintaining 0.5% linearity.**
- **CW operation; external FM (DC to 2 kHz with full band deviation).**
- **Automatic, manual or triggered sweeps; sweep times from 0.01 to 100 seconds.**

Frequency accuracy, frequency stability, sweep linearity, residual FM and spurious signal levels are all *specified* parameters (rarely done for RF sweepers).

The 8690A/8698A provides full band sweep capabilities and excellent narrowband performance, eliminating the need for two separate sweepers. Both high-Q and wide-band devices can be swept with just one instrument. In addition, the frequency stability, signal purity, calibrated output power and precision output attenuator of the 8690A/8698A commend it for many applications calling for a precision signal generator.

And the 8690A Sweep Oscillator main unit accepts 17 other HP microwave sweeper units covering 1 to 40 GHz in octave- and waveguide-bands.

Performance of 8698A RF Sweeper Generator

(installed in 8690A Sweep Oscillator)

FREQUENCY SPECIFICATIONS

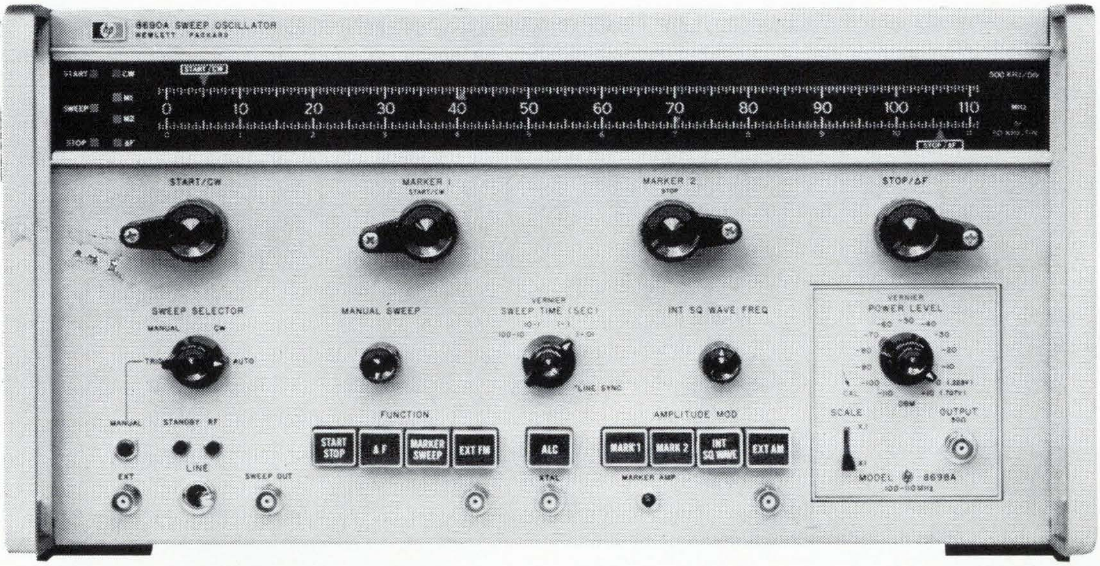
Frequency Range:
0.1 to 11 MHz and 1 to 110 MHz, selected by front-panel switch.

Frequency Accuracy:
0.1 to 11 MHz, ±1% or ±10 kHz, whichever is greater; 1 to 110 MHz, ±1% or ±100 kHz, whichever is greater.

Frequency Linearity:
±0.5%

See New Hewlett-Packard Instrumentation at IEEE Show, New York Coliseum, March 20-23

Linear RF Sweeper



Residual FM:
0.1 to 11 MHz <150 Hz peak, 1 to 110 MHz <500 Hz peak.

Frequency Stability:
With temperature: 0.1 to 11 MHz, ±0.01%/°C or ±200 Hz/°C, whichever is greater; 1 to 110 MHz, ±0.01%/°C or ±2 kHz/°C, whichever is greater.

With 10% line voltage change: 0.1 to 11 MHz, ±5 kHz; 1 to 110 MHz, ±50 kHz.

Spurious Signals:
Non-harmonics at least 40 dB below CW output. Harmonics at least 35 dB below +10 dBm CW output.

POWER SPECIFICATIONS

Power Output:
At least +20 dBm max. (2.23 VRMS into 50 ohms). Calibrated power output adjustable in 10 dB steps from +10 dBm to −110 dBm; 10 dB vernier permits continuous adjustment between steps. Source impedance is 50 ohms.

Power Accuracy:
±1 dB + attenuator accuracy (vernier in CAL position).

Attenuator Accuracy:
±1 dB to 70 dB attenuation; ±2 dB to 120 dB attenuation.

Output Flatness:
±0.25 dB (±0.1 dB over any 10 MHz bandwidth).

Price: Model 8698A RF Sweeper Generator, $950.
(Model 8690A Sweep Oscillator, $1550.)

For more information contact your local HP field engineer or write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304, Tel: (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

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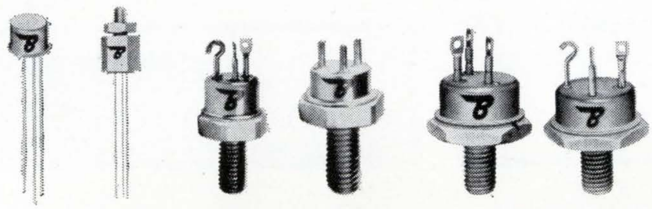
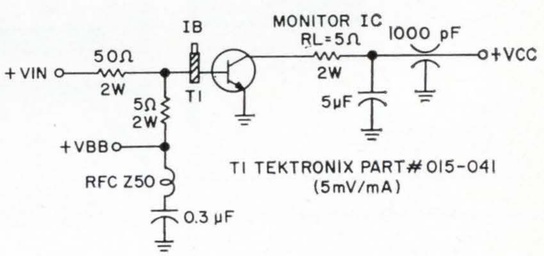
IC	VCEO	hFE	VCE(sat)	PT	SWITCHING TIME			
					t on ns	t off ns	@ IC A	@ ± IB mA
3A	40 to 60V	25 min @ 2A, 10V	0.5V max @ 1A, 0.1A	5W	35	75	1.5	150
5A	40 to 80V	120 min @ 3A, 10V	0.75V max @ 3A, 0.3A		40	300	3.0	300
10A		40 min @ 5A, 10V	1V max @ 5A, 0.5A	25W to 50W				
15A	60 to 100V	15 min @ 10A, 5V	1.5V max @ 15A, 3A	100W	225	600	10	1000
20A		20 min @ 10A, 5V	1.5V max @ 20A, 4A					



TO-5 MT-27 TO-59 TO-60 TO-61

SATURATED SWITCHING TEST CIRCUIT



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

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PHASE METERS—PM 730 measures phase relationship between all types of waveforms; sine, rectangular, triangular, pulse, etc • Both models feature 10 mV per degree DVM output at .2% full scale accuracy, selectable phase response time and 100 mV to 500 V peak to peak input • Precision 180° phase shifter optionally available on both models

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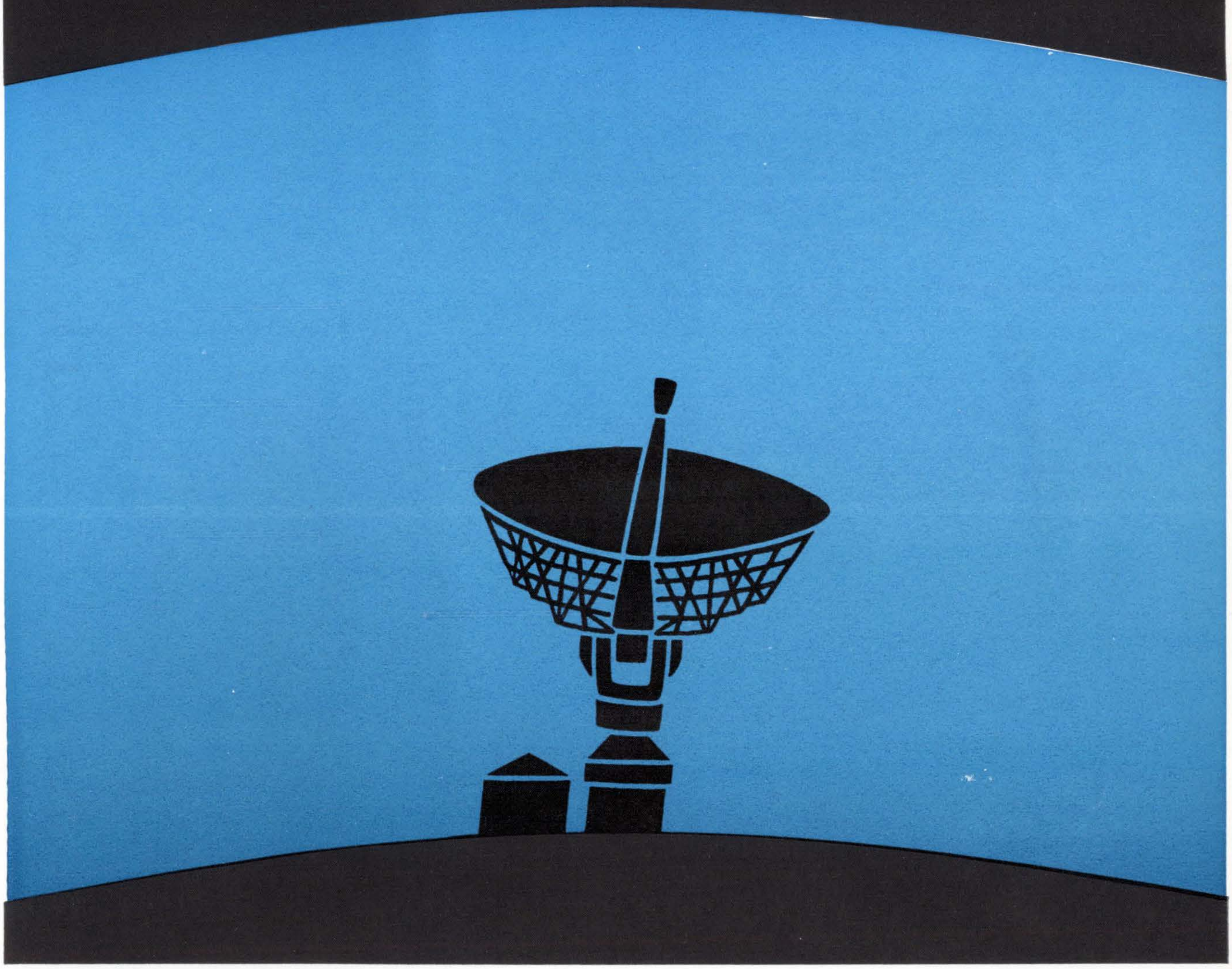

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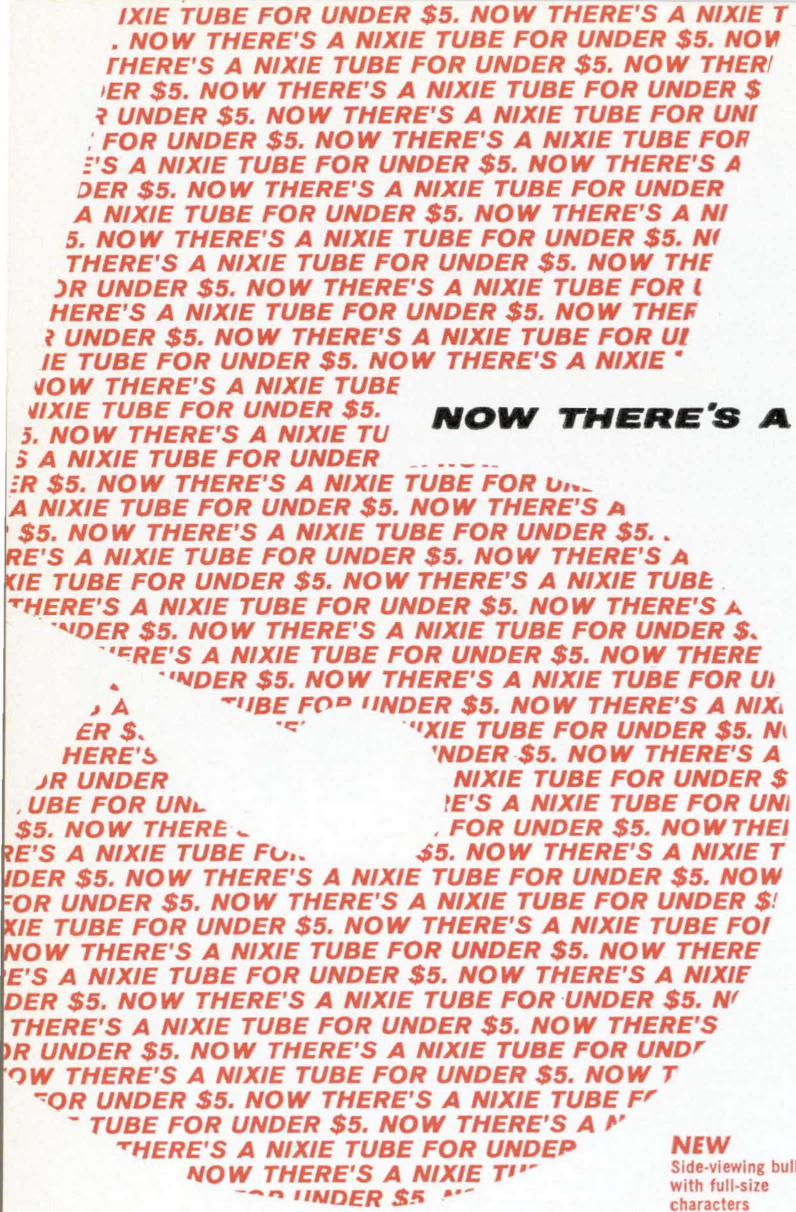

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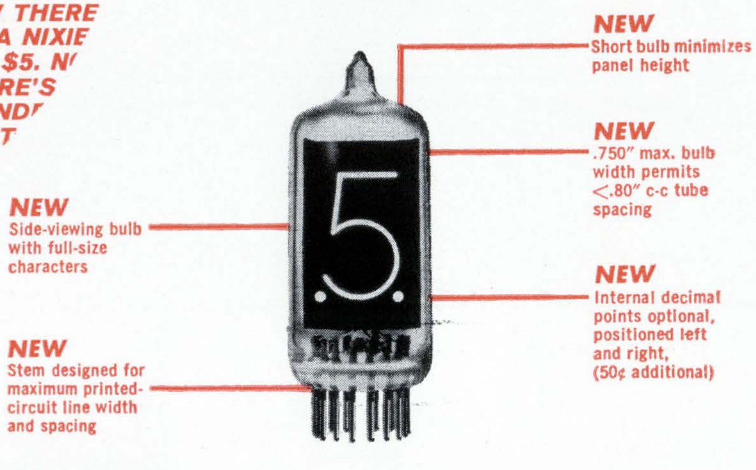

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Remember—the low cost of the new NIXIE tube Type B-5440 precludes consideration of other types of numerical readouts such as electro-luminescent and projection types where cost is a major factor. Get a *real* NIXIE tube with *real* NIXIE-tube performance and acceptability.

Use the reply card for full information on the new NIXIE tube and complete readout-application assistance.

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March 6, 1967 | **Highlights of this issue**

Technical Articles

Product planning at IEEE
page 116

This year will see integrated circuits move into a variety of new equipment. In this examination of some significant products to be introduced at the annual show of the Institute of Electrical and Electronic Engineers, the emphasis is on integrated circuits and instruments to test them. The trend in new products shows industry has a continuing interest in reducing production costs.

Worldwide look at the Gunn effect
page 134

The Gunn effect is the best known of the new phenomena that are exciting semiconductor engineers and microwave experts. Except for some production in Europe, however, the Gunn effect is confined to research laboratories. Some newer effects like limited space-charge accumulation now hold greater promise. On the cover is a many-times magnification of a voltage tunable oscillator, built at Bell Telephone Laboratories, that is tapered to allow control of the Gunn effect. The oscillator is about 30 mils long.

Computer-aided design, part 7: Performing nonlinear d-c analysis
page 140

Earlier in this important series, there were extensive descriptions of how a computer can help in design when linear elements like resistors and capacitors are involved. These components require simple models. But nonlinear devices like the transistor and zener diodes require more complex models and procedures. A computer program has been prepared to solve nonlinear d-c problems and statistical, worst-case, and stress analysis.

Integrated circuits in action, part 5: In search of the ideal logic scheme
page 149

In the brief history of integrated electronics, many different logic schemes have been proposed. The engineer who has to choose one ought to understand the weaknesses and strengths of each.

1. Dilemmas galore—a survey of types of integrated logic
2. Understanding integrated-circuit logic—the engineer has to know how the logic works because specifications are often sketchy
3. Logic IC's don't live alone—the system affects the choice of circuit logic too

Coming March 20

- **How the computer handles transient analysis**
- **Measuring the transconductance of field effect transistors**
- **Computers for research satellites**
- **Glass isolation at work**

The Year of the IC

Integrated circuits will be turning up routinely in new products throughout 1967. The big switch from discretes is on. After a couple of years of getting their feet wet—investigating, surveying and testing—most suppliers of electronic equipment are now putting products made with integrated circuits into production. The new equipment includes instruments and subassemblies, computers and radios, industrial and military gear.

The trend will be crystal clear at the show held during the annual meeting of the Institute of Electrical and Electronics Engineers in New York, March 20 to 25. For example, the Hewlett-Packard Co., the giant of the instrument industry, will exhibit new counters, its first products made with its own integrated circuits [Feb. 20, 1967, p. 50]. When company engineers found they needed some special instruments to test the circuits for these new products, they designed an automatic tester [p. 129] that the company has decided to sell as a commercial product; it will be on exhibit at the New York show.

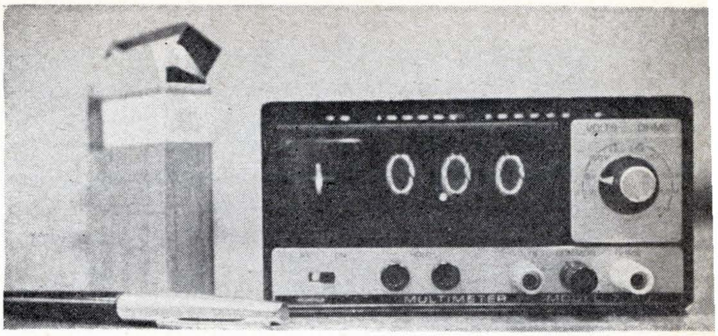
Executives at Texas Instruments Incorporated will demonstrate the depth of their belief in transistor-transistor logic by introducing two additional complete lines [p. 121] to complement the few products it built around this logic last year.

The driving force behind many new products to be unveiled at the show is a continuing pressure to reduce prices. With a new digital voltmeter design, the Instrumentation division of Fairchild Camera & Instrument Co. will dramatically demonstrate the cost reductions possible with integrated circuits. Its newest product, made with integrated electronics, will be on display at the show with a $249 price tag [p. 117].

Engineers at Monsanto Co., a chemical concern that is a relative newcomer to electronics, have used a computer to minimize the components in a new frequency synthesizer [p. 119]. Because the new instrument has only half the components of a conventional synthesizer, it costs about 40% less. Printed Motors Inc. has produced a new flat armature motor that does the same job as printed circuit motors in computer peripheral equipment but at one-fifteenth the cost.

The factor behind many other innovations to be introduced at the show is customer need—still the most important spur to product development. Some of the more significant products are described on pages 117 to 131. They include a phased-lock receiver for the measurement of antenna patterns; an oscillator capable of both variable frequency and constant voltage, and a thin-film thermistor.

Price of meter drops near predicted level



Some scoffed at the prediction four months ago that mass-produced integrated circuits would make possible a $100 digital instrument for measuring voltage and resistance [Electronics, Nov. 28, 1966, p. 88]. Well, it hasn't been done yet, but the Instrumentation division of Fairchild Camera & Instrument Corp. has brought the price of a multimeter down to $249, and claims this is one-fourth the cost of a comparable unit with conventional circuitry.

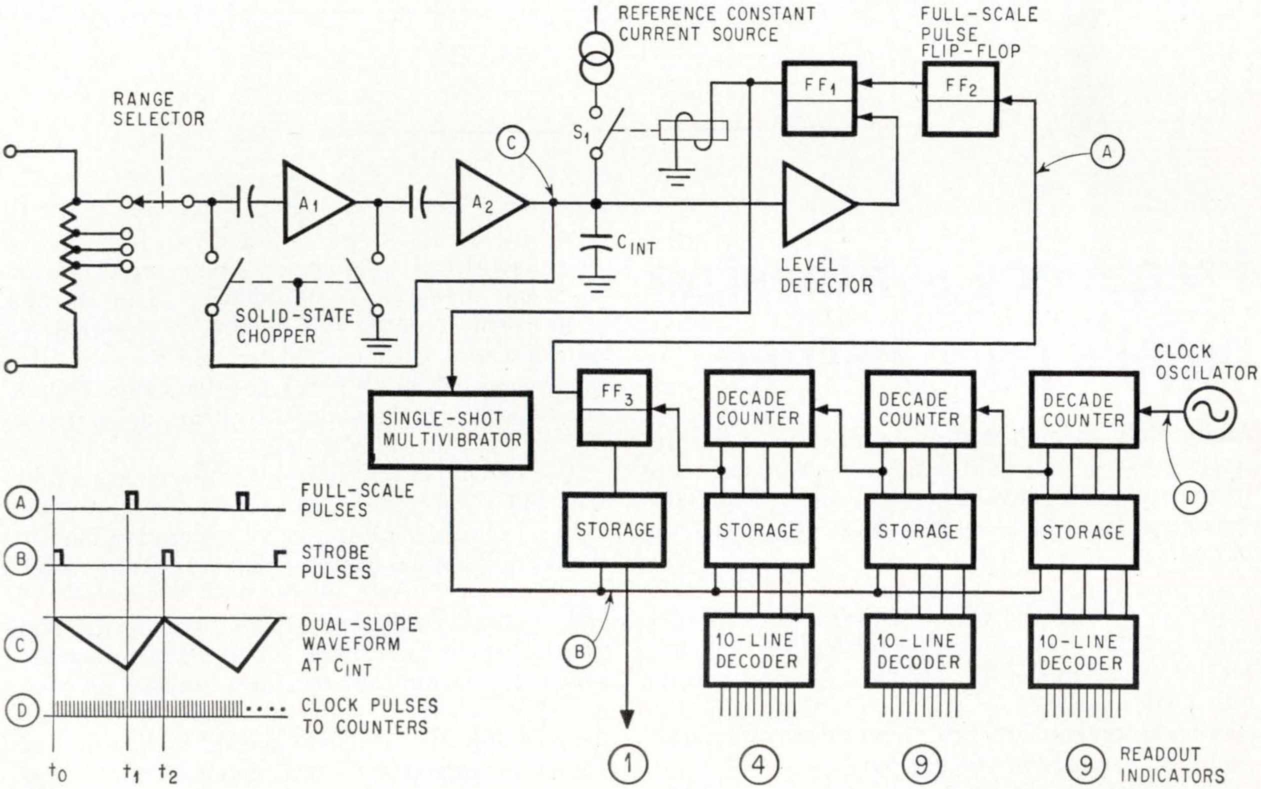
The company says the meter's size and price make it ideal for production-line use, systems testing and calibration, quality assurance, field service and educational applications.

Like the $100 prototype predicted, the Fairchild multimeter uses a dual-slope (up-down) integrating technique for making measurements, but with fewer components. Besides combining the noise-rejection capability of integration with the accuracy and stability provided by automatic comparison to an internal standard, the dual-slope integrating method is better suited to IC's than are other digital voltmeter techniques.

Fairchild's model 7050 uses off-the-shelf IC's for a pair of linear amplifiers and a number of logic elements.

According to the company, the model 7050 can replace not only analog meters and panel indicators but digital voltmeters costing much more. Measured values are displayed on Nixie tubes and are easy to read, even from a distance and at wide angles. The three-digit readout is said to be accurate to within 0.1% of reading. With analog instruments, on the other hand, operator and parallax errors, meter movement wear and aging often reduce their nominal accuracies—1% to 3%, typically. The model 7050 can withstand input voltages up to 1,000 volts d-c on any of its ranges without being damaged, according to Fairchild.

The meter measures d-c voltages from 1.5 to 1,000 v full scale and resistance from 1.5 kilohms full scale to 15 megohms full scale. For voltage measurements, the input is connected directly to the dual-amplifier range selection circuit (below).



To measure voltage, multimeter measures the time required for the constant-current reference to discharge the integrating capacitor to zero volts after it has been charged to an initial value by an input voltage. The level detector senses the moment when C_{int} reaches zero volts and generates a strobe pulse to transfer the count from the counters to the readout and restart the measurement cycle.

But when measuring resistance, a constant-current source is placed across the unknown resistance to generate a proportional voltage.

The output voltage of amplifier A_2 is always negative. The instant the input voltage is applied at t_0, switch S_1 is open and the capacitor C_{int} charges at a rate proportional to the input voltage. Under these conditions, pulses from the clock oscillator fill the decade counters. When all the counters are filled, time t_1, they produce a full-scale pulse.

This pulse switches S_1 to the constant current reference and enables the flip-flop FF, to be activated by the level detector. Switching in the reference source discharges the integration capacitor C_{int} until the level detector is activated at zero volts. At this time, t_2, the level detector changes FF_1's state and returns S_1 to its original position, causing the single-shot multivibrator to generate a strobe pulse, waveform B, that transfers the count in the decades to the readout.

Since the clock oscillator is fixed and feeds pulses to the counters continuously, the number of pulses stored in the counters between times t_1 and t_2 is proportional to the charge originally impressed upon the integrating capacitor. When the level detector is activated, the entire measuring cycle repeats itself. The model 7050 can make six measurements per second.

Changes in components and shifts in the oscillator due to temperature or aging are avoided, Fairchild says, because the same components are used in both counting steps. Also, making a direct comparison during each measurement enhances long-term stability and eliminates the need for daily or weekly calibration adjustments, the company states.

A fourth digit yields a full-scale readout of 1,500 v—equivalent to 50% overranging—with no degradation of accuracy.

Standard features are an input impedance greater than 1,000 megohms on the low range, a floating input that can be operated up to 500 v above ground, and readout storage for a non-blinking display. The multimeter weighs less than four pounds and measures 3¼ x 6¼ x 7¼ inches.

Specifications

D-c volts	to 1,000 v full scale in four ranges 1.500 v full scale (1 ohm resolution)
Resistance	1.500 kilohms full scale (1 ohm resolution) to 15.00 megohms full scale in five ranges. 125 v may be applied to any range without damage
Accuracy	
Volts	±0.1% of reading, ±1 digit
Megohms	±0.2% of reading, ±1 digit
Kilohms	±2% of reading, ±1 digit
Input impedance	
1.5 v range	1,000 meg ohms
15 v to 1,000 v ranges	10 meg ohms
Response time (to step input)	1 second (typical)
Price	$299 (1-4) 275 (5-9) 260 (10-24) 249 (25 and more)

Fairchild Camera & Instrument Corp., 475 Ellis St., Mountain View, Calif. 94040

Frequency synthesizer breaks price barrier

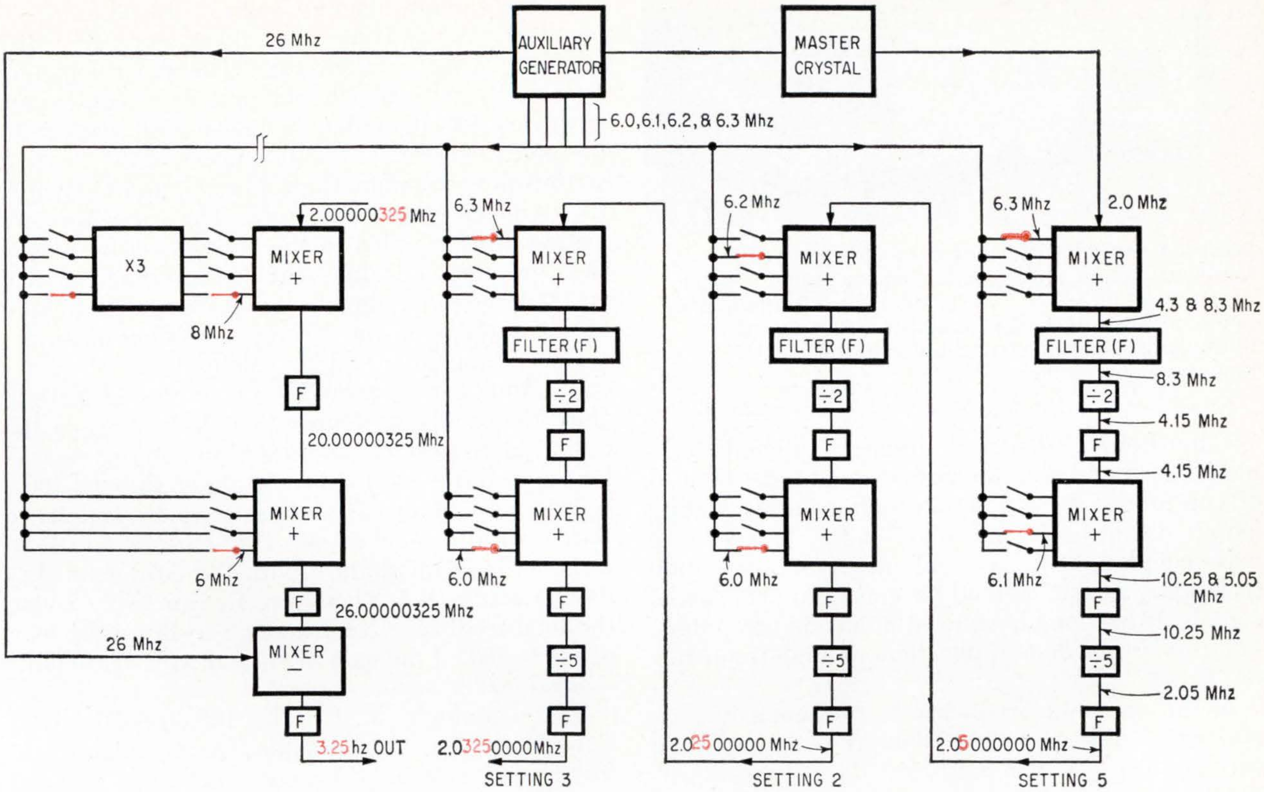
Monsanto's opening shot in its invasion of the frequency-synthesizer field is a device that has more features than its rival units yet sells for $4,000—making it from 30% to 40% less costly than the others.

Designed to supply stable frequencies from 0.01 hertz to 1.3 megahertz for testing electronic circuits, communications equipment and instruments, the unit, model 3100A, combines a signal generator, a sweep oscillator and a precision frequency source. More than 70% of its circuits are integrated. Stability is 1 part in 10^9 per day.

Monsanto claims its digital synthesizer outperforms competitors' models because of an improved method of generating the crystal controlled output. Instead of using divide-by-10 circuits in the synthesizer's decades, Monsanto intersperses divide-by-2 and divide-by-5 countdowns as in the diagrams. This reduces the number of internal frequencies to a master oscillator and five slave frequencies—6.0, 6.1, 6.2, 6.3 and 26 Mhz. The desired outputs, in steps of 0.01 hz, are generated by mixing, filtering and dividing.

The technique also simplifies the filtering problem and results in lower spurious outputs. This occurs because there is a 2-to-1 separation between the desired and undesired sidebands at the mixer's outputs, rather than a 15%-to-25% separation as in conventional synthesizers. This enables the company to use simple, singly tuned filters rather than expensive and difficult to adjust stagger tuned filters. The simpler circuits eliminate over 90% of the adjustments previously needed, reduce production costs, and simplify field maintenance.

Most synthesizers include the vco feature, but not an internal sweep circuit, controlled by knobs on the front panel which can automatically vary the output frequency over any desired range. As an ex-



Decade modules mix signals produced by crystal oscillator to produce desired output—3.25 hertz in this example. Selecting the desired frequency closes various switch-contacts to feed the proper slave frequencies into mixer. Decimal portion (in color) of each decade's output is shifted one digit to the right as it progresses.

ample, the unit can sweep from 1 Mhz to 1.001 Mhz or from 1 kilohertz to 1.3 khz. The two fixed sweep rates are either 1 hz for monitoring on a recorder or 50 hz for viewing on the scope. As in other synthesizers, an external source can control the vco to frequency modulate the output or to provide other sweep rates. This instrument also makes it possible to amplitude modulate the output frequency derived from either the vco or the crystal. A d-c offset feature permits placing the output signal on a d-c bias level, variable between ±2 volts—useful for testing solid state circuits. An attenuator can vary the output amplitude in 10 decibel steps from -70 db above a milliwatt to 20 dbm.

The instrument can be remotely programed for testing frequency-sensitive devices like narrow band filters, delay lines and amplifiers. In this mode, the synthesizer can derive its output from the crystal source or the vco or a combination of both. Frequencies can be selected in any desired pattern.

The unique doubly-balanced mixer circuits in this unit aid in reducing spurious outputs. Using only diodes, transistor and resistors, they suppress input frequencies about 60 db below the sideband. Eventually, Monsanto expects to fabricate these mixers in a special-purpose integrated circuit.

Specifications

Output frequency	0.01 hz to 1.3 Mhz in 0.01 hz steps
Stability	1 x 10^{-9} per day
Output voltage	2 v across 50 ohms
Spurious signals	80 db below desired output
Harmonic signals	50 db below desired output
Modulation	Amplitude or frequency
Size	5¼ in. high, mountable in 19-in. rack
Weight	Approx. 35 pounds
Price	Approx. $4,000

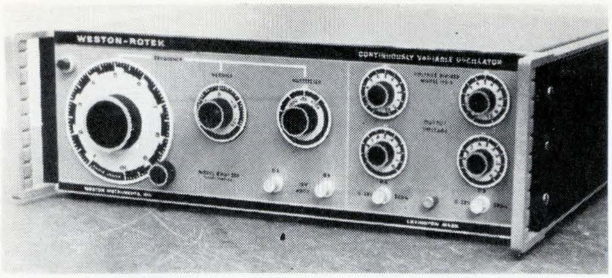
Monsanto Co., 620 Passaic Ave., West Caldwell, N.J. 07006

'Unusual marriage': Constancy, variation

"It took an unusual marriage to do it," says an official of the Weston-Rotek division of Weston Instruments Inc. The comment by Peter Richman, a vice president of the division, refers to the development of an oscillator that provides both a continuously variable frequency capability and a constant output voltage.

Until now, engineers measuring frequency response have had to choose between these two properties. An instrument with a constant output was tunable in discrete steps only, so that if one continuous tuning was required, one had to learn to live with sizable amplitude changes in the output.

In designing its new oscillator, Richman says,



Precision oscillator provides continuously variable frequency output while maintaining the output voltage constant within ±0.01% over the range. The frequency range is indicated by the multiplier dial to the right of the larger dial, which is coupled to the range-changing system.

Weston-Rotek "departed from traditional techniques for regulating the output amplitude. Instead of controlling the amplitude within the oscillating loop, we control the net phase shift." This scheme was coupled with a dual-integrator oscillating technique, a basic method for generating sinusoidal signals. It has long been used in analog computers, but this is its first application to high-frequency oscillators.

In the new unit, frequency is continuously variable from 9.6 hertz to 104 kilohertz with amplitude variations of less than ±0.01%. "The phase-adjusting technique also results in very low distortion and negligible cycle-to-cycle instabilities," Richman states.

Continuous frequency variation permits the same flexibility in precision instrumentation that has long been the case in less precise applications. While direct decade-frequency setting is often desirable, continuous variation allows for manual sweep over a range in order to rapidly locate response irregularities. Weston's oscillator includes an electrical vernier permitting main-dial-setting to be varied ±1%, with a resolution of 0.01%.

Also, filters or other selective systems can be calibrated more readily with a continuous search.

In the circuit diagram below, the operational amplifiers A_1 and A_2 with their associated RC networks are the integrators. The potentiometers R_1 and R_3 are ganged and provide a continuous frequency variation that is linear with respect to the potentiometer ratio and, consequently, the dial setting on each range. Capacitors C_1 and C_2 switch the frequency in decade steps. The capacitors are mechanically coupled to the continuous frequency dial and automatically switch every time the dial is rotated one complete turn. Range switching occurs as the large dial is rotated in either direction.

Each integrator supplies almost 90° of phase shift. Amplifier A_3 provides an additional 180° to close the oscillating loop. A network between the output of A_1 and the summing junction of A_3 can be set to bring the total loop phase shift to 360°.

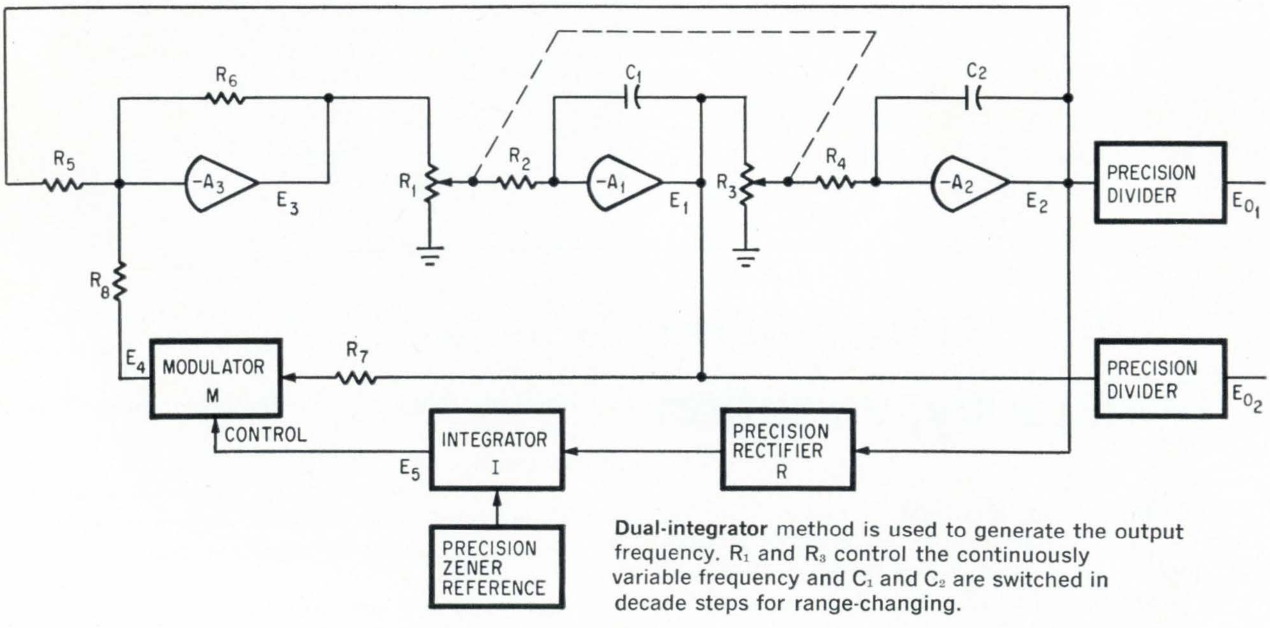
This network consists of resistors R_7 and R_8 in series with a modulator. The current in these resistors is in quadrature with the current in A_3's input resistor (R_8). Therefore, E_4 can easily swing the total feedback vector enough to bring the loop phase to 360° if the gain of A_1 and A_2 is reasonable —say 1,000.

The magnitude of E_4, the incremental phase signal, is set by the modulator. The modulator control signal is created by combining the rectified signal E_2 with the output of a precision reference, and applying the sum to an integrator with a gain of over 50,000 for the amplitude-controlling loop.

The oscillating frequency of the loop is controlled by the potentiometers R_1 and R_3, which, together with R_2C_1 and R_4C_2, determine the frequency when the net loop gain is unity.

The use of potentiometers, as opposed to variable capacitors, makes possible a linear frequency dial scale, plus low and virtually constant circuit impedances—even at the lower frequencies. Also, since the potentiometers are made of film, they provide low-noise performance and high reliability.

The oscillator is available with a number of



Dual-integrator method is used to generate the output frequency. R_1 and R_3 control the continuously variable frequency and C_1 and C_2 are switched in decade steps for range-changing.

output dividers to provide flexibility when using the instrument in both one-and two-phase applications.

Specifications	
Frequency range	9.6 hz to 104 khz
Voltage output	12 v rms
frequency response (flatness)	±0.01% to 50 khz ±0.02% to 100 khz
Total harmonic distortion	0.01% above 20 hz
Frequency stability	0.01% per hour above 100 hz 0.02% per hour from 10 to 100 hz
Price	about $900

Weston-Rotek division of Weston Instruments Inc., 17 Hartwell Ave., Lexington, Mass.

Plug-in modules for blue-collar job

Setting its sights on a new market—bench and production-line instrumentation—Electronic Associates Inc. is offering a low-cost, flexible digital measuring system. The modular instrumentation concept was first exploited by oscilloscope makers.

EAI, which previously had limited itself to costly laboratory-type precision-accuracy units, has developed an instrument built around a universal main frame and a plug-in approach—the main frame for display of the measured variable, the plug-ins to adapt the system for measurements such as voltages, frequency and resistance.

"The modular approach," says Andy Anderson, the EAI Instrument division's marketing manager, "affords maximum flexibility at low cost by enabling the user to mix or match modules according to his particular needs. Previously, if an engineer wanted to measure voltage and frequency, he would buy a voltmeter and a counter—a fairly expensive procedure. This no longer has to be the case." The company's basic display unit, the model 6200, will sell for about $525, including a d-c plug-in. "Other measurement capabilities can be added for as little as $185," says Anderson. The unit contains power supplies, high-speed counting circuits, a display-time generator and numerical readout indicators. Drawer space is provided with wired receptacles for up to two plug-in modules, and a switch that permits the output of either module to be read out eliminates changing modules when more than one measurement is made.

The readout is displayed on Nixie tubes. There are four digits—three full range plus the fourth digit 1 for overranging. An illuminated decimal point is automatically positioned according to the range selected. Display time is variable, from 0.2 second to six seconds; it can also be held. Readout reset is both automatic and manual, and can be done from the front panel. The main frame can be supplied with a data output consisting of binary-coded decimal (1-2-4-8) logic. The unit's dimensions are a compact 7 x 8½ x 11 inches.

The model 6201 voltmeter module provides the system with a means of measuring d-c voltage from 100 millivolts to 1,000 volts full scale in five ranges. The module has automatic polarity selection and pushbutton ranging for fast operation.

EAI's voltmeter module operates on the integrating principle, thereby reducing the system's susceptibility to superimposed noise and hum. The module includes a high-speed solid state chopper to eliminate amplifier drift and reduce circuit time constants. This permits fast response to full-scale input step functions. A built-in calibrating system allows the operator to check the instrument's accuracy— ±0.1% ± 1 digit. The voltmeter module's 10-megohm input impedance is constant over the measuring range.

When the a-c converter module is used with the voltmeter module, the system can measure a-c voltages from 20 hertz to 200 kilohertz. The unit, the model 6204, converts an a-c input to a d-c output voltage proportional to the root-mean-square value of the input sine wave. The module allows the measurement of voltages from 1 volt rms to 300 volts rms full scale.

Specifications	
Display readout	4 digits in-line (40% overranging)
Display time	Continuously variable from 0.2 sec to 6 sec
Signal input	0 to 10 Mhz from compatible plug-in module
Voltmeter	
Full-scale ranges	100.0 mv (100 μv resolution) 1.000 v 10.00 v 100.0 v 1000.0 v
Overrange capability	40% on all except 1,000=v range
A-c rejection	80 db at 60 hz 90 db at 120 hz
Conversion time	100 msec
Response time	700 msec to reach 99.9% of value for full-scale step input
A-c converter	
Frequency range	20 to 200,000 hz
Full-scale voltage ranges	1, 10, 100, 300 v rms
Accuracy	± 0.02% to 10 khz, ± 0.3% for 10 to 100 khz, 0.4% for 100 to 200 khz
Input impedance	1 megohm shunted by 30 pf.
Floating input	Enables a-c measurement of signals having ± 500 volts d-c with respect to line ground

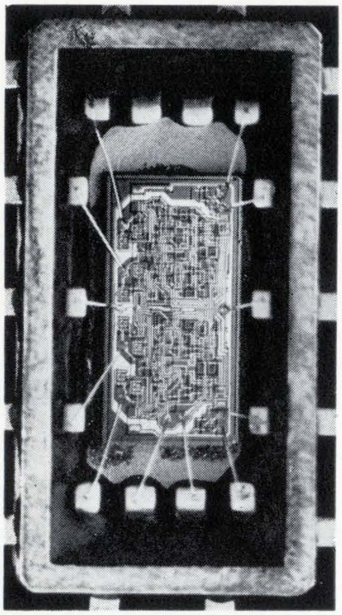
Electronic Associates Inc., West Long Branch, N. J.

Integrated circuits

TI backs bet on TTL with two new series

The wave of the future—that's the way Texas Instruments Incorporated views the place of transistor-transistor logic (TTL) in the integrated circuit business.

TI has been backing this conviction with a $5

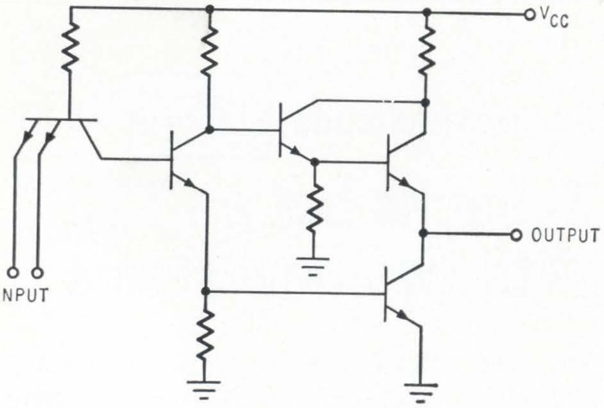


Complex functions like this will be part of the Series 54 line. First product will be a quadruple binary latching circuit with four flip flops on a chip.

million investment that dates back to March 1964, and it is now increasing its commitment with the introduction of two new TTL series, one high speed and the other featuring low power. The company will also introduce new complex-function TTL circuit.

TI's 40% price increase on diode-transistor logic (DTL) circuits in January foreshadowed its latest moves. The company cited at the time a shift to TTL in equipment design.

Instead of gradually building a line by periodically adding custom-tailored IC's to duplicate or replace discrete versions, TI is creating a complete new line of TTL circuits designed for the needs of the future, including complex-function circuitry and large-scale integration (LSI). Particularly stressed are those functions that only monolithics can do.



Typical two input TTL gate circuit used in the new high-speed Texas Instruments' Series 54H logic line.

For TI, this wave of the future will start cresting in 1968. "TTL's are going into new designs of equipment scheduled for production in the second half of 1968," says William Fowler, TI's assistant marketing manager for IC operations. "The big switch will involve equipment slated for production beyond 1970."

Behind TI's commitment to TTL are both engineering and economic motivations. "TTL's fit monolithic technology," says the concern's marketing manager, Charles Phipps. "They permit a whole spectrum of products with the highest speed possible with saturated logic," he continues. "This is difficult to achieve with other logic types. Also, they are good building blocks for complex circuits and for LSI. You have low output impedance and fewer noise problems. You can do the same things with diode-transistor logic, but not with the same ease. A low-power DTL, for example, requires very large resistor values and is difficult to fabricate in monolithic form."

The economic thinking behind TI's commitment is almost paradoxical. The way to cut the costs of new equipment, company planners reason, is to make circuitry as complex as possible in the design stages. Early costs may be higher, but long-range savings can be realized because fewer packages are required. Behind this reasoning is the assumption that prices of complex-function packages will drop as production volume increases.

"The per-gate price using complex functions is now running at about 30 cents," Phipps estimates. "By 1970, this will drop to 10 cents."

All of the company's TTL families—those being introduced this year and the series 54 "standard" line shown in 1964—will be compatible.

The new series 54L will feature low power—typically 1 milliwatt per gate—and a gate propagation delay of 35 nanoseconds. These devices will have the same logic levels, 4.5-to-5.5-volt power supply and 1-volt noise margin as other TTL's in the 54 series.

The new series 54H devices will feature high speed—6 nsec—noninverting gates and a relatively high power dissipation of 25 mw per gate. The complex-function device consists of a quadruple TTL latch, four flip-flops in one plastic-encapsulated dual inline package.

With these additions and some new entries in the standard Series 54 line, TI will catalogue 133 types of TTL devices, compared to 145 DTL types. "DTL's won't disappear overnight, but we will see a trend away from them," says Fowler. "At least 80% of the new equipment designs of the saturated-logic type are being converted now to TTL's. Designs scheduled for development five to 10 years from now are going to TTL's entirely."

TI began its TTL developmental work early in 1964 when Honeywell Inc. came to it with a request for a high-speed flip-flop for an avionics computer. Eight months later, TI announced its first

Series 54 TTL "family" of eight gates and a flip-flop, with 13 nsec propagation delay and 10 new power dissipation.

Prior to this, Litton Industries Inc. had developed the "Phoenix gate" TTL for the Phoenix missile. It contained a multiple-emitter transistor, a device nonexistent in discrete-component circuitry and a key element in TTL work. The logic family, originally called TCL for transistor-coupled logic, was first developed by Pacific Semiconductor Inc., now TRW Semiconductor, Inc.

TI's TTL's are diffused-planar, double-layer epitaxial structures. Circuit construction is similar to DTL layouts, but the input diode gate of the DTL is replaced with the multiple-emitter transistor.

"The diffusion techniques and other manufacturing steps are much simpler for TTL's," Fowler declares. "They actually have fewer component elements than earlier DTL types but they perform more functions."

Specifications

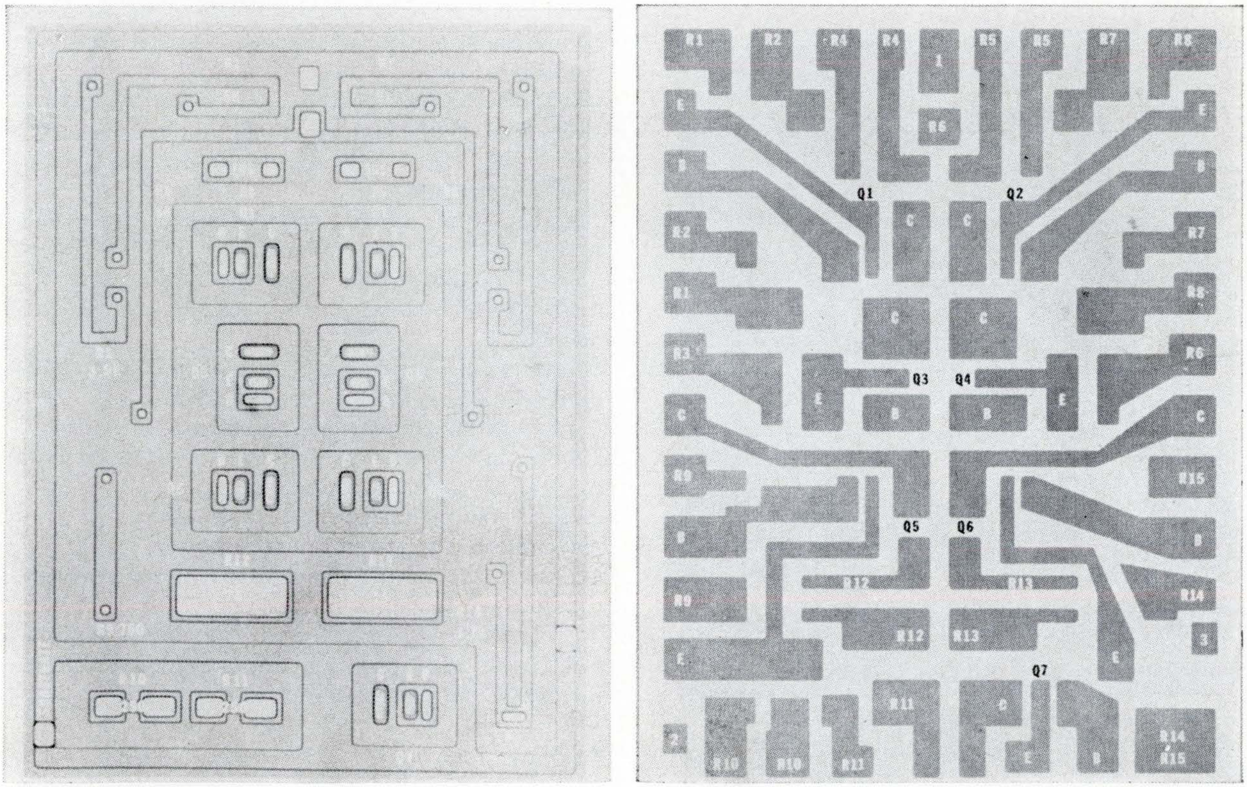
	Series 54H (High speed)	Series 54 (Standard)	Series 54L (Low power)
Propagation delay	6 nsec	13 nsec	35 nsec
Power dissipation	25 mw	10mw	1mw
Fanout	10	10	10
Power supply voltage	4.5 to 5.5 v	4.5 to 5.5 v	4.5 to 5.5 v
Temperature range	Military and industrial ranges on all three		
Packages	Flatpack and plastic	Flatpack and plastic	Flatpack
D-c noise margin	1 v	1 v	1 v

Norden is putting zip in tailored IC service

Telephoning an order one day and getting the integrated circuit a day or so later is normal service when buying off-the-shelf IC's. But the Norden division of United Aircraft Corp. offers the same service for custom-made, dielectrically isolated circuits.

Norden can prepare either digital or linear IC's by stitch bonding wires between component elements on chips. Although breadboard chips have been sold by Norden and other semiconductor manufacturers for several years, these, Norden claims, are the first with dielectric isolation.

The isolated elements speed the design work



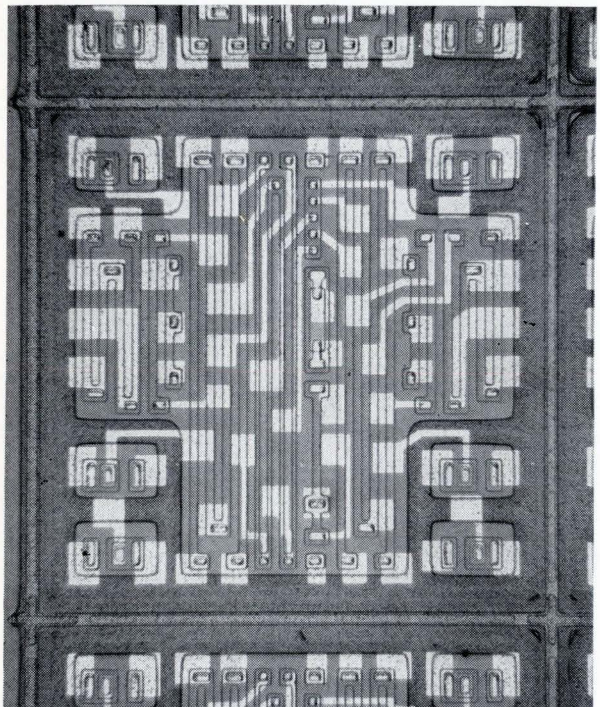
Master dice breadboard has six transistors and 33 resistors varying in value from 75 ohms to 10,000 ohms. Aluminum bonding pads shown in photo at right are connected to each resistor and to the emitter, base, and collector of each transistor.

because they simulate discrete components more closely than do elements of a conventional monolithic integrated circuit, says Don Smith, a Norden engineer. However, he points out that breadboarding on a chip is still necessary. The designer can't save time by breadboarding with discrete componets, because of difficulties in duplicating the inductances, capacitances, device matching, and thermal characteristics of the IC version, says Smith. But the dielectrically-isolated circuits eliminate these problems, he adds.

Isolation is provided by the Glastrate process Norden uses to make production circuits. The silicon crystal is etched into small areas, then silicon dioxide is filled in between the areas to isolate them and polycrystalline silicon is added for strength. The single-crystal silicon is then diffused to form the circuit elements. One major difference between the breadboards and the production IC's is the thin-film aluminum wiring used on production IC's.

Applying the isolation process to breadboards wasn't difficult, says the Norden engineer. The problem was in developing sets of elements that could be used to make many different circuits.

The new chips are about 62 mils square and are mounted in 12-lead TO-5 cans or ¼- by ⅛-inch flatpacks. Each chip contains up to six transistors and three resistors, with each transistor and the resistor block isolated by a glass-like dielectraic. The resistors can be matched and can vary in value from 75 ohms to 10 kilohms. Typical transistors are low-level, high-gain n-p-n devices able to conduct 30 milliamperes of current.



Production dielectrically isolated integrated circuits. The chips were developed from breadboards like this.

These chips, says Smith, can be used to make dozens of circuits, including differential and sensing amplifiers, Schmitt triggers and drivers.

The price of each custom IC is about $30. Price varies somewhat with circuit complexity, the number of interconnections and quantity of breadboards ordered. Breadboard chips are also available from stock.

Specifications

Maximum temperature	
Storage	−55°C to +300°C
Junction	+175°C
Voltage	
Collector-to-base	20 v max.
Collector-to-emitter	20 v max.
Emitter-to-base	20 v max.
Collector current	30 ma
Resistor power dissipation	4 mw per square mm

Components

Mechanical approach short circuits p-c's

As a precision servo loop component, the printed-circuit motor is finding wide use in computer peripheral equipment such as analog and digital tape transports, line printers and disk files. Recently, it has replaced hydraulic drives in precision machine tools.

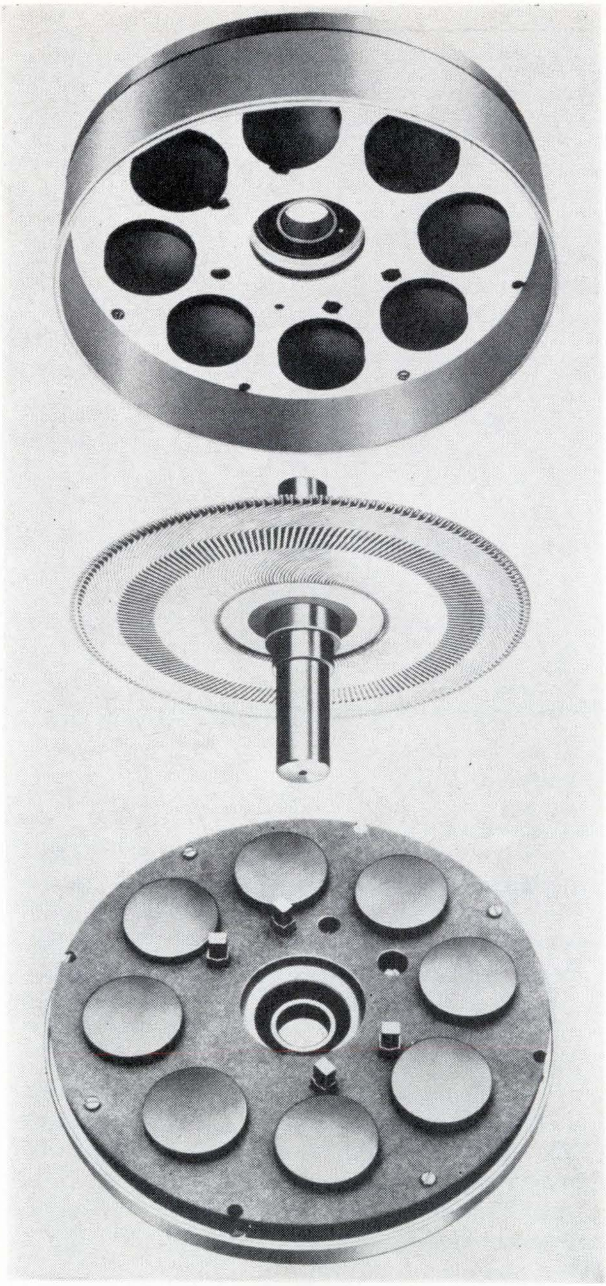
Hardly a time, it would seem, to rock the boat, particularly for the rocking to be done by Printed Motors Inc., a division of the Photocircuits Corp., which holds the North American license for the motor's manufacture.

But the company is now offering three flat-armature motors to replace the printed-circuit designs. The continuous copper conductors in the armature will be stamped mechanically from sheets of copper.

Mechanically, the printed-circuit and stamped-armature motors are interchangeable. Both have the same outer dimensions. Electrically, however, the new motors promise several advantages. For the same size armature and frame, says the company, the stamped-armature motors offer:

- Double the maximum output power.
- Double the torque constant or motor sensitivity (expressed in ounce-inches per ampere), which allows the motor to start and stop more rapidly.
- A rise in the maximum operating temperature from 125°C to somewhere between 150°C and 175°C.
- Lower cost.

Printed Motors is turning to the manufacturing approach worked out by the Yaskawa Electric Manufacturing Co. of Tokyo. Yaskawa is licensed to sell flat-armature motors in Japan by a French



Armature for new line of precision motors is stamped from sheet of copper. Flat armature is shown between two sets of Alnico field magnets.

company, Societe Electronique et Automatisme, which holds the basic flat-armature patent. This is the same firm that licenses Printed Motors' parent concern.

Instead of printed circuit techniques, Yaskawa uses mechanically stamped-out armatures for its line of inexpensive d-c motors. These have been sold in large volume for about $5 to $6 each to the automotive industry; precision printed-circuit motors have been selling for 15 to 20 times these prices.

The mechanical armature has one distinct advantage over the printed-circuit design: its basic fabrication approach allows four layers of continuous conductors to be placed on a single armature. The printed circuit approach permits only two layers, one on each side of the insulating copper-clad laminate on which the conductors are etched.

With twice the conductors, each armature should have twice the torque sensitivity. Based on this and the fact that production costs could be lowered, Printed Motors decided to upgrade the mechanical approach for the manufacture of a precision servo motor.

Conductor patterns in the new armatures are stamped from copper sheets by a notching press that can make 700 notches per minute. Two sheets of conductors are laminated and welded at their inner diameters, and two sets of these double-conductor sheets are then laminated together and their outer diameters are welded.

The result: a sturdy structure that doesn't require the support ring for the less rigid armature.

In addition, the stamped armatures don't have the thickness variations of the printed circuit armatures, variations due to control problems in the electro-plating process.

Printed Motors has also improved on the low-cost motor design by using:

- Higher flux density Alnico magnets, instead of ferrite magnets.
- Four brushes instead of two, reducing the current density per brush and allowing higher currents in the motor.
- Ball bearings rather than a sleeve bearing, so that the armature turns with considerably less wobble and more concentricity.
- Epoxy-glass insulating materials that can withstand higher temperatures than the copper-clad laminates used in the printed circuit motors.

Specifications

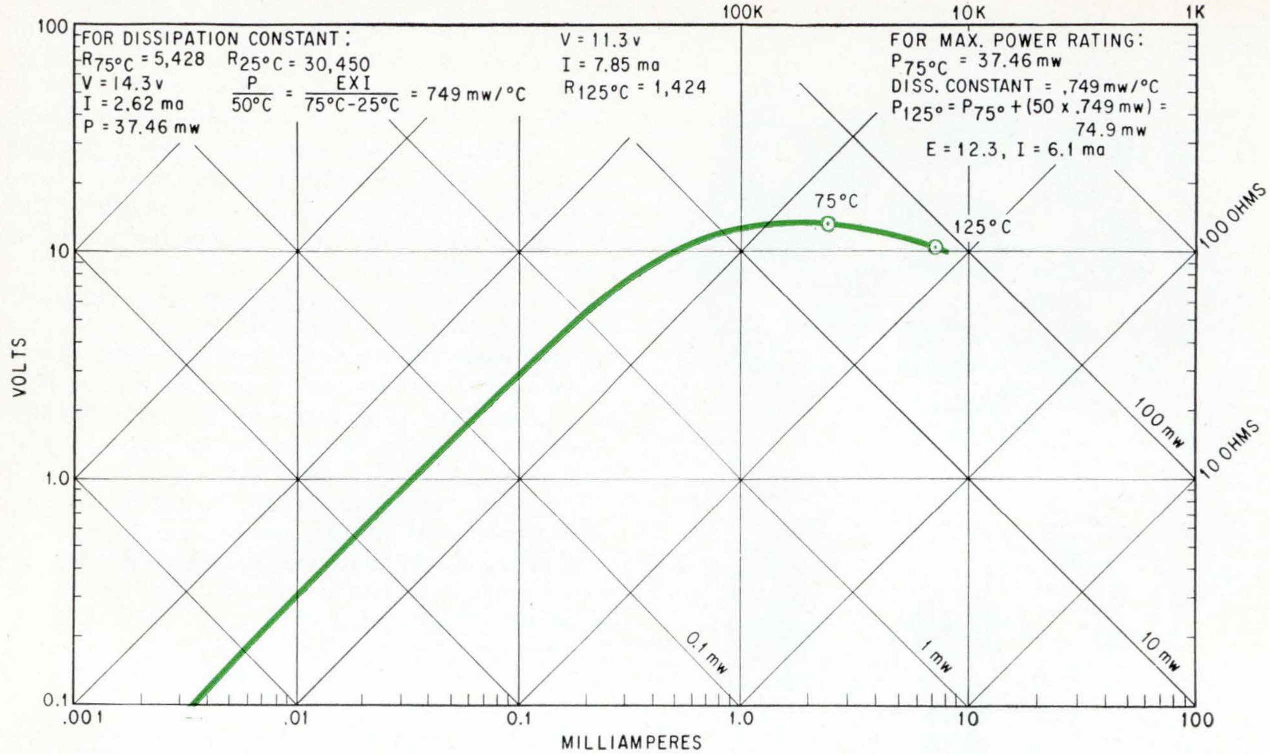
	U9M4	U12M4	U16M4
Power (horsepower)	1/12	1/3	1/2
Torque constant (K_t-ounce-in./amp)	7.0	16.0	31.2
Mechanical time constant (seconds)	.013	.010	.011
Terminal resistance (R_T-ohms)	.8	.75	.79
Inertia (J-ounce-in./sec^2)	.0055	.023	.099
Weight (pounds)	4-1/2	8	16-1/2
Diameter (inches)	4-3/8	5-1/2	7-3/8
Length (inches)	1-27/32	2-7/64	2-9/16
Cost per motor (in quantities of 100)	$77	$94	$140

Printed Motors Inc., 31 Seacliff Ave., Glen Cove, N.Y.

Sputtered oxides form thin-film thermistor

A new low-energy sputtering technique, combined with a multiple-oxide target material, adds a thin-film thermistor to the circuit designer's bag of tricks.

The A-Thinistor, the first deposited-film thermistor, can be attached at a critical area in a circuit to trigger a signal when a predetermined



Typical voltage current characteristic for a beryllium oxide substrate. Maximum power rating for this unit is 75 milliwatts.

or desired temperature is reached.

The device is being marketed by the Victory Engineering Co., the developer of the sputtering technique. The company is initially offering the thermistor as a discrete component, but it says the process could be used to coat thermistors directly onto silicon integrated circuits.

With a negative temperature coefficient as a function of the multiple-oxide target material, the component's resistance increases when the surrounding temperature rises.

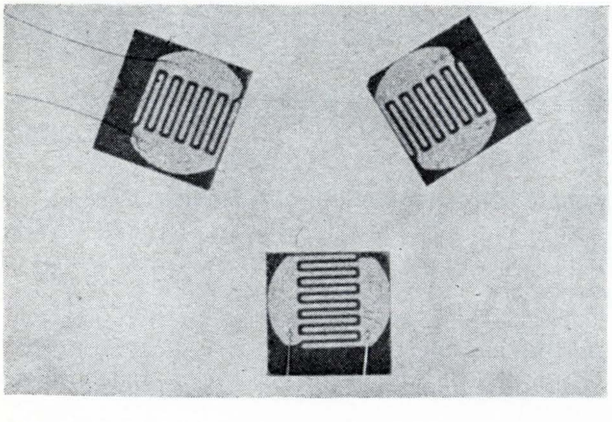
The thermistor can be used to maintain a constant resistance value when wired in parallel with a critical resistor. When the temperature rises, the critical resistance increases and the resistance of the film-thermistor decreases, so the net parallel resistance remains constant.

The component can also trigger a warning light or bell. When the critical temperature is reached, the resistance of the thermistor changes to allow the proper value of current to flow, and this trips a relay. It is only necessary to wire the thin-film component in the vicinity of the critical area. Satisfactory results have been obtained with film thicknesses of a few hundred to a few thousand angstroms, according to Victory Engineering.

Successful sputtering has been achieved on beryllium oxide, aluminum oxide, quartz, aluminum foil and nickel foil substrates. By proper adjustment of the sputtering parameters it's possible to maintain a substrate temperature of 70° to 80°C. Hence, a monolithic integrated circuit can be temperature compensated as a last step without affecting the other components during the process.

The thin-film thermistor has been tested in accordance with Mil-T-23648 specifications. Changes due to environmental exposures are comparable to those allowed for bead-type thermistors and are smaller than those permitted for disk types.

The component is suited to applications in IC temperature compensation, surface temperature measurement and infrared bolometry.



Specifications

Typical surface resistivity	0.5 M/sq. at 450 angstroms
Bulk resistivity	260 ohm-cm
Typical voltage-current characteristic	3 volts at 0.1 ma
Cost	$40 to $50 for single unit $20 to $25 for each of 100 units $5 to $10 for each of 10,000 to 50,000
Availability	Off the shelf and custom

Victory Engineering Co., Springfield, N.J.

Subassemblies

Test display uses IR missile scanner

Adapted from a Sidewinder missile technique, an infrared scanner will compete in the fast-developing market for thermal sensing and display devices.

The Sierra Electronic division of the Philco-Ford Corp. sees a broad market, ranging from tests of printed circuit boards to diagnosis of muscle inflammations, for its 710B scanner, which incorporates both direct-viewing and picture-taking capabilities.

Sierra's system uses the output of the Sidewinder device, an indium antimonide cell, to provide two types of oscilloscope display:

- A video display of the subject's infrared radiation, with 10 black-to-white ranges covering temperatures from 2 degrees to 1,200 degrees centigrade.
- A scope tracing that shows i-r energy as a curve derived from the video signal, with the amount of energy determining vertical deflection.

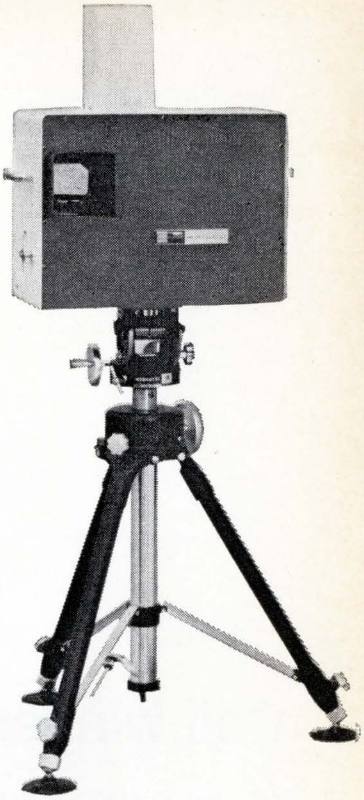
Both types of display, known respectively as C-scan and B-scan, can be shown on one cathode ray tube, but the Sierra console has two scopes because the light levels best for the human eye are less than optimum for cameras. Either scope will provide both types of display.

The Boeing Co. was the catalyst in the development of the 710B, a follow-on to an earlier scanner-plus-scope system that was more suited to laboratory than production-line use. Boeing wanted to test the bonding process in which plastic skin is mated to the aluminum honeycomb used in helicopter rotor blades. The company had been leaning toward ultrasonic testing, but Sierra pointed out that if a heat source were placed behind the blade, bonding flaws would show up as cool spots on the front.

That test is passive, but the system is equally valuable for active testing of components on a printed-circuit board. As diodes heat up, for example, their picture becomes brighter and brighter on the cathode-ray tube. Poor welds are also shown by irregular heat transfer.

In the single-scope system, the operator had to swing the camera away in order to see the crt picture. Not only was this procedure awkward, but the light settings that were best for direct viewing were too bright for picture-taking and they washed out detail. The persistence of the scope that was necessary for a raster scan took five seconds from top to bottom, and did not have enough grey scale for good pictures.

In the 710B, the top scope is coated with P7 phosphor for good persistence, and the bottom with



Infrared scanner developed for the Sidewinder's guidance system nondestructively test solid state components. The output signal . . .

P4 phosphor, which has short persistence but a good grey scale. Both scopes are modified by their builder, Tektronix Inc., Beaverton, Ore.

The raster is produced by a mirror that is mechanically rotated at 30 revolutions per second. It is tilted up and down so that a complete 150-line picture is produced every five seconds.

Sierra also offers a "quantizer" that puts thermal contours, analogous to the isometric lines on a weather map, on the scope. The analog traces are digitized into six discrete temperature levels.

The company sees applications in reliability testing and in medical electronics. In solar cell tests, a malfunctioning cell would show up as a cold spot. Subcontractors to the Lockheed-Georgia Co., a subsidiary of the Lockheed Aircraft Corp., are now required to take thermal pictures of circuit boards for reliability testing. The University of Washington medical school will use a Sierra system to study muscle inflammation. The company says that the

. . . from an indium antimonide cell paints a picture with 10 black-to-white ranges on the monitor console's oscilloscope. A built-in Polaroid camera makes a permanent record of the scope's traces.

system can sense a one-half-degree temperature difference in tissue.

The instrument costs $14,950, plus $2,950 for the optional quantizer.

Specifications

Scan width	20°
Scan height	20°
Time per raster	5 sec
Picture resolution	
Lines per raster	150
Elements per line	100
Target temperature range for black-to-white picture contrast:	Room temperature to 1200° in 10 ranges
Temperature resolution at 30°C 0.5°C	
Spatial resolution (3½-inch distance)	0.029 in.
Response time	10 μsec

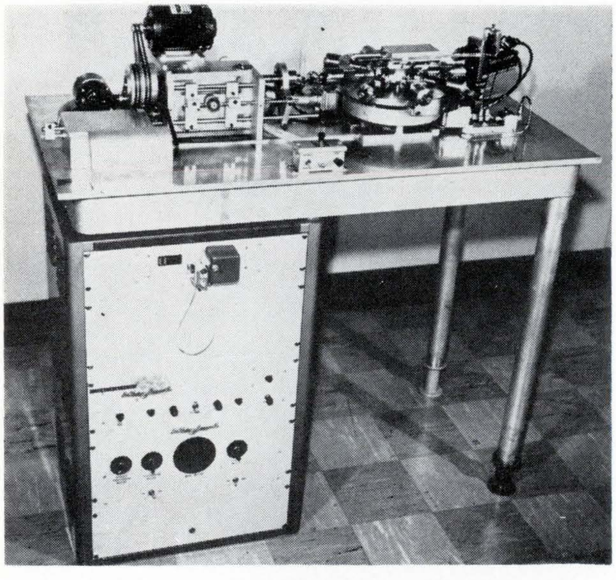
Production equipment

Coil winder plus tape gives speed, accuracy

While a high-speed coil-winding machine hums along efficiently, putting thousands of turns on a wire bobbin every minute, it may be prudent to watch quietly and do nothing. The Coil Winding Equipment Co. of Oyster Bay, N.Y., (Coweco) doesn't think so, however.

Now, with the introduction of programed tape, the company's machines literally harass the coil through the winding process by pulling taps, cutting wires, cementing turns, and putting on terminal plugs and identification tapes.

Coweco's tape control unit is programed to handle all of the operations required for automatic assembly and testing of coils. It can be used with any of the company's standard turret-transfer coil winding machines.



Tape control unit fits beneath a coil winding machine, and sequences any number of winding operations while controlling auxiliary assembly and test functions as well.

The major advantage of tape control for a coil winder is the ease with which changes can be made in the winding program. This is done simply by substituting one previously prepared tape for another. Another plus for tape control is that coils can be wound very accurately to specifications, with little operator skill required.

In the Coweco unit, the standard eight-channel paper or Mylar tape triggers any number of sequential winding operations. It can also control auxiliary operations—such as the automatic testing of finished coils—that are going on while a coil is being wound. This is possible because not all of the tape channels are needed to control the winding cycle.

In fact, rather than using holes punched in the tape to set the winding speed, the code uses a zero signal from the tape to keep the winder turning at maximum speed. One channel slows the winder down, a second stops it. A third channel indexes the turret, rotating the coil to the next operating station.

The tape control unit is not part of the machine it controls, but is housed in a separate box. By modifying the interface lines, the control can be used with a variety of winding machines.

The tape is read by a mechanical reader with electromechanical relay logic decoding the instructions. Reading speeds of 25 bits per second control winding speeds of up to 6,000 turns per minute.

All external attachments on the coil winder can be controlled from the tape. Perhaps the most unusual is the attachment that allows taps to be pulled automatically during the winding cycle.

The tap puller fits atop the center of the winding turret. Under tape control, the winder is brought to a stop. A mechanical arm pushes the wire for the tap out through a slot and then the wire loops back in and resumes winding. Even though the machine may have been winding thousands of turns per minute, the stop for the tap is scarcely discernible. Any number of taps can be pulled at several points along a coil during a winding program.

Cost of a tape control unit with a basic turret winding machine will be about $10,000.

Specifications

Model CKCP turret-transfer coil winder with tape control.

Coil winder	
Size	17 x 36 x 14 in.
Weight	200 lbs
Tape control	
Size	14 x 20 x 26 in.
Weight	75 lbs
Power	230 v, 5 amp, single phase
Tape reading speed	25 bits per sec
Coil winding speed	up to 6,000 rpm
Coil diameter (maximum)	2 in, nominal
Coil length (maximum)	2 in.
Wire size (maximum)	#16 AWG
Wire size (minimum)	#56 AWG
Index time	1 sec
Time for each tap	2 sec

Maximum recommended production rate—1,000 coils per hour

(Tape control also available for larger-capacity machines)

Coil Winding Equipment Co., Railroad Plaza, Oyster Bay, N.Y.

Fast, low-cost testing with limit comparator

"It looked like an instrument we'd be able to use on our own production lines. If we could use it, probably other people could too. So we went ahead and built it."

That, according to one of the design engineers, is the uncomplicated reasoning behind the Hewlett-Packard Co.'s first instrument aimed at the production line—a high-go-low limit comparator for automated testing of electronic components, including integrated circuits. The new production tool marks a departure for Hewlett-Packard from laboratory-type instrumentation.

The high-speed, multifunction model 3434A has a basic price of $1,575 and can be used in sorting, batching and matching components, testing printed circuit boards and cables, and calibrating.

The comparator can handle four types of limit measurements—a-c voltage, d-c voltage, direct current and resistance—against the single d-c voltage measurement available with most analog comparators. Limits can be selected automatically or manually. As many as 12 different sets of limits can be preprogramed and quickly selected by a 12-position rotary switch as test conditions change.

Its versatility and cost make the comparator attractive for automated testing on low-volume production runs of from 50 to 100 pieces. But it is fast enough—at 15 decisions per second—to be used on high-volume lines as well.

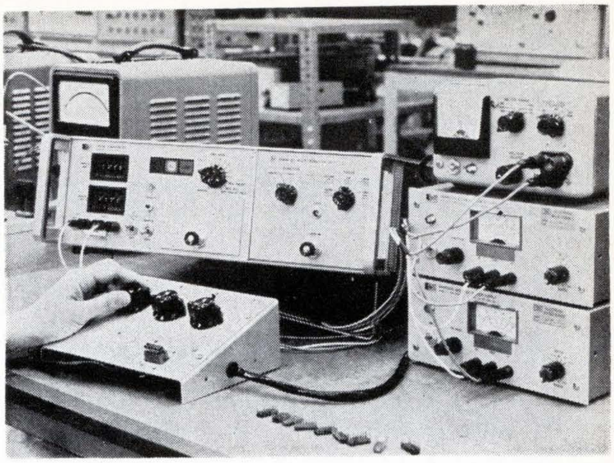
The comparator can accept the plug-in function modules Hewlett-Packard has designed for its line of digital voltmeters, as the comparator circuitry uses the same ramp-comparison techniques.

The plug-ins range in price from $40 for the 3441A voltage range selector with 10-, 100- and 1,000-volt ranges, to $575 for the 3444A d-c multifunction unit with voltage, current and resistance functions.

High and low limits can be set separately on the comparator by:

- Dialing thumbwheel switches on the front panel during routine testing.
- Plugging in a preprogramed board on which 12 different pairs of limits are set.
- External binary-coded decimal limits driven by a computer or other programing source.
- Remote analog voltage inputs.

When the comparator is used to test integrated circuits, both the 3444A d-c multifunction plug-in and the preset limit board are needed. The built-in rotary switch brings in bias and signal voltages to the IC test jig, selects the appropriate input and output pins and programs the comparator's 12 sets of test limits. A complete test set



Limit comparator can be used with external test jig for integrated circuits.

(without the jig) would cost $2,375. This includes $225 for the limit program board.

If IC's are to be tested semiautomatically at high speeds, an external scanning switch is needed.

Except for the external analog signals, the limit voltages are produced in digital form and converted to analog form before they're applied to the comparator circuit.

The comparator circuit takes the two input analog voltages and compares them with a +12- to −12-volt ramp. Output pulses appear when the ramp voltage is coincident with the analog voltage, and are applied to the decoding and logic circuits. The time sequence of the pulses yields the proper decision—high, go or low.

Each decision is flashed by colored lights on the front panel. The indication is held until the next limit condition occurs. The decision circuits can also drive floating contact closures, which can be used, in turn, to activate such production-line accessories as parts counters and materials-handling equipment, or a printer. A switchable input filter allows the comparator to operate in a noisy environment.

Specifications

Functions (plug-ins required)
HP 3441A range selector (d-c voltage)
HP 3442A automatic range selector (d-c voltage)
HP 3443A high gain/auto range unit (d-c voltage)
HP 3444A d-c multifunction unit (d-c voltage, d-c current resistance)
HP 3445A a-c/d-c range unit
HP 3446A a-c/d-c remote unit

Accuracy (10-, 100-, 1000-volt ranges)	
External analog:	±0.02% full scale
Other modes:	±0.04% full scale
Other accuracies depend on plug-ins	
Decision rate	
Normal:	fixed at 15 decisions/sec
Manual:	front panel control
Remote:	variable to 15 decisions/sec
Power:	115 and 230 volts ±10% 50-1,000 hertz Approximately 30 watts
Dimensions:	16¾ x 5 7/32 x 18⅜ in. deep
Weight:	18 lbs.
Price:	$1,575 with thumbwheel limit set $225 for limit programer

Hewlett-Packard Co., Loveland Div., P.O. Box 301, Loveland, Colo. 80537

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.

Gain-multiplied capacitance generates ramp waveform

By Gilbert Marosi

General Precision Equipment Corp., Link Group, Sunnyvale, Calif.

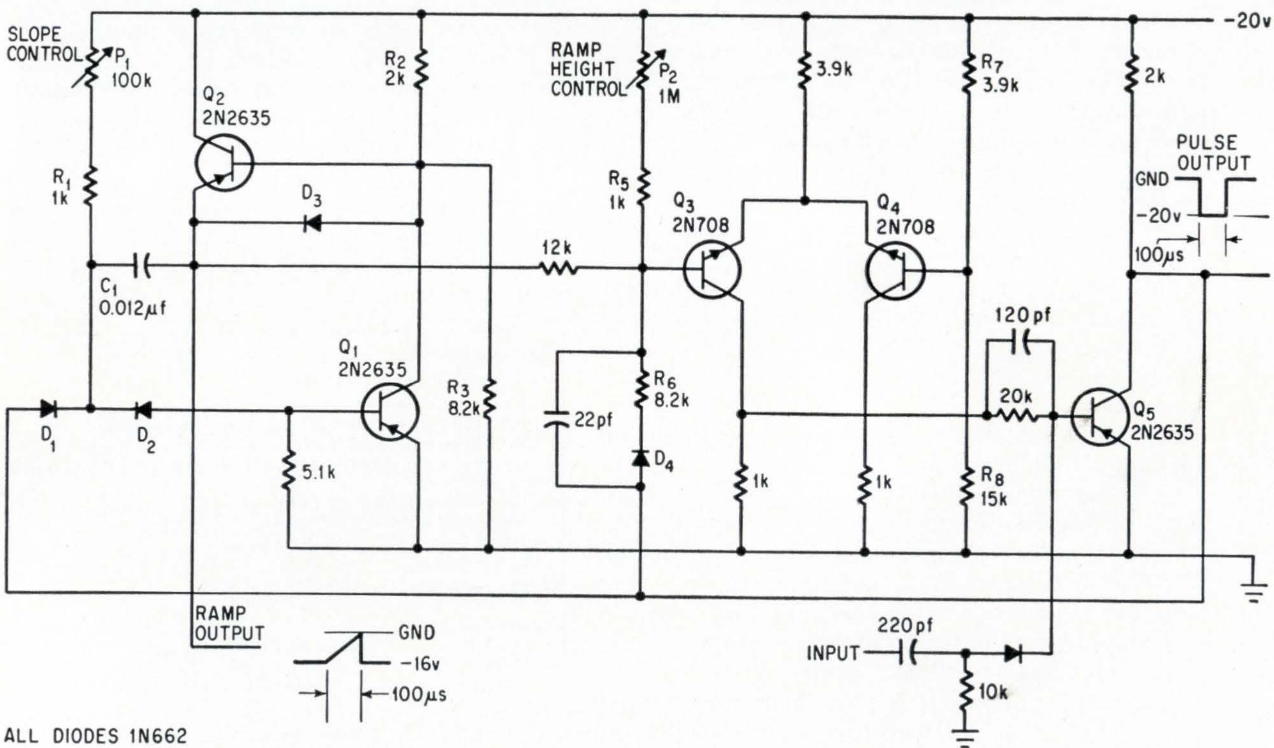
A transistorized ramp generator can be built on the principle that the input capacitance of a triode amplifier is equal to the product of voltage gain and grid-to-plate capacitance. In applying this principle, called the Miller effect, to a transistor, the equivalent base-to-emitter capacitance of a capacitor connected from base to collector becomes the rated value of the capacitor multiplied by the voltage gain of the transistor.

The small capacitor, C_1 in the circuit shown below makes a substantial contribution to the time constant of the ramp since its capacitance is multiplied 100 times by the Miller effect; yet it charges up quickly, giving the circuit a recovery time of 200 nanoseconds. Because it is generated by discharging C_1 with constant current, the ramp is linear to within 0.5%, requires no clipping, and is not distorted by loading.

A Schmitt trigger incorporated in the circuit as a switch puts out gating pulses as a byproduct; the circuit can be made to modulate these pulses. If appropriate resistor values are chosen, the circuit will oscillate, simultaneously generating a sawtooth wave and pulse train.

Transistors Q_3, Q_4 and Q_5 form the Schmitt trigger that terminates the ramp at any point and resets the circuit. The circuit is normally operated as a combination monostable and ramp generator by gating pulse inputs.

Transistors Q_3 and Q_5 are normally on, while Q_1, Q_2 and Q_4 are normally off. Diode D_1 is conducting with its anode connected to ground due to the conduction of Q_5. With the left side of C_1 clamped near ground, C_1 is charged to -16 volts as set by the dividing action of bias resistors R_2 and R_3. The base of Q_4 is also set at -16 volts by R_7 and R_8.



Transistors Q_1 and Q_2, together with P_1, R_1, C_1 and associated components, make up the Miller-effect ramp generator. The remainder of the circuit, including Q_3, Q_4, and Q_5, is a differential Schmitt trigger that can terminate the ramp at any point.

If Q_1 is kept off, the charge on C_1 is maintained until an incoming pulse triggers the circuit and starts the ramp.

Transistor Q_1 is kept off by the conduction to ground through D_1 and Q_5, which back-biases D_2 and prevents base current from reaching Q_1. Transistor Q_5 is held on by Q_3; Q_3 conducts because its base potential is slightly more positive than Q_4's due to the action of R_4, P_2 and R_5 together with R_6 and D_4.

The ramp is started when a positive triggering pulse at the base of Q_5 turns Q_5 off, dropping this transistor's collector voltage to −20 volts and back-biasing D_4. With D_4 off, the base of Q_3 goes more negative than the base of Q_4 because of the action of R_4, R_5 and P_2; thus Q_3 cuts off (holding Q_5 off) and Q_4 turns on.

The turnoff of Q_5 also back biases D_1, so D_2 turns on, starting the Miller effect ramp generator. With D_2 conducting, Q_1 turns on, turning on D_3. Constant current is then provided by Q_1 to linearly discharge C_1, and the output ramp is generated.

When the combinations of currents through R_4, R_5 and P_2 bring the potential at the base of Q_3 to −15.9 volts (or slightly more positive than the base of Q_4), Q_3 turns on, turning Q_4 off and Q_5 on. With Q_5 on, diode D_1 again conducts, back-biasing D_2 and cutting off Q_1. Now that Q_1 is off, diode D_3 is back-biased and Q_2 turns on, rapidly charging C_1 to −16 volts. The cycle is now complete and the circuit is ready to accept the next input pulse.

The slope of the ramp is controlled by P_1 and R_1, which can vary it through a range of 50 to 1 by changing the amount of constant current through C_1.

Ramp height is controlled by P_2 and R_5. The output voltage for the ramp is given by

$$V = V_{out} = \frac{-V_{cc}R_4}{P_2 + R_5} + \frac{V'_{B4}R_4}{R_{equiv}} \qquad (1)$$

$$\text{if } R_{equiv} = \frac{(P_2 + R_5)R_4}{P_2 + R_5 + R_4}$$

where V_{cc} is the −20 volt supply and V'_{B4} is the voltage at the base of Q_4. This equation shows the ramp amplitude to be inversely proportional to P_2 and R_5.

The ramp reaches its maximum amplitude at ground when the combination of P_2 and R_5 is 3 kilohms. With P_2 almost an open circuit, the ramp amplitude is zero volts.

$$\text{The timing equation is: } T = \frac{\Delta V \cdot C}{\Delta I} \qquad (2)$$

where ΔV is the increment of voltage across C_1 and I is the increment of current.

$$\Delta I = \frac{V_{cc}}{P_1 + R_1} \qquad (3)$$

Substituting equations 1 and 3 into 2 yields

$$T = \frac{R_4(V_{cc} - V_{B4})(P_1 + R_1) \cdot C_1}{(P_2 + R_5)V_{cc}} \qquad (4)$$

where

$$V_{B4} = \frac{V'_{BA}(R_4 + P_2 + R_5)}{R_4}$$

Setting $R_2' = (P_2 + R_5)$ and $R_1' = (P_1 + R_1)$ yields:

$$T = \frac{R_4(V_{cc} - V_{B4})(R_1')(C_1)}{(R_2')(V_{cc})} \qquad (5)$$

Equation 5 indicates that the duration of the ramp may be varied by slope control R_1' or amplitude control R_2'.

Pulse-width modulation can be achieved with the circuit by fixing $(P_2 + R_5)$ and connecting the top of potentiometer P_2 to a control voltage V_c. The new timing equation then becomes:

$$T = \frac{R_4(V_c - V_{B4})(R_1')(C_1)}{(R_2')(V_{cc})} \qquad (6)$$

Equation 6 indicates that T is directly proportional to control voltage V_c.

If R_1 is made large enough the circuit will oscillate:

$$f = \frac{(R_2')(V_{cc})}{(R_4)(V_c - V_{B4})(R_1')(C_1)} \qquad (7)$$

and if P_1 goes to a control voltage V_c, then

$$f = \frac{(R_2')(V_c)}{(R_4)(V_{cc} - V_{B4})(R_1')(C_1)}$$

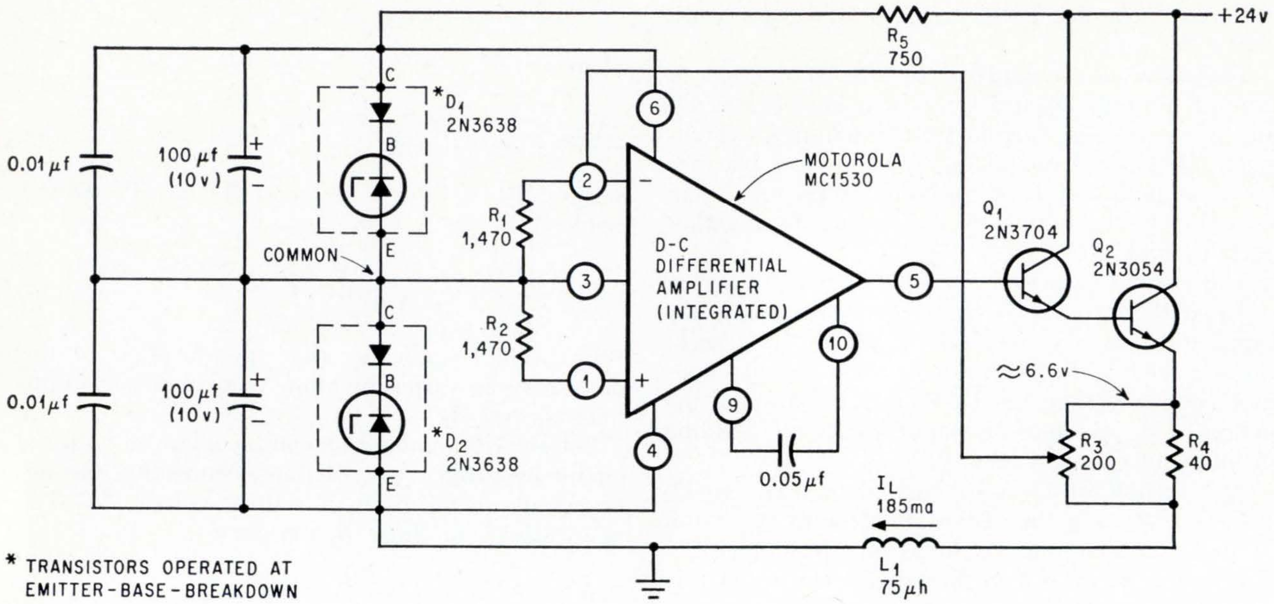
The operating frequency may then be controlled by the same voltage V_c. The resulting output is a train of negative-going pulses and a positive-going sawtooth wave.

IC amplifier serves as stable current source

By Clement S. Pepper

Marine Physical Laboratory
Scripps Institution of Oceanography, San Diego

For less than $40, a stable 185-milliampere current source can be built with an integrated amplifier and a feedback circuit. The circuit has excellent regulation and serves as a laboratory standard for



Rising load current, I_L, raises the potential at pin 2 of the integrated amplifier. Pin 2 is the inverting input, so the higher voltage decreases the base current to transistors Q_1 and Q_2, reducing I_L.

calibrating magnetometers; hence, only a moderate output current is needed. However, the circuit can generate several amperes of constant current with the addition of appropriate output transistors.

The two differential inputs, at pins 1 and 2, are connected to the amplifier through low value resistors R_1 and R_2; amplifier common is at pin 3 and pin 6 is biased at 13 volts. This voltage level is maintained by the back-to-back diode arrangement between pin 6 and the amplifier's input common, pin 3.

Two transistors, shown as back-to-back diode pairs D_1 and D_2, are operated at their emitter-base breakdown voltages and produce nearly identical zener reference voltages of about 6.6 volts; the zener voltages across D_1 and D_2 maintain the common node equilibrium voltage at 6.6 volts.

The feedback loop is formed by connecting the amplifier's inverting input (pin 2) to potentiometer R_3. When power is first applied, transistors Q_1 and Q_2 are off and pin 2 is at ground; the voltage at the common node rises quickly to 6.6 volts. The zero signal at pin 2 creates a large difference voltage which drives the differential amplifier into saturation, producing a large output current at pin 5; this current turns on Q_1 which then turns on Q_2. These are cascaded emitter followers which generate load current I_L and isolate the amplifier from the load.

As I_L increases, the voltage across R_3 and R_4 increases, raising the potential at pin 2. Since pin 2 is the inverting input, the higher voltage decreases the amplifier's output current, reducing I_L. Any decrease in load current I_L reduces the voltage at pin 2, causing a compensating increase in I_L. At equilibrium, the signal at pin 2 is slightly less than the 6.6-volt potential at pin 1 so that a small output current continues to flow to keep Q_1 and Q_2 from turning off. A full-scale adjustment of R_3 changes the output current approximately 10%.

To achieve load current stability with changes in temperature, the passive components outside the feedback loop must have low temperature coefficients. Resistor R_5 is a Sprague Blue Jacket resistor with a temperature coefficient of 0.003% per degree centigrade and R_3 is a cermet trim pot. Diodes D_1 and D_2 have good thermal stability. The forward biased collector-base diode provides temperature compensation to the emitter-base breakdown diode.

Spraying the passive components with Instant Freeze lowered their temperature below −5°C with no effect on the output current. Since the output transistors and the integrated amplifier are both a part of the feedback loop, any change in their parameters will be compensated.

Specifications for the MC1520 amplifier include an open loop gain of 5,000 and an output impedance of 25 ohms. The amplifier's common mode rejection is 75 decibels and its power supply sensitivity is 100 microvolts per volt. The temperature coefficient that occurs for the input offset voltage is 3.8 μv/°C.

At the time the circuit was constructed, the integrated amplifier cost $27. Since then, the prices of comparable devices have been reduced and it should now be possible to build the complete circuit for less than $40.

Constant relay on-time for any input pulse

By Ken Wahl

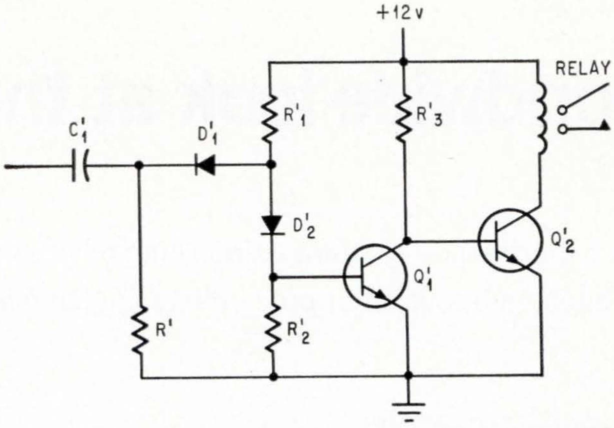
Photo Bell Co., New York City

A monostable relay driver can be made independent of the input pulse's amplitude or duration by feeding back a negative pulse generated by the output circuit. The pulse holds the input transistor off for a predetermined time. The circuit shown below was designed to drive a 4-watt relay momentarily. Since the circuit holds the output transistor in conduction for 25 milliseconds regardless of the input pulse duration, the power to drive the relay is generated without the additional transistor stage normally required for pulse stretching. Thus the circuit's cost is reduced by 25%.

In the conventional high-gain pulse amplifier at the right transistor Q'_1 is normally on, Q'_2 is off and the relay is not energized. When an incoming negative pulse turns Q'_1 off, Q'_2 turns on and the relay energizes. The time Q'_1 is off depends on the pulse duration, pulse amplitude, and the time constant $R'_2C'_1$.

With the modified circuit the relay's on-time is independent of input pulse characteristics. Diode D_3 is normally off and capacitor C_2 is charged to +10 volts.

When a negative input pulse turns Q_1 off, Q_2 turns on and its collector voltage drops to ground. Since the charge on C_1 cannot change instantaneously, the voltage at point A will drop to −12 v which turns on diode D_3, enabling C_1 to charge toward the +12-v supply with time constant R_1C_2.

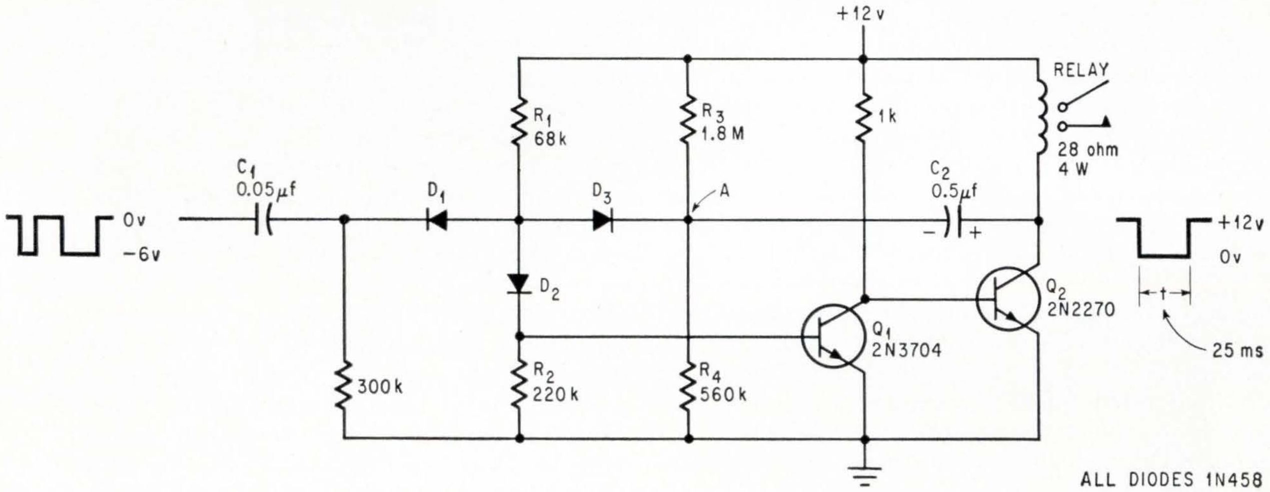


Conventional high-gain pulse amplifier generates output pulses whose duration is determined by the time and amplitude of input pulses together with time constant $R'_2C'_1$.

When the voltage at point A nears +0.6 v, the base of Q_1 turns on, terminating the output pulse and causing the relay to drop out.

The output pulse duration of 25 milliseconds is approximately 0.7 of the time constant R_1C_2, since C_1 stops charging when point A becomes slightly positive, far below the charging potential of +12 v. Resistors R_3 and R_4 are large with respect to R_1 so their contribution to the charging (and hence to the timing) is negligible; they are in the circuit to provide back bias for D_3 when the circuit is in its stable state. The relay's on-time can be adjusted by replacing R_2 with a potentiometer.

A desirable feature of this circuit is that the turn-on time of the relay is very sharp. However, the turn-off time is slightly exponential. The exponential condition does not cause any problems during normal operation of the circuit for any of the intended applications of the relay.



Modified circuit generates a fixed output pulse of 25 milliseconds for each input pulse.

Worldwide look at the Gunn effect

Some experimental systems using Gunn devices as microwave sources have been built; but other bulk effects appear even more promising

By Stephen E. Scrupski
Senior associate editor

"Everything remains to be done in the device development. So far we've only scratched the surface. We know something about the basic mechanism, but the material is still not under control, nor is the method of contacting, nor even the quality of material needed for contacting"—Arthur Foyt of the Massachusetts Institute of Technology's Lincoln Laboratory on the present state of the Gunn-effect art.

Ever since J.B. Gunn of the International Business Machines Corp. reported in 1963 that a simple chip of gallium arsenide generated microwaves when he impressed a high d-c voltage across it, microwave engineers have been waiting for the potentially low-cost device to be made practical. All that would be needed for a microwave source then would be a battery, a resonant cavity and the gallium arsenide chip. No longer would a microwave system require a klystron and its power supply, or a radio-frequency oscillator with several stages of varactor harmonic multipliers, or a power-limited microwave transistor.

The high cost of present conventional microwave sources has probably been the major factor in limiting the use of microwaves to military or critical industrial applications. With a low-cost source, many applications, like small radar and communications systems, could be open to microwaves.

Although the theory of the device's operation has been thoroughly studied (particularly at Bell Telephone Laboratories, a subsidiary of the American Telephone & Telegraph Co.), little insight has been gained into device design. In a bulk-effect device there is little to design other than the material and contacts—but that's where the problems lie. Performance is usually uniform in devices fabricated from a given slice of gallium arsenide, but it tends to vary when devices are made from different slices—not necessarily for known reasons. "That's the bugaboo of the Gunn-effect business," says Foyt, a member of Lincoln Labs' technical staff.

With some experimental systems already successfully tested, the promise of achieving a low-cost microwave source is gradually nearing fulfillment. At present, there are no American-made Gunn-effect devices on the market. But a British firm, Mullard Ltd.—a subsidiary of the Netherlands' Phillips Gloeilampenfabrieken NV—is marketing such a device [Electronics, Jan. 9, p. 214]. Priced at $175, it is available in sample quantities with a four- to six-week wait for delivery. A similarly-priced American unit was put on the market last August, but was withdrawn shortly thereafter, reportedly because of difficulties in obtaining reliable materials. However, American semiconductor makers, with an extensive materials research backup, will enter the field before the year is out.

Efforts are now concentrated on three aspects of Gunn-type devices. The first is developing better materials and contacts; the second, designing special-purpose devices that do more than simply supply single-frequency microwave power; and the third, extending studies to modes other than the one found by Gunn. The Gunn mode is only one of several possible methods of bulk operation. The recently discovered limited space-charge accumulation (LSA) mode [Electronics, Feb. 6, p. 127], for example, now being studied at Bell, Varian Associates and other laboratories, will deliver more power at higher frequencies. And there may yet be better mechanisms in the offing.

First uses as local oscillators

Gunn devices probably will be put to use first as low-power local oscillators, replacing klystrons and their associated bulky power supplies. Most firms look for the Gunn-effect devices to follow the route of other semiconductors starting with military applications then working their way down to industrial and other uses.

But according to Frank Brand, head of the Microwave and Quantum Electronics Branch at the

Army's Electronics Command, Ft. Monmouth, N.J., if he were to design a low-power local oscillator today, he says he would choose the avalanche diode over the Gunn device. "The major reasons are better reliability, better yield and better [lower] cost," says Brand. For a higher power pulsed radar, however, Brand says he would look more closely at the Gunn and LSA mode devices.

The LSA device, since it is not a transit-time device, can be made thick enough to take high voltages and thus deliver high power. The conventional Gunn unit, as a transit-time device, must be kept thin for high microwave frequencies, which limits its power capabilities.

The limited space-charge accumulation device suppresses the Gunn mode and operates as a bulk negative resistance which, when properly biased and driven, provides power at a frequency determined by the external resonant circuit and not by the device itself. Rudolf Engelbrecht, head of Bell's microwave integrated device department, compares it, in a gross sense, to a giant tunnel diode, in that its volt-ampere characteristic is similar to the tunnel diode's, biased on the negative-resistance portion of the curve to allow oscillations in the circuit. The LSA device, however, doesn't have a junction whose width limits the available power from tunnel diodes. The only limitation of the LSA device is that the voltage must swing back over the current hump during each cycle to quench the space charge that would build up to force the device to operate in the Gunn mode.

If he were questioned six months ago, says Brand, he would probably have said that the first bulk gallium-arsenide devices in general use would be the original Gunn type. Now, however, he believes the LSA mode could conceivably leapfrog its predecessor and be used first because of its high peak power, reasonable efficiency, and the possibility of easy tuning.

The new devices will affect varactor multipliers in cases where frequencies near X-band are needed. At this frequency, where several stages of varactors are needed, Gunn devices can operate directly. Present efficiencies of the two systems, though, still are comparable.

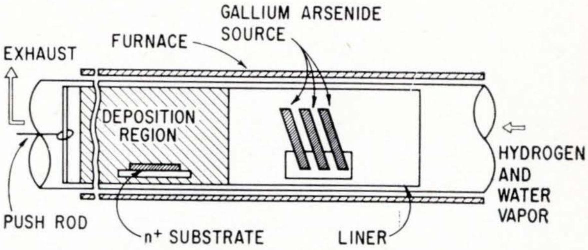
Much more can be done with Gunn-effect devices beyond supplying microwave power. Since an electric field controls the operation of the device, researchers are studying methods of shaping the electric field by means of device geometry. A variable voltage to modulate or sweep the frequency of the device is a likelihood. The high-resolution mask-making capability of semiconductor manufacturers suggests that a high level of dimensional control of the devices is possible.

But the immediate problem is to design devices to perform predictably. To reach this point, more research on the materials and contacts is needed.

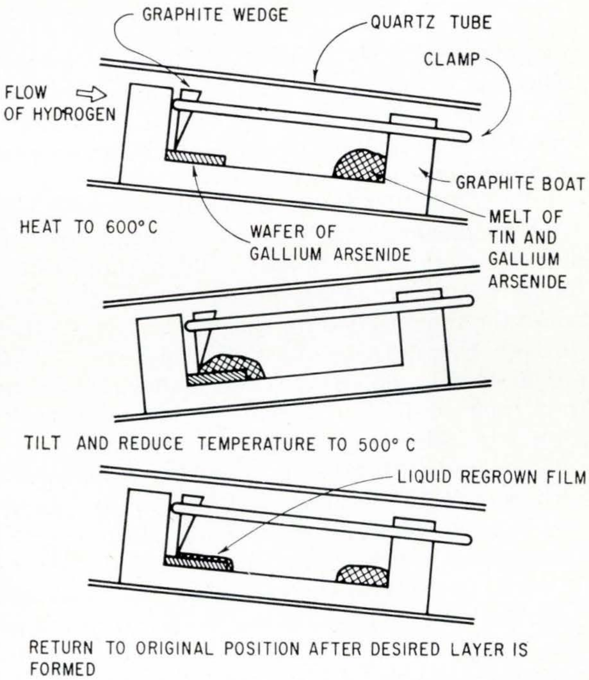
Better materials technology needed

While gallium arsenide has been used in many semiconductor devices, the effort expended on de-

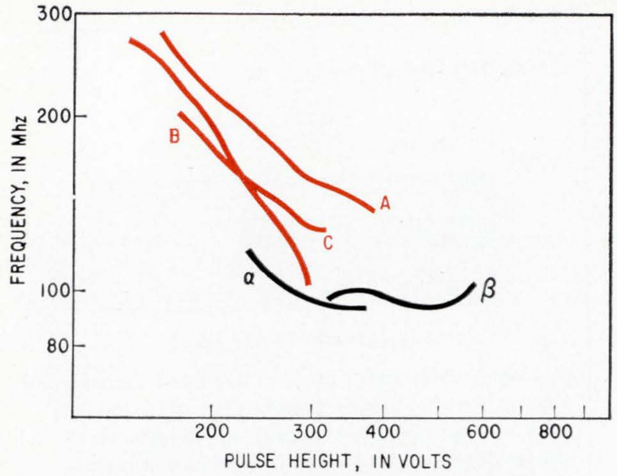
Growing the layers . . .



Hydrogen-water vapor process has been successfully used at Bell Telephone Laboratories to epitaxially grow an intermediate-resistivity active layer on a low-resistivity n^+ substrate. The gallium-arsenide source is maintained at 1,050°C and the substrate at 1,000°C. A mixture of hydrogen and water vapor enters one end of the tube and flows over the GaAs, forming gases of gallium sub-oxide and arsenic. When these gases flow into the lower temperature region containing the substrate, they reform into GaAs and water vapor. The water vapor exhausts from the tube while the GaAs deposits onto the substrate.



Liquid-regrowth process is used at Bell Labs to grow the low-resistivity n^{++} layer on the active layer which was grown in the hydrogen water-vapor process. A graphite wedge holds the n-type gallium arsenide in place at one end of the boat and a melted solution of tin and GaAs is placed at the other end. Hydrogen is admitted into the reaction tube to prevent formation of gallium oxide. The boat is first tilted while the temperature is increased to 600°C and then is tilted back to allow the melt to run onto and cover the wafer. The boat then is cooled to 500°C and as it cools, the gallium arsenide precipitates from the melt and deposits on the wafer to form the n^{++} layer.



Tapered Gunn-effect oscillator developed by Masakazu Shoji of Bell Labs allows an octave tuning range with applied voltage. The curves show the results observed with three tapered samples A, B, and C, and with two uniform samples, α and β. The field is strongest at the narrow end. As the voltage is increased, the field will exceed the critical value over a greater length of the structure and the Gunn effect will occur over a greater length, producing lower frequency oscillations. Thus, as the voltage is increased, the frequency decreases. The length of the sample is about 30 mils.

veloping the material has been limited compared with, for example, silicon processing technology. The technology gap in GaAs will be overcome in time, but at present device developers are hampered most by inadequate materials.

Inhomogeneities in the materials cause the operating frequency of each device to deviate from the desired operating frequency, which supposedly is set by the width of the device (the width determines the time needed for the charge layer to travel through the device, and this transit time is the period of the oscillations). The scatter of operating frequencies found in ostensibly identical devices cannot be tolerated on a production basis.

Compared with other possible Gunn materials—such as cadmium telluride and indium phosphide—GaAs has received the greatest amount of attention. Most researchers looked at the other materials only to verify their Gunn-effect properties, and then channeled their efforts toward GaAs, since the material's back-up was much stronger. At Texas Instruments Incorporated, for example, some research has been done on indium phosphide, arsenic phosphate, and indium arsenide. But for practical applications, the company is restricting its efforts to GaAs. "We know better how to control it," says Shing Mao, a TI engineer.

In their attempts to overcome the variability of GaAs, some researchers are concentrating on bulk GaAs, while others are growing their own epitaxial GaAs layers on the bulk substrates.

Three-layer devices effective

Among the most successful schemes reported to date is one from Bell Labs. Over an n^+ (a heavily doped) bulk gallium-arsenide substrate with a carrier concentration of about 2 x $10^{18}/cm^3$ (a resistivity of about 0.002 ohm-centimeter) is epitaxially grown a 4- to 40-micron active layer (the thickness depends on the frequency) with the proper Gunn concentration of about 3 x $10^{15}/cm^3$. An n^{++} (an extra heavily doped) layer about 4 microns thick then is grown with a concentration of about 8 or 9 x $10^{19}/cm^3$. The high conductivity of this layer improves the contacts. The substrate then is lapped until the overall thickness is 75 microns. Indium-gold contacts then are deposited and alloyed on each side of the slice, and the slice is finally broken up into samples of about 100 microns by 100 microns each. With devices made in this manner, Bell experimenters have found uniform performance from device to device and have reported about 110 milliwatts at 11 gigahertz, with 3% efficiency.

The difficulty in obtaining high-quality epitaxial gallium arsenide from materials vendors is causing many researchers to grow their own epitaxial layers on the vendor's bulk substrates.

At the Raytheon Co.'s Research division, Robert A. Pucell, manager, says the biggest obstacle to Device development is poor material. Experiencing some difficulty getting the sandwich of different doping levels that has proven effective for the devices, Pucell's group is returning to the use of a single epitaxial layer. It is finding that ohmic heating in the device induces diffusions that form p-n junctions. Unhappy with the epitaxial material supplied by outside vendors, Pucell's group is among those growing their own material.

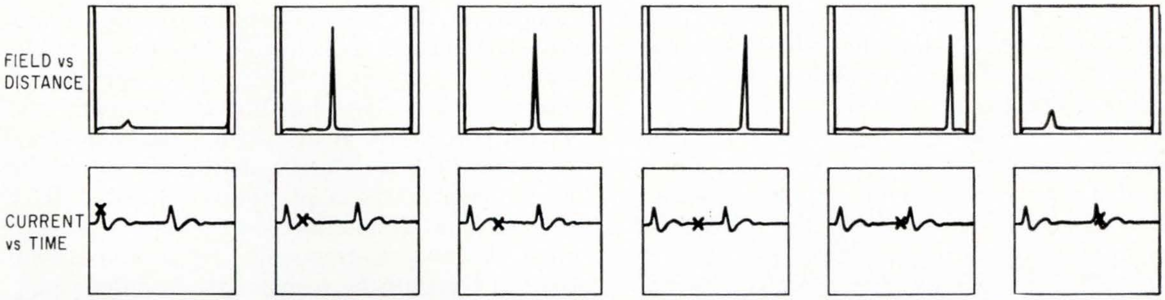
T.B. Ramachandran, senior semiconductor development engineer at Microwave Associates, Burlington, Mass., says his group has abandoned work on bulk gallium arsenide devices and is now concentrating on the sheet type. After growing a high-resistivity (100,000 ohm-cm) substrate, Ramachandran's group grows a 0.25 ohm-cm epitaxial layer 1 to 2 microns thick. Two contacts then are attached to the top of this layer for the d-c voltage and power output.

The materials problem, says Ramachandran, is a major reason no one has gotten as much power out of Gunn-effect devices as they have out of avalanche diodes. "Silicon technology [used in avalanche diodes] is much further advanced than gallium arsenide," he points out. Eventually, he says, Gunn and LSA devices will be better than avalanche devices in power, noise level, line width and efficiency.

Voltage-tunable devices

The device shown on the magazine cover magnified many times is a tapered Gunn-effect oscillator, voltage-tunable over a 2-to-1 frequency range. In operation, the frequency of any Gunn-effect device depends on the length of the sample in which the critical field is exceeded. For nontapered units, this length has always been about equal to the length of the device. But for this tapered device, the field is stronger near the narrower end. The critical field extends over a distance

Simulating the Gunn Effect



Several frames of computer-produced motion picture show how the dipole layer propagates through the sample after being nucleated at a point where the doping is 10% lower than the doping throughout the rest of the sample. The X's on the current curve show the current at the instant which is pictured in the field distribution plot. The time between frames is about 0.6 nanosecond. The repetition frequency is 680 megahertz.

Some of the most important research on Gunn effect is being done at the computer console, not the lab bench. Engineers are gaining a wealth of knowledge from computer simulations by Dean E. McCumber and others at Bell Telephone Laboratories. The new limited space-charge accumulation mode, for example, was identified by Bell's John Copeland while working on a computer simulation of the Gunn effect.

The basic, observed facts of the Gunn effect are: when the d-c voltage impressed across a small sample of gallium arsenide is slowly increased, the current rises at first according to the material's normal positive bulk resistance, but at a particular critical voltage, the sample suddenly begins to produce a high-frequency current oscillation. Capacitive probe measurements made by J.B. Gunn at IBM showed that a dipole layer was moving through the sample at a velocity of about 10^7 centimeters/second, and that the time needed for one passage through the device corresponded to the period of the oscillations. For example, a 0.01 cm-long device oscillated at 10^9 hertz, or 1 gigahertz.

The Gunn effect is seen only in semiconductors having two electron conduction bands separated by an energy gap. The normal conduction band is at the lower energy level. In the higher conduction band, electrons have a lower mobility, but in normal operation this state is unfilled. A high electric field can excite electrons to the higher-energy, lower mobility band. As the electric field is increased from zero, the current increases at first as the normal conduction band electrons are accelerated. But as the field is increased further, more electrons are excited to the lower-mobility band where they move more slowly. The net effect: overall current tends to decrease with increasing voltage and the material is said to have a negative resistance.

Repeats itself. This kind of situation is unstable. Any deviation in charge concentration will cause the building up of a charge accumulation layer and a depletion layer. For example, at a point where the electron density suddenly decreases due to, say, nonuniform doping, the field will increase and the electrons will move more slowly. (On the negative resistance portion of the characteristic, increased field produces decreased current.) Thus, at the edge of the depletion layer nearer the negative electrode, electrons traveling toward the positive electrode tend to accumulate and the accumulation layer grows; at the edge nearer the positive electrode, electrons tend to move away from the depletion layer faster than they move into the layer, so the depletion layer grows. The layers move across the sample at the average electron drift velocity until they reach the positive electrode, where they disappear. Then a new accumulation-depletion layer appears and the process repeats itself.

Working from the basic field and charge-continuity equations and the doping and energy band structure of the material, McCumber programed the computer to produce the internal field pattern and oscillating current waveforms on a cathode-ray tube. These clearly show the dipole layer moving through the device.

The crt display of the computed field distribution at each instant can be photographed and the photos sequenced to produce a motion picture of the field's movement through the device. Bell researchers used a Stromberg-Carlson microfilm recorder to photograph the output display from an IBM 7094 computer and produced movies of the device's operation. The film has been shown at technical meetings.

Transactions award. The computer studies show that the moving dipole layer originates, or nucleates, at a point where the doping level of the sample deviates from the average doping level. Although measurements on the first samples showed an approximate relationship between frequency and sample length, the computer studies show how the frequency depends on the length of the dipole path. If the dipole layer is nucleated at one end, then the period would be equal to the transit time from one end of the device to the other. However, if the dipole nucleates at a point inside the sample, then the path length will be less and the frequency higher.

A flip-page sequence of the film's individual frames was published in the January 1966 issue of the IEEE Transactions on Electron Devices. For their paper accompanying it, McCumber and A.G. Chyonweth—also of Bell—will receive the W.R.G. Baker Prize at the IEEE convention this month for the year's outstanding Transactions paper.

that can be varied by changing the applied voltage.

For a low applied voltage, the critical field covers only a short distance near the narrow end. As the voltage is increased, the critical field region lengthens toward the wider end. Thus, for low voltages, the transit-time length is short and a high-frequency output is observed. For high voltages, the field is long and thus the frequency is low.

In the devices studied by Masakazu Shoji, a Bell engineer, the frequency was varied from 140 to 270 megahertz by varying the bias pulse amplitude from 173 volts to 395 volts. Since the relationship between frequency and bias voltage is determined by the shape, Shoji says the linearity of the sample can be improved by more careful shaping.

The material was n-type GaAs with a carrier concentration of about 4 to 6 x $10^{14}/cm^3$. The wafers were sliced and diced to a 40- by 40-mil size, 10 to 20 mils thick. The sides of the wafer were then ground to the desired taper, samples were etched and pure indium contacts alloyed at 450°C for 30 seconds. The length of the tapered sections were finally about 25 to 35 mils.

The significance of this device is that the shaping of the material easily lends itself to the usual semiconductor etching processes. Thus, with present capabilities of 10-micron lengths with etching, 10-Ghz Gunn-effect oscillators made by conventional integrated circuit technology can be envisioned. (With a typical velocity of 10^7 cm/sec and a 10-micron length, the frequency would be 10 Ghz.)

Another example of a special-purpose, voltage-tunable device was reported at the October 1966 electron devices conference in Washington by researchers at the Radio Corp. of America Laboratories in Princeton, N.J. In this device, a field effect was used to control the device frequency. Experimenters took a GaAs junction diode and made a saw cut perpendicular to the junction in the n side, producing three terminals: one at the p side and one on each of the n platforms separated by the saw cut. The Gunn-effect d-c voltage was placed across the two n terminals and the oscillations occurred through the n material. A voltage placed on the p material, however, allowed tuning the frequency over a 10% range. This device was recently demonstrated by RCA as the key element in a frequency-modulated transmitter.

Making saw cuts in each device is unthinkable as a production method, but there is the possibility that separation in the n layer could be achieved by some process of masked epitaxial growth. Research is now under way along these lines.

Recent results

The field is moving so rapidly that it's difficult to pin down specific power and frequency figures as the present state of the art.

A sampling of some recent laboratory results with Gunn-type sources:

Foreign firms feel materials pinch

The materials problem plaguing U.S. firms is also affecting researchers abroad. At a glance, here is what is happening overseas:

Germany. With U.S. companies as their major suppliers of gallium arsenide, researchers at AEG-Telefunken and at Siemens AG are having difficulty getting high-quality material. Delivery times are long, and the amounts and grades specified aren't always met. Gallium arsenide from German suppliers is said to be of inferior quality. Siemens plans to step up its in-house production of GaAs. Results thus far appear to lag behind those in the U.S. At Siemens, a power output of 100 milliwatts continuous wave has been achieved at 1.5 to 3.7 gigahertz with 0.6% efficiency in one type of pulsed Gunn oscillator. AEG-Telefunken reports "oscillating frequencies of elements developed so far are several gigahertz with pulse power outputs of several hundred milliwatts and efficiencies up to several percent."

France. Two companies doing the most research on the Gunn effect are CSF-Compagnie Generale de Telegraphie sans Fil and a subsidiary of Philips Gloeilampenfabrieken NV, La Radiotechnique SA. Both firms say materials are posing the greatest difficulty in developing reproducible devices. Neither has turned to dopants, but are working with natural impurities of domestically obtained GaAs. CSF recently started experiments with gallium phosphide for use with long pulses. Researchers have found that GaAs produces deformation of the spectrum because of internal heating. Both firms have agreed to coordinate efforts to avoid duplication. CSF reports watt-level peak power between 500 megahertz and 14 Ghz with efficiencies up to 6%. La Radiotechnique won't comment on research pending definitive results.

Japan. The Electrical Communication Laboratory of Nippon Telegraph and Telephone Public Corp. is using pellet-type Gunn-effect devices made from a U.S. supplier's boat-grown 0_2 doped GaAs. Results appear to be reproducible. Best results thus far are 1 watt in pulse operation at 4 Ghz with efficiency of about 5% and 30 mw in continuous wave operation at 6 Ghz and 1% efficiency. Bulk temperature treatment of material is expected to lead to improved results. At Tokyo Shibaura Electric Co., major efforts are directed at developing a 1.7-Ghz oscillator for use in a telemetering transmitter for rockets. Experimenters are concentrating on developing a practical oscillator with presently available materials. Power outputs now obtainable are in the 20- to 50-mw range for continuous-wave operation, and in the order of 1 to 2 watts for pulse.

Great Britain. Researchers at Elliott Electronic Tubes Ltd., a member of the Elliott Automation Group, say the major problem now is to learn how to make epitaxial GaAs directly with the required degree of doping or to make pure epitaxial GaAs and then devise a doping technology. Highest frequency achieved is 3 Ghz with 20 mw output and poor reproducibility. At Marconi Co., a subsidiary of English Electric Co., devices have delivered a maximum of 7 mw in the 12.5 to 17.5 Ghz with 1% efficiency.

■ 140 mw continuous wave at 6 Ghz at TI, Dallas, where devices are reported to have been subjected to 3,500 hours of test operation.

■ 10 mw c-w at 10 Ghz with efficiency of 0.5% at Mullard, London. Carrying out the work in conjunction with the Royal Radar Establishment in Malvern, the Gunn-effect oscillators have been used as local oscillators in radar systems and as pumps for parametric amplifiers.

■ 100 mw c-w at 8 to 12 Ghz and 5 to 10 mw at 24 Ghz with 2 to 3% efficiency at Japan's Nippon Electric Co. The life of these epitaxial devices appears to be good, with the company reporting continuous operation in excess of 700 hours with 10 mw output. Nippon engineers say the resistivity of the undoped epitaxial material increases with increasing temperature, which decreases the input current and thus prevents thermal runaway.

■ 120 mw c-w in S band with 18% efficiency at the Westinghouse Electric Corp.'s Aerospace division in Baltimore, Md., where a Read avalanche diode oscillator also has been operated in X band, delivering 240 mw c-w with 3.8% efficiency.

■ 60 mw c-w at 13.5 Ghz at Raytheon. Pucell calls conventional packages unsatisfactory for Gunn devices—"We'd like to expand the holder in a way that does not forfeit high-frequency performance." Two methods are being tried: mounting the chip on a waveguide wall and making a package resonant to the desired frequency and coupling it to the cavity structure. Neither method will sacrifice high-frequency performance, says Pucell. But for c-w operation, the most serious problem is appropriate heat-sinking. "We need an ingenious way of getting heat out of the top and the bottom of the device," says Pucell.

■ 1 kw peak at 1 Ghz at NASA's Electronics Research Center, Cambridge, Mass. "We don't know if this is a single frequency pulse or not," says Harold Roth, head of advanced research. "When it runs that high, it's difficult to see separate frequencies." Roth suspects that this diode was operating in the LSA mode, but the results were obtained before the LSA mode was identified. "Now we're looking specifically for LSA operation," adds Roth. A Gunn transmitter using pulse rate modulation has been tested. The device was driven by a pulse circuit triggered by a modulated, voltage-controlled oscillator.

■ 15 w peak in the 4 to 7 Ghz range, with efficiency about 2.5% at Standard Telecommunications Laboratories, Harlow, Essex, England. Frequency stability with time and temperature was found to be largely determined by the cavity. The shape and the construction of the cavity, it is reported, also affects the noise.

■ 2 w peak at 10 Ghz with 0.5 microsecond pulses and an efficiency of 9% at Lincoln Laboratory. "It's a question of power dissipation," says Foyt. "You can't get rid of more than a few watts." But in the LSA mode, Foyt adds, it may be possible to get away from dimensional problems and thereby get more heat out.

■ 1.5 w peak at X band at Motorola Inc.'s aerospace center at Scottsdale, Ariz. "It is not a transit-mode type of operation," says Tony Kallas, Gunn-effect project leader, noting that the 45 to 50-volt input was well above the transit-time voltage. "By going to a higher voltage, you can get a higher power output, but efficiency is only about 1%," he says. "Reproducibility is now very, very poor." Motorola's preliminary objective is to reproduce a 10-watt output and then extend this to 400 watts by paralleling several chips. It feels it has solved the heat sinking problem on peak powers up to 100 watts by thermally bonding the chip to a heat sink on its lower side. The upper contact is a low-inductance bellows contact. "Before we developed this system, we were burning contacts out one after the other," Kallas says.

Motorola also is investigating the use of a Gunn-effect device in the construction of microcircuit modules in an active phased array configuration to drive a phased-array antenna. The goal is 1- to 5-watt output in X band. "We think we will have circuits for prototype demonstration by the end of the year, particularly in phased arrays," says Kallas. He expects Gunn-effect devices will be in general use in the field in 18 to 24 months.

Comparing Gunn-effect devices with avalanche type devices, Kallas sees greater power potential in Gunn devices because of the greater area available compared with the small active area of the junction devices. However, at present, the results with junction devices are much easier to reproduce because the technology is more advanced.

Says Kallas: "Once they [Gunn devices] are in production, costs will be considerably less than conventional devices, such as ceramic triodes."

But regardless of the promise shown by Gunn devices, NASA's Carol Veronda, head of microwave circuits research, says the Electronics Research Center will continue working on tubes and other solid-state sources. He points out that "if people had given up triodes when the traveling-wave tube was invented, we would have missed out on the higher frequency, better performing triodes that came along."

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Computer-aided design: part 7
Performing nonlinear d-c analysis

Resistors, capacitors and other linear devices can be analyzed from simple models—but nonlinear devices like transistors and zener diodes require a different approach

By Martin J. Goldberg and Jerry W. Achard
Norden Division, United Aircraft Corp., Norwalk, Conn.

Nonlinear elements are contained in almost all electronic circuits, and their behavior is extremely difficult to predict accurately. If the engineer wants accurate circuits he must have a computer program that analyzes nonlinear d-c problems. One such program, developed at the Norden division of United Aircraft Corp., not only solves nonlinear d-c problems but others in three major design areas—statistical, worst-case and stress analyses.

These three analyses are valuable because they predict circuit performance accurately without a breadboard. For example, worst-case circuit analysis determines the worst possible effect on the output parameters due to changes in the values of circuit elements. These elements are set to the values within their anticipated ranges that produce the maximum detrimental changes in the output. The technique usually requires tedious calculations of partial derivatives making it impractical to solve without a computer.

The Norden program features:

- A nonlinear model of a transistor and one of a diode.
- Automatic development of nonlinear equations.
- Automatic solution of nonlinear equations.
- Optional analysis routines, such as statistical, worst-case and stress analysis.
- Fortran language, which permits it to be used on any computer having a Fortran compiler.

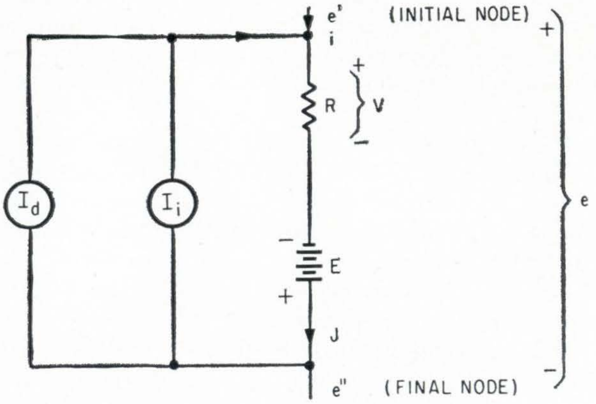
Operational procedures

To use the program, the designer first fills out coding forms that describe the circuit schematic. The forms include data specifying the values and tolerances of passive elements, how the circuit elements are connected, parameter values for the conventional models of the program and which operational analysis routines are desired. Initial estimates of the operating currents of the nonlinear devices may be entered on the forms.

The data is then keypunched to generate the input data cards. The program sets up models for transistors, diodes and zener diodes from the parameter values specified for the devices. An Ebers-Moll model is used for transistors and diodes, a piecewise nonlinear model for zener diodes.

The currents in all nonlinear devices are computed first. This is accomplished with a Newton-Raphson iterative technique[1] starting from the initial current values estimated by the operator. With these currents a set of linear node-voltage equations is obtained. Once the operating points and circuit node voltages are obtained, worst-case, stress or statistical analyses can be performed as requested by the operator.

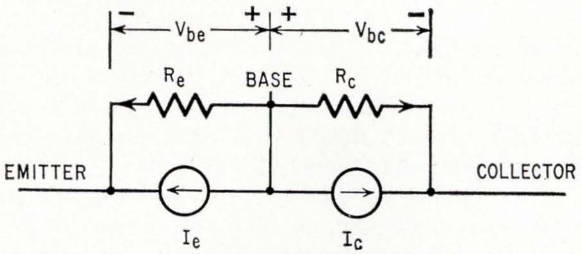
In a typical circuit branch, upon which the pro-



A circuit branch is defined from the initial node to the final node with each branch containing a nonzero R-parameter. The dependent current source is represented by I_d and I_i is the independent current source.

Active circuit models

TRANSISTOR MODEL



Transistor equations:

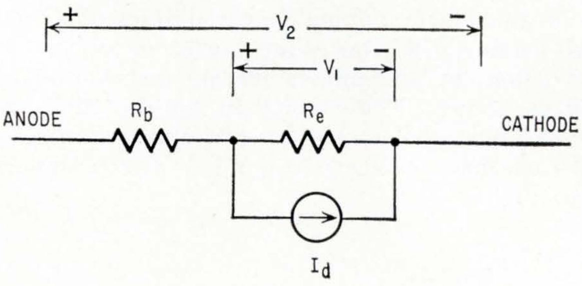
$$I_e = I_{es}(e^{\frac{qV_{be}}{M_e kT}} - 1) - \frac{\beta_R}{\beta_R + 1} I_{cs}(e^{\frac{qV_{bc}}{M_c kT}} - 1)$$

$$I_c = I_{cs}(e^{\frac{qV_{bc}}{M_c kT}} - 1) - \frac{\beta_F}{\beta_F + 1} I_{es}(e^{\frac{qV_{be}}{M_e kT}} - 1)$$

Definition of terms:

I_{cs}, I_{es} = Saturation currents
q = Electronic charge
k = Boltsmann constant
T = Absolute junction temperature
β_F = Forward beta gain
β_R = Reverse beta gain
M_e, M_c = Constants determined empirically

DIODE MODEL



Diode Equations:

$$I_d = I_s\left(e\,\frac{qV_1}{MkTN} - 1\right)$$

$$V_2 \approx M\,\frac{kTN}{q}\log\left(\frac{I_d + I_s}{I_s}\right) + NI_dR_b$$

Definition of terms:

N = Number of diodes in series
R_b = Bulk resistance
R_e = Leakage resistance
I_s = Saturation current
M = A constant determined emperically
k = Boltzmann constant

Model for the transistor and the diode are used for d-c analysis. Equations represent current-source relations.

gram is based, each branch can have a voltage source, a dependent current source, an independent current source and a passive element (written as an impedance, or an admittance). Nonlinearities of the circuit branches are included in the dependent current source and solved by iterative procedure.

The equivalent circuit for the transistor model consists of two diodes, one each for the base-emitter junction and collector-base junction. It is a nonlinear version of the Ebers-Moll model and is similar to the model used in NET-1; however, it contains far fewer parameters. Capacitors have been removed since they are not pertinent to d-c analysis. To reduce computational complexity and the number of model elements that the operator must specify, the following parameters are omitted: the emitter-bulk resistance, base-spreading resistance and collector-bulk resistance. The dependency of the current gains β_F and β_R on junction voltages is also neglected.

All four regions of operation are covered by the model: cutoff, active normal, active inverted and saturation. The nonlinear equations for the dependent current sources appear on the diagram. These equations are combined with linear network equations and solved iteratively for the operating points of the transistors.

The equivalent circuit for the zener diode or a conventional diode model is represented by the same model. The zener diode operates in three distinct regions with each region described by an appropriate equation. The term N in the equations represents the number of series diodes.

When strings of series diodes are examined, it is usually the voltage drop across the entire chain that is of interest. Therefore, the equations were modified to account for the number of diodes in a series string. Thus, the desired effect was obtained without the addition of extraneous nodes that occur when each diode is examined individually.

Field effect transistors and other less conventional devices require different models than the program provides. Because of this, the program has been extended to allow the inclusion of linear equivalent circuit models with appropriate input data. However, these models must be constructed from the basic circuit branch. An equivalent circuit model for a transconductance, G_m, can also be inserted between branches. The transconductance sets up a dependent current source in one branch related to the voltage drop across the resistance in another. The equation is expressed by $I_d = G_m V$.

A nonlinear d-c analysis

The capabilities of the program are best illustrated with a sample problem. In the problem circuit all nodes and branches are arbitrarily numbered. Additional nodes and branches are automatically inserted by the program where required for the equivalent models of the transistors and diodes.

The operator enters both control and general information—which describe the circuit—on the first coded form. From this, three input cards are punched. Data on the first card includes the title of the run; the second card includes the number of branches, nodes, transistors, diodes, zeners, transconductances, modifications and simultaneous modifications (these inputs alert the machine as to the number of individual cards to expect for branches, nodes, etc.). Also, usually included on the second card but not indicated, are two additional terms—Δ between successive iterations for terminations and ambient temperature in degrees centigrade. The Δ term is the difference ratio between the currents on successive iterations. It represents a figure of merit and indicates when convergence occurs for the iterative calculations of nonlinear device currents.

Any desired optional analysis routines are indicated on the third card, stress, worst-case, etc.

On the typical input cards for branch, node, transistor and diode data E±xx refers to the multiplying factor $\pm 10^{xx}$; thus, 10.E + 03 equals 10×10^3. (Note that relatively few parameters are required for the transistor model.) The estimates for the currents in the base-emitter and base-collector junctions are inserted on the card under the headings of "emitter diode current" and "collector diode current." In most cases, the operator can accurately approximate these circuits. However, even if he approximates incorrectly, the program will still converge. If no value is entered, the initial current is assumed to be zero.

Diode data is coded in two ways. In the first, a separate entry is made for each of the two diodes in the sample circuit. The second method combines the diodes into a string of two series diodes, reducing by one the number of circuit nodes and nonlinear equations. The "current" heading on the coding form refers to an initial guess of the diode current.

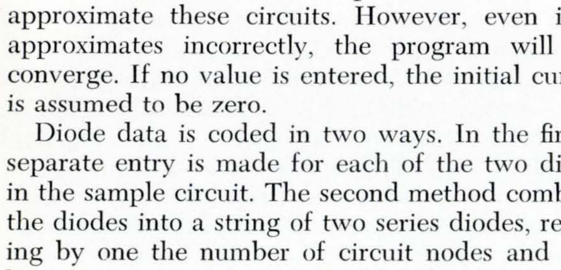
The output of the program begins with a verification listing of the input data. Units are volts, amperes, ohms and watts. For example, the voltage at node 2 is 22.87 volts. The "stress analysis" gives the current, voltage, and power for each branch. With reference to the branch definition these are i, e, and i x e, respectively. The coil voltage (voltage drop across the resistance) and power dissipated are v and v^2/R, respectively. The "summation of branch powers" is always zero for passive circuits. However, since the branches established by the computer for the additional transistor and diode models have not been included in the program, the summation is not zero in the sample circuit. If the power dissipated in the transistors and diodes is added to the sum of the branch powers, a value of zero is obtained. Transistor and diode analyses give the state of each device and corresponding voltages, currents and power dissipations.

In the results, the first routine gives the sensitivity of each node voltage with respect to the network parameters (resistance, voltage, and current source of every branch and the forward beta for each transistor). The beta parameter, for example, is specified as BF 1 for transistor number 1. The print-out shows that node 4 changes positively by 1.7% from its nominal value for a positive 1% change in the beta for transistor 1. Sensitivities show the amount of change required in a particular parameter to adjust a node voltage by a specified amount. Since the sensitivities are computed from partial derivatives of the nodal equations, they are valid for small deviations from a given operating point of a circuit.

The next analysis, "worst case and variability," is computed from parameter tolerances specified on the input data cards and the partial derivatives computed in the sensitivity analysis. The "worst case min" and "worst case max" printouts give the maximum and minimum node voltage with all parameters set at their tolerance extremes, causing the maximum excursion of the node voltage. In most cases the probability of such an occurrence is extremely small, so that a more meaningful output is obtained by examining the variabilities. The original parameter tolerances are converted to standard deviations by assuming a normal distribution for all parameters. These are then substituted in the propagation of variance formula and the variance of each node voltage is computed. The formula is given by

$$\sigma_v^2 = \sum_{i=1}^{N} \left(\frac{\partial v}{\partial P_i} \right)^2 \sigma_{P_i}^2$$

In the formula, σ_v^2 is the variance and σ_v is the



WHERE:

I_S = SATURATION CURRENT

R_L = LEAKAGE RESISTANCE = V_R / I_R

$Z_Z = R_Z$ = AVALANCHE RESISTANCE = MAX. ZENER IMPEDANCE

I_K = VOLTAGE/$(R_L - R_Z)$, CALCULATED BY PROGRAM

VOLTAGE = $V_Z - I_{ZT}(Z_{ZT})$

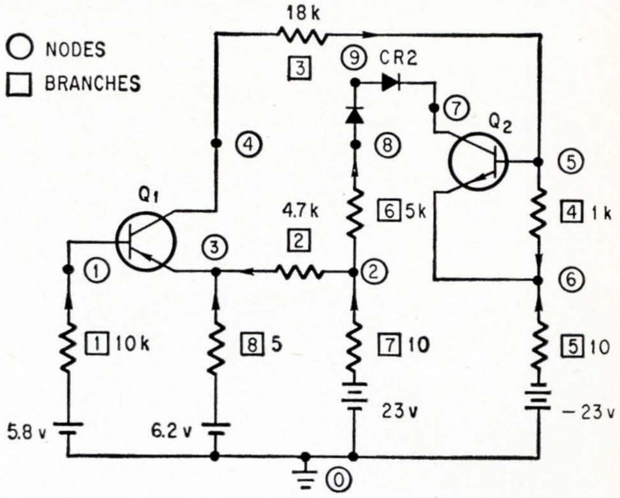
N = NUMBER OF ZENER DIODES IN SERIES BETWEEN ANODE AND CATHODE NODES

Typical characteristic current versus voltage curve for a zener diode. Plot is broken into three parts with each part represented by an appropriate current-voltage equation.

Nonlinear d-c analysis example

The sample circuit at the right contains nonlinear transistors and diodes. To begin the nonlinear d-c analysis of the circuit the operator arbitrarily numbers all the node points and branches—circled numbers for the nodes, boxed numbers for the branches. Then a description of all the branch-node connection data is entered in the three input cards that are shown below in abridged form.

Also entered on the cards are the values for the node voltages, transistor emitter saturation currents and diode currents, emitter and collector resistances, diode saturation currents, diode currents, bulk resistances, and diode leakage resistances.



RESISTOR	NODES FROM	TO	RESISTANCE-OHMS	± % R	VOLTAGE-VOLTS	± % E	CURRENT-AMPS
1–6	7–10	11–14	15–24	25–28	29–38	39–42	43–52
R 1	0	1	10. E+03		5.8		
R 2	2	3	4700.	5.			
R 3	4	5	18. E+03	5.			
R 4	5	6	1000.	5.			
R 5	0	6	10.				
R 6	2	8	5000.	1.			
R 7	0	2	10.		−23.		
R 8	0	3	5.				
					23.		
					6.2		

Branch-node resistor connection data for input card.

TRANSISTOR	NODES E	B	C	TYPE	BETA FORWARD NOM.	LOW	HIGH	BETA REVERSE	EMITTER 1. SAT. CURRENT	EMITTER 2. DIODE CURRENT	COLLECTOR 2. DIODE CURRENT	EMITTER LEAKAGE RESIS.	COLLECTOR LEAKAGE RESIS.
1–6	7–8	9–10	11–12	13–14	15–18	19–22	23–26	27–30	31–40	41–50	51–60	61–70	71–80
Q1	3	1	4	P	60.	30.	90.	.8	5. E−09	.001		1. E+06	2. E+06
Q2	6	5	7	N	60.	30.	90.	.8	1. E−08	.005		1. E+06	2. E+06

Transistor connection and parameter data for input card.

DIODES	NODES ANODE	CATHODE	SATURATION CURRENT	CURRENT	BULK RESISTANCE	LEAKAGE RESISTANCE	NO
1–6	7–10	11–14	15–24	25–34	35–44	45–54	55–64
CR1	8	9	1. E−12	.005	10.	1. E+06	1.
CR2	9	7	1. E−12	.005	10.	1. E−06	1.
CR1+2	8	7	1. E−12	.005	10.	1. E+06	2.

ALTERNATE METHOD OF CODING, FORMING A STRING OF DIODES AND ELIMINATING NODE 9

Diode connection and parameter data for input card.

Program outputs

SAMPLE CIRCUIT NORDEN NON-LINEAR DC CIRCUIT ANALYSIS PROGRAM
JUNCTION TEMPERATURE= 25.0 DEGREES CENTIGRADE

BRANCH DATA

BRANCH	INITIAL NODE	FINAL NODE	RESISTANCE(OHMS)	PERCENT TOL	VOLTAGE(VOLTS)	PERCENT TOL	CURRENT(AMPS)
1	0	1	1.000E+04	0.00	5.800E+00	0.00	0.000E-99
2	2	3	4.700E+03	5.00	0.000E-99	0.00	0.000E-99
3	4	5	1.800E+04	5.00	0.000E-99	0.00	0.000E-99
4	5	6	1.000E+03	5.00	0.000E-99	0.00	0.000E-99
5	0	6	1.000E+01	0.00	-2.300E+01	0.00	0.000E-99
6	2	8	5.000E+03	1.00	0.000E-99	0.00	0.000E-99
7	0	2	1.000E+01	0.00	2.300E+01	0.00	0.000E-99
8	0	3	5.000E+00	0.00	6.200E+00	0.00	0.000E-99

TRANSISTOR DATA

	EMIT NODE	BASE NODE	COL NODE	TYPE	BETA FORWARD NOM	LOW	HIGH	BETA REV	INITIAL GUESS EMIT DIODE CUR	INITIAL GUESS COL DIODE CUR	EMIT REVERSE SAT CURRENT	EMIT LEAKAGE RESISTANCE	COL LEAKAGE RESISTANCE
Q 1	3	1	4	P	60.0	30.0	90.0	.80	1.000E-03	0.000E-99	5.000E-09	1.000E+06	2.000E+06
Q 2	6	5	7	N	60.0	30.0	90.0	.80	5.000E-03	0.000E-99	1.000E-08	1.000E+06	2.000E+06

DIODE DATA

DIODE	ANODE NODE	CATH NODE	SAT CURRENT	CURRENT	BULK RES	LEAK RES	NO.
1	8	9	1.000E-12	5.000E-03	1.000E+01	1.000E+06	1.00
2	9	7	1.000E-12	5.000E-03	1.000E+01	1.000E+06	1.00

OPTIONAL ROUTINES CALLED FOR
SENSITIVITIES
STATISTICAL ANALYSIS
MANDEX WORST-CASE ANALYSIS

NO. OF ITERATIONS = 4

NODE VOLTAGES ARE

1= 5.900E+00, 2= 2.287E+01, 3= 6.212E+00, 4=-5.650E+00, 5=-2.254E+01,
6=-2.290E+01, 7=-2.281E+01, 8=-2.146E+01, 9=-2.213E+01,

STRESS ANALYSIS

BRANCH	CURRENT	VOLT-BRANCH	VOLT-COIL	POWER-DISSIPATED	POWER-BRANCH
1	-1.007E-05	-5.900E+00	-1.007E-01	1.015E-06	5.947E-05
2	3.545E-03	1.666E+01	1.666E+01	5.907E-02	5.907E-02
3	9.387E-04	1.689E+01	1.689E+01	1.586E-02	1.586E-02
4	3.543E-04	3.543E-01	3.543E-01	1.255E-04	1.255E-04
5	-9.806E-03	2.290E+01	-9.806E-02	9.616E-04	-2.245E-01
6	8.867E-03	4.433E+01	4.433E+01	3.931E-01	3.931E-01
7	1.241E-02	-2.287E+01	1.241E-01	1.540E-03	-2.839E-01
8	-2.596E-03	-6.212E+00	-1.298E-02	3.370E-05	1.613E-02

SUMMATION OF BRANCH POWERS =-2.411E-02 WATTS

TRANSISTOR ANALYSIS

NO.	STATE	VBE	VBC	VCE	IE	IB	POWER
1	-ACT-NOR	-3.121E-01	1.155E+01	-1.186E+01	-9.487E-04	-1.007E-05	1.113E-02
2	- SAT	3.543E-01	2.690E-01	8.528E-02	9.452E-03	5.843E-04	9.633E-04

DIODE ANALYSIS

NO.	STATE	VOLTAGE	CURRENT	POWER
1	- ON	6.772E-01	8.867E-03	6.005E-03
2	- ON	6.768E-01	8.867E-03	6.002E-03

TOTAL POWER DISSIPATED IN CIRCUIT= 4.948E-01 WATTS

SENSITIVITIES
PERCENT CHANGE IN NODE VOLTAGES FOR A ONE PERCENT CHANGE IN PARAMETERS

PARAMETER	NODE 1	NODE 2	NODE 3	NODE 4	NODE 5	NODE 6	NODE 7	NODE 8	NODE 9	NODE 10
R 1	1.92E-03	1.47E-06	2.85E-04	-1.10E+00	-2.26E-04	-1.52E-04	6.64E-04	7.02E-04	6.83E-04	
R 2	-2.65E-03	1.54E-03	-2.79E-03	-1.94E-01	-3.59E-05	-2.37E-05	1.21E-04	1.36E-04	1.28E-04	
R 3	1.60E-03	1.25E-06	2.36E-04	2.04E+00	-1.93E-04	-1.30E-04	5.68E-04	6.00E-04	5.84E-04	
R 4	1.55E-07	-1.65E-06	1.74E-08	2.04E-04	7.50E-05	1.64E-06	-8.36E-04	-8.84E-04	-8.59E-04	
R 5	9.29E-06	8.47E-06	1.40E-06	1.18E-02	4.33E-03	4.27E-03	4.28E-03	4.53E-03	4.40E-03	
R 6	3.53E-06	3.83E-03	1.31E-05	-1.23E-02	-4.89E-03	-3.83E-03	-5.28E-03	-1.61E-02	-1.05E-02	
R 7	-1.97E-05	-5.40E-03	-2.07E-05	-1.48E-03	-1.39E-05	-1.09E-05	-1.38E-05	-4.42E-05	-2.85E-05	
R 8	1.94E-03	1.01E-06	2.05E-03	1.42E-01	2.92E-05	1.96E-05	-8.59E-05	-9.08E-05	-8.83E-05	
E 1	1.10E-01	8.50E-05	1.64E-02	-6.34E+01	-1.30E-02	-8.76E-03	3.82E-02	4.04E-02	3.93E-02	
E 5	-2.18E-03	-1.98E-03	-3.29E-04	-2.78E+00	-1.01E+00	-1.00E+00	-1.00E+00	-1.06E+00	-1.03E+00	
E 7	3.66E-03	1.00E+00	3.84E-03	2.74E-01	2.58E-03	2.02E-03	2.57E-03	8.19E-03	5.29E-03	
E 8	9.30E-01	4.82E-04	9.79E-01	6.80E+01	1.39E-02	9.40E-03	-4.10E-02	-4.34E-02	-4.21E-02	
BF 1	-2.89E-03	-2.27E-06	-4.28E-04	1.70E+00	3.49E-04	2.35E-04	-1.02E-03	-1.08E-03	-1.05E-03	
BF 2	3.05E-08	-7.86E-07	1.88E-09	4.19E-05	1.54E-05	7.84E-07	-3.98E-04	-4.21E-04	-4.09E-04	

WORST CASE AND VARIABILITY ANALYSIS

NODE	NOMINAL	WORST-CASE MIN	WORST-CASE MAX	STANDARD DEVIATION	VARIANCE	1-SIGMA MIN	1-SIGMA MAX	3-SIGMA MIN	3-SIGMA MAX
1	5.900E+00	5.890E+00	5.910E+00	2.867E-03	8.220E-06	5.897E+00	5.903E+00	5.892E+00	5.909E+00
2	2.287E+01	2.287E+01	2.287E+01	6.565E-04	4.310E-07	2.287E+01	2.287E+01	2.287E+01	2.287E+01
3	6.212E+00	6.210E+00	6.215E+00	5.304E-04	2.813E-07	6.212E+00	6.213E+00	6.211E+00	6.214E+00
4	-5.650E+00	-1.110E+01	-1.976E-01	1.617E+00	2.617E+00	-7.268E+00	-4.032E+00	-1.050E+01	-7.971E-01
5	-2.254E+01	-2.255E+01	-2.254E+01	1.369E-03	1.874E-06	-2.254E+01	-2.254E+01	-2.255E+01	-2.254E+01
6	-2.290E+01	-2.290E+01	-2.289E+01	9.471E-04	8.970E-07	-2.290E+01	-2.290E+01	-2.290E+01	-2.289E+01
7	-2.281E+01	-2.283E+01	-2.279E+01	4.231E-03	1.790E-05	-2.282E+01	-2.281E+01	-2.282E+01	-2.280E+01
8	-2.146E+01	-2.148E+01	-2.144E+01	4.347E-03	1.889E-05	-2.146E+01	-2.145E+01	-2.147E+01	-2.144E+01
9	-2.213E+01	-2.216E+01	-2.211E+01	4.273E-03	1.825E-05	-2.214E+01	-2.213E+01	-2.215E+01	-2.212E+01

BREAKDOWN OF VARIANCE (PERCENT)

PARAMETER	NODE 1	NODE 2	NODE 3	NODE 4	NODE 5	NODE 6	NODE 7	NODE 8	NODE 9	NODE 10
R 1	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
R 2	8.29E-01	8.01E+01	2.97E+01	1.27E-02	9.73E-03	9.17E-03	1.18E-02	1.26E-02	1.23E-02	
R 3	3.01E-01	5.34E-05	2.13E-01	1.42E+00	2.81E-01	2.75E-01	2.60E-01	2.44E-01	2.54E-01	
R 4	2.82E-09	9.20E-05	1.15E-09	1.41E-08	4.23E-02	4.37E-05	5.64E-01	5.29E-01	5.50E-01	
R 5	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
R 6	5.87E-08	1.97E+01	2.64E-05	2.07E-06	7.22E+00	9.54E+00	9.01E-01	7.07E+00	3.32E+00	
R 7	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
R 8	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
E 1	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
E 5	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
E 7	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
E 8	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	0.00E-99	
BF 1	9.88E+01	1.75E-02	7.00E+01	9.85E+01	9.22E+01	9.01E+01	8.54E+01	8.01E+01	8.33E+01	
BF 2	1.09E-08	2.08E-03	1.34E-09	5.96E-08	1.79E-01	1.00E-03	1.28E+01	1.20E+01	1.24E+01	

MANDEX WORST-CASE ANALYSIS, NODE 5 HIGH

NO. OF ITERATIONS = 2

NODE VOLTAGES ARE

```
1= 5.894E+00,   2= 2.287E+01,   3= 6.212E+00,   4=-2.194E+00,   5=-2.254E+01,
6=-2.289E+01,   7=-2.282E+01,   8=-2.146E+01,   9=-2.214E+01,
```

STRESS ANALYSIS

BRANCH	CURRENT	VOLT-BRANCH	VOLT-COIL	POWER-DISSIPATED	POWER-BRANCH
1	-9.444E-06	-5.894E+00	-9.444E-02	8.919E-07	5.566E-05
2	3.731E-03	1.666E+01	1.666E+01	6.216E-02	6.216E-02
3	1.189E-03	2.034E+01	2.034E+01	2.421E-02	2.421E-02
4	3.389E-04	3.558E-01	3.558E-01	1.206E-04	1.206E-04
5	-1.014E-02	2.289E+01	-1.014E-01	1.029E-03	-2.323E-01
6	8.957E-03	4.434E+01	4.434E+01	3.972E-01	3.972E-01
7	1.268E-02	-2.287E+01	1.268E-01	1.610E-03	-2.902E-01
8	-2.531E-03	-6.212E+00	-1.265E-02	3.205E-05	1.572E-02

SUMMATION OF BRANCH POWERS =-2.311E-02 WATTS

TRANSISTOR ANALYSIS

NO.	STATE	VBE	VBC	VCE	IE	IB	POWER
1	-ACT-NOR	-3.182E-01	8.088E+00	-8.407E+00	-1.199E-03	-9.444E-06	1.000E-02
2	- SAT	3.558E-01	2.832E-01	7.261E-02	9.808E-03	8.510E-04	9.533E-04

DIODE ANALYSIS

NO.	STATE	VOLTAGE	CURRENT	POWER
1	- ON	6.786E-01	8.957E-03	6.079E-03
2	- ON	6.783E-01	8.957E-03	6.076E-03

TOTAL POWER DISSIPATED IN CIRCUIT= 5.095E-01 WATTS

MANDEX WORST-CASE ANALYSIS, NODE 5 LOW

NO. OF ITERATIONS = 3

NODE VOLTAGES ARE

```
1= 5.913E+00,   2= 2.289E+01,   3= 6.213E+00,   4=-1.129E+01,   5=-2.257E+01,
6=-2.292E+01,   7=-1.416E+01,   8=-1.285E+01,   9=-1.351E+01,
```

STRESS ANALYSIS

BRANCH	CURRENT	VOLT-BRANCH	VOLT-COIL	POWER-DISSIPATED	POWER-BRANCH
1	-1.130E-05	-5.913E+00	-1.130E-01	1.278E-06	6.686E-05
2	3.380E-03	1.668E+01	1.668E+01	5.638E-02	5.638E-02
3	5.970E-04	1.128E+01	1.128E+01	6.738E-03	6.738E-03
4	3.651E-04	3.468E-01	3.468E-01	1.266E-04	1.266E-04
5	-7.677E-03	2.292E+01	-7.677E-02	5.894E-04	-1.759E-01
6	7.080E-03	3.575E+01	3.575E+01	2.531E-01	2.531E-01
7	1.046E-02	-2.289E+01	1.046E-01	1.094E-03	-2.394E-01
8	-2.771E-03	-6.213E+00	-1.385E-02	3.841E-05	1.722E-02

SUMMATION OF BRANCH POWERS =-8.179E-02 WATTS

TRANSISTOR ANALYSIS

NO.	STATE	VBE	VBC	VCE	IE	IB	POWER
1	-ACT-NOR	-3.007E-01	1.720E+01	-1.750E+01	-6.084E-04	-1.130E-05	1.045E-02
2	-ACT-NOR	3.468E-01	-8.410E+00	8.757E+00	7.312E-03	2.319E-04	6.208E-02

DIODE ANALYSIS

NO.	STATE	VOLTAGE	CURRENT	POWER
1	- ON	6.534E-01	7.080E-03	4.626E-03
2	- ON	6.535E-01	7.080E-03	4.627E-03

TOTAL POWER DISSIPATED IN CIRCUIT= 3.999E-01 WATTS

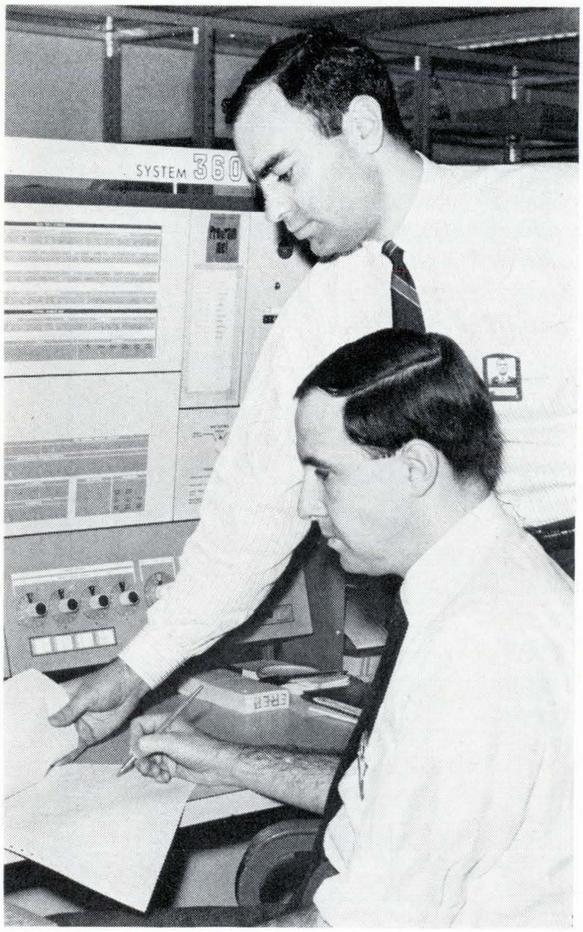
MANDEX ANALYSIS COMPLETED

Not the answer, but it's a beginning

The availability of a computer program is no assurance that an effective circuit analysis can be made. In fact, the circuit analysis problem really begins once the program is obtained, according to authors Martin J. Goldberg (standing in photo) and Jerry W. Achard, because the program merely provides a capability for analysis—nothing more. This is true whether a program is developed in-house or obtained from outside sources. To use a circuit-analysis program effectively, a complete system is required which includes the capabilities for maintaining the programs, instructing users, providing improvements and developing and controlling device models for the various programs.

There is no single design for a circuit-analysis system, since each must be tailored to a particular user's installation. However, there are general problems that the system designer should consider. For example:

- Since no one program provides all the capabilities or features required, several programs may have to be used, each with incompatible data requirements.
- Programs available from outside sources may not run directly on a particular user's computer, especially if written in a symbolic language. But even if written in Fortran, conversion may still be required.
- Documentation on a program may be insufficient for tailoring the program to a particular user's requirements.



- In-house program development is expensive and usually requires long lead times.

Human engineering is a consideration, too. At many installations, the system users will be engineers who not only design circuits but who may have little training in computer programing and how to use them. Therefore, computer applications engineers must maintain and extend the analysis programs in response to user requests. They can instruct users on the limitations of various programs and how to choose the best one for their particular needs. This education program must include the following concepts:

- Programs are only as effective as the designer who interprets the results they produce. An inexperienced designer will not automatically become a more experienced designer simply by using circuit analysis programs.
- Computer-aided analysis, compared with manual methods in the design phase of a circuit, may not necessarily lower costs. The reason is that a much more accurate, detailed, and complete analysis is usually performed with CAD than attempted with manual methods. The result is that a better circuit design is obtained, but not necessarily at lower design costs. However, production and redesign costs can be significantly reduced.
- Breadboarding for testing temperature may still be required in programs unable to perform such analysis. They are also valuable in verifying device models used in the programs, especially if they are new models for new applications. Basically, the programs reduce the amount of breadboard testing required and also help in selecting the optimum design from several alternatives preceding the breadboarding stage. In some cases, the analysis programs must substitute for breadboarding, particularly in the design of integrated circuits where off-the-shelf parts are not available.
- Sometimes, circuits may have to be conditioned to be compatible with particular analysis programs or to permit successful numerical analysis of the circuit. The circuit may have to be broken up into smaller functional parts, or parameter values may have to be adjusted to prevent numerical inaccuracies in the programs. This must be done in such a way that the over-all electrical properties of the circuit are not affected.

The Norden systems. Goldberg and Achard have taken several approaches to obtain an effective system, ranging from original program development to applying programs from outside sources. They are using NET-1 for nonlinear transient analysis. The ECAP program is used for a-c analysis and for some transient analyses in which new models are required that cannot be effectively modeled with NET-1. Both Circus and Sceptre will be used very shortly for transient analysis. The Norden program for nonlinear d-c analysis is used in place of the d-c analysis section of ECAP. It was developed in response to user complaints on the lack of nonlinear capability in ECAP.

Other computer-aided design techniques are in use or in various stages of development as part of Norden's over-all computer-aided design system. These include programs for component placement, wiring conventional circuitry and one for computer-aided design of integrated circuits.

standard deviation for node voltage v. The term $\partial v/\partial P_i$ is the partial derivative of the node voltage with respect to the i-th parameter and σP_i is the standard deviation of the i-th parameter. The formula is valid only for small excursions about the nominal values of the node voltages, but requires less input information on parameter distributions and far less computing time than a more sophisticated Monte-Carlo analysis. The outputs of this analysis are the standard deviation, variance and the 1-sigma and 3-sigma limits for each node voltage. The 1-sigma limit is obtained by adding the standard deviation to the nominal value of the node voltage, with the corresponding operation for the 3-sigma limits.

Examination of the outputs indicates whether circuit voltage excursions due to parameter variations will remain within specified limits. The "breakdown of variance" printout lists the percent contribution of each parameter to the variance of the node voltage and shows which parameter tolerances are most critical. These are obtained by dividing each parameter in the propagation of variance formula by the total variance, σ_v^2. By scanning the printout for a particular node, the designer can find the parameters that cause most of the variance.

Conversely, it is possible to determine the parameter tolerance that yields a desired value of variance for a particular node voltage. With this information the circuit is easily optimized with respect to design centers and parameter tolerances. This reduces the amount of overdesign that often occurs when only sketchy information is available for parameter tolerances on circuit performance.

The last optional routine in the sample problem is the "Mandex worst-case analysis." This analysis is helpful where large tolerance extremes are encountered. The approximate solution obtains worst-case limits by summing the contribution of each parameter tolerance to the worst-case limit. The formulas are

$$\Delta_v = \sum_{i=1}^{N} \frac{\partial v}{\partial P_i} \Delta P$$

$$V_{wc} \approx V_{nom} \pm \Delta V$$

where V_{wc} is the worst-case limit, and ΔP is the parameter tolerance expressed as the tolerance extreme minus the nominal value of the parameter. The solution breaks down for nonlinear circuits with large parameter variations because the partial derivative is not constant throughout the range of the variation.

The Mandex analysis obtains a new nominal solution with all parameters set to their tolerance extremes. It requires more computer time to obtain the worst-case limits but gives more accurate results.

A Mandex analysis was run for node 5 in the sample problem and the results are tabulated. The analysis is made first for node 5 at its high (maximum) value and then for the low (minimum) value. The values for all the node voltages are given along with the stress, transistor and diode analyses. This additional information may show overstressed components even for the node voltage that is within worst-case tolerance limits.

A comparison of the approximate worst-case minimum and maximum values with the Mandex high and low values for node 5 is:

Node 5

	Mandex	Approximate	
High	−22.54	−22.54	Maximum
Low	−22.57	−22.55	Minimum

The small tolerances on the circuit's parameters caused the node voltage is almost identical for both analyses. This would not be the case, however, if the tolerances had been large, i.e. 10-20%.

It should also be noted that the Mandex analysis for the low value on node 5 shows that transistor 2 has changed state, whereas no indication of this was given in the approximate analysis.

Communication—still a stumbling block

One of the biggest bottlenecks to the efficient use of circuit analysis is man-machine communication. Normally several computer runs are required per circuit to correct input errors and to investigate the effects of design modifications. With each computer run the user must contend with delays associated with the mechanics of getting a job run. Also, it is difficult for him to gain insight into a circuit's operation by looking at printouts.

Norden is planning to add on-line graphics to its circuit analysis programs. This will enable the user to correct input errors and make modifications directly with a light pen on a cathode-ray-tube display console. Thus, as fast as the modifications can be made they will appear as program outputs displayed directly on the crt. With the display console time-shared with the central processor, the computer can be doing other jobs while the user is observing outputs on the crt and deciding what to do next. Time sharing will make on-line operation economically feasible.

An experimental version of ECAP with on-line graphics has already been developed at IBM. Thus, the trend to graphics combined with circuit analysis programs is already started.

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Integrated circuits in action: part 5
In search of the ideal logic scheme

Dilemmas galore confront the uninitiated designer trying to pick the logic form that is best for his application

By Donald Christiansen
Senior editor

The history of the integrated circuit is a short one but already many logic schemes have been proposed and a score of them have been fabricated. Trying to make sense of the mishmash has caused sleepless nights for the prospective user of IC's.

Circuit experts, on the other hand, maintain things are a good deal simpler than they appear. For example, if consideration is restricted to bipolar gate topologies, they note, there are just three basic forms of IC logic schemes. They are: collector-coupled, input-coupled inverter, and emitter-coupled logic. The types are also known as current sourcing, current sinking, and current mode, respectively.

Sourcing and sinking

In those types of logic classified as collector-coupled or current-sourcing, current flows from the output of a circuit and is forced into the input of a similar circuit to activate the circuit which it drives.

Input-coupled or current-sinking logic types on the other hand, require that current flow out of the input of a circuit and back into the output of the preceding stage, which serves as a current sink instead of a source.

Finally, current-mode logic circuits can be either sink or source types. The salient point is that such circuits switch logic levels by assuming one of two active current modes. The circuits have common-emitter inputs and emitter-follower outputs.

Easy way in

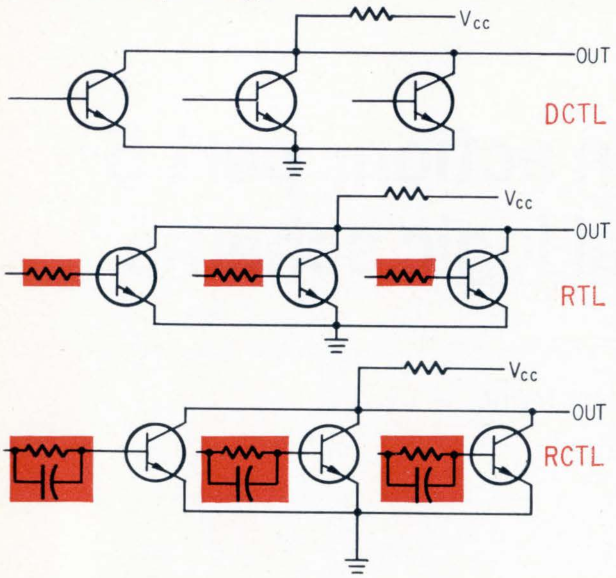
When IC designers first began building logic devices, they took the path of least resistance, converting directly from well-known and widely used discrete component logic schemes. One of the earliest formats was direct-coupled transistor logic (DCTL), shown in the schematic on page 150, a basic form of collector-coupled logic. An advantage of this logic is that power dissipation is low, but current hogging by one of several transistors which it is attempting to drive limits its usefulness. To overcome this shortcoming, the logic was modified by adding either resistor or resistor-capacitor coupling networks. The resulting circuits were resistor-transistor logic (RTL) and resistor-capacitor-transistor logic (RCTL), shown in the schematics on page 150. RTL was popularized by Fairchild Semiconductor, a division of Fairchild Camera & Instrument Corp. in its Micrologic lines. Texas Instruments Incorporated made its debut into the IC field with its Series 51 RCTL line. RCTL differs from RTL chiefly in the use of small speedup capacitors across the input resistors. The resistors in commercial RTL circuits are significantly smaller than those in RCTL circuits, and the signal swing for RTL is about a volt compared to 6 volts for RCTL. As a result, the problem of noise rejection is more serious in RTL, though it can be improved at the expense of fan-out.

Less noise

Attempts to improve noise margin resulted in the development by the Signetics Corp., a subsidiary of the Corning Glass Works, of the first input coupled logic scheme, diode-transistor logic (DTL), whose basic schematic is shown on page 150. In this circuit, R_3 and C form a dynamic battery whose purpose is to set the input threshold level of the gate.

Usually R_3 and C are replaced by one or more diodes. What is sought is a fast turnoff of Q_1. Therefore, the coupling diodes should be charge-storage diodes (unlike the input diodes). Since the two types of diodes are hard to achieve in a mono-

Collector-coupled logic



Collector-coupled or current-sourcing logic types include, from top to bottom, direct-coupled, resistor-coupled, and resistor-capacitor coupled transistor logic, abbreviated DCTL, RTL, and RCTL, respectively. The resistors in RTL overcome current hogging, while the RC input in RCTL avoids current hogging and, theoretically, improves speed.

lithic IC, a separate power supply is used, connected to the bottom of R_3, to provide turnoff drive at the base of Q_1.

Amplification can be built into the DTL gate, as shown in the circuit schematics on this page. The circuit at the lower left was introduced by Fairchild in 1964. The extra stage drives Q_2 hard, and also permits the use of loose tolerance resistors. Pull-down-resistor R_4 is grounded, avoiding the need for the second power supply. Q_1 is kept out of saturation by returning its collector to a resistor divider.

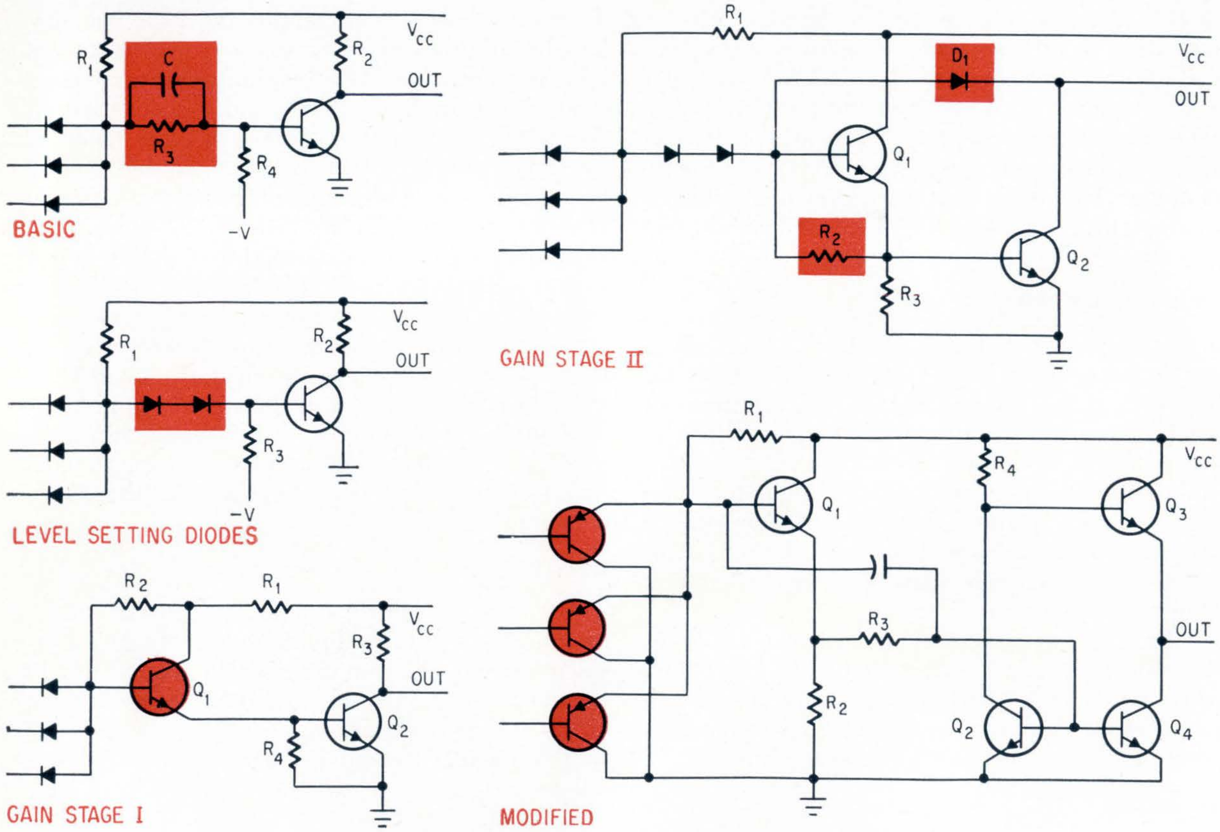
In the next version, Q_1 and R_3 form an emitter follower to give the input current amplification. R_2 improves transient response while diode D_1 compensates for load variations.

Alternate routes

A three-way contest to fabricate the first practical low-cost DTL IC's resulted in three different approaches. Signetics and Fairchild built versions by triple diffusion and double epitaxy, respectively, while TI fabricated the "modified DTL" circuit shown directly below using triple diffusion (its Series 53 line).

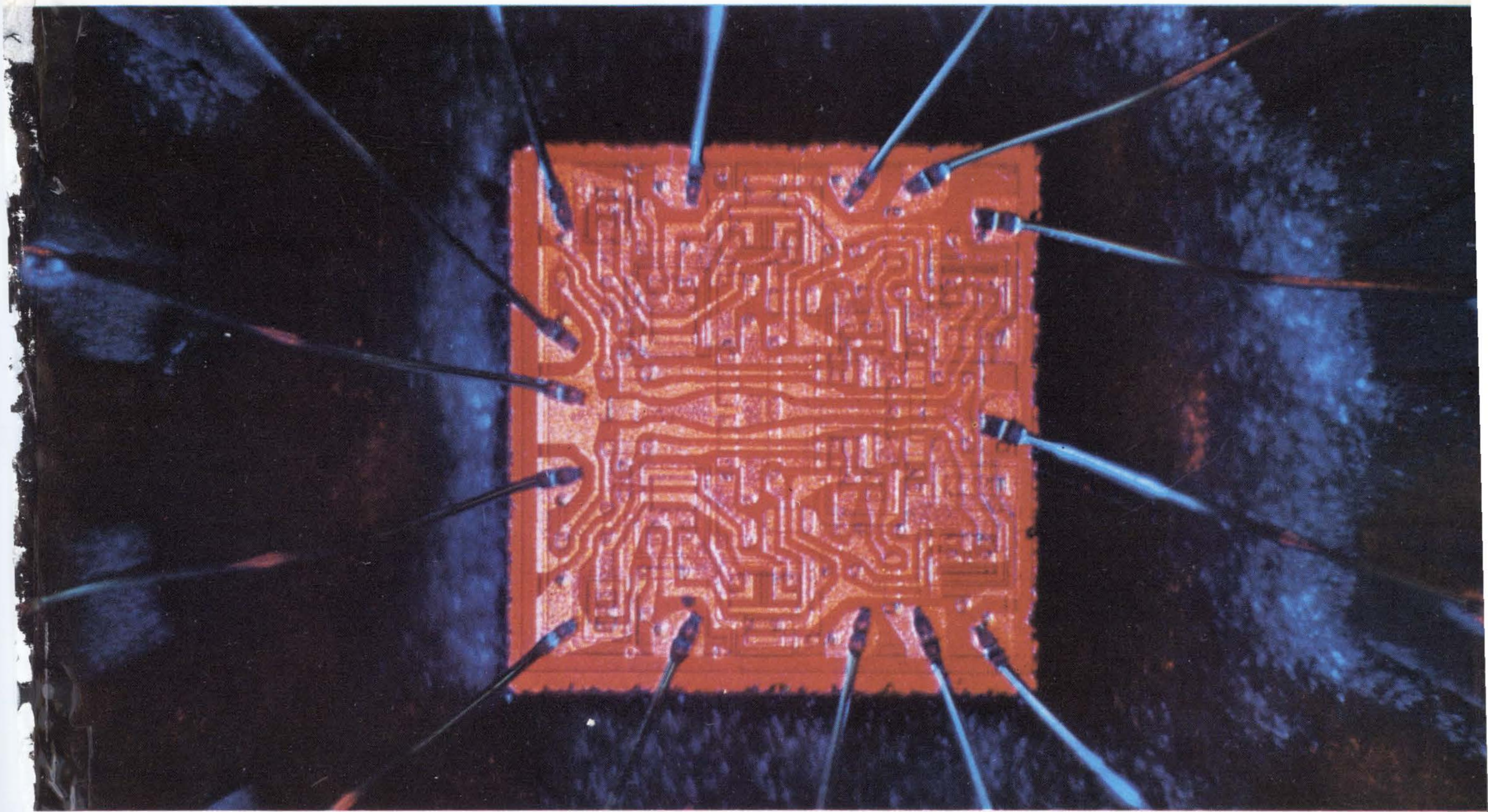
In spite of its name, the modified DTL actually contains no diodes at all. Instead it has both npn and pnp transistors, leading some circuiteers to

Input coupled logic: DTL

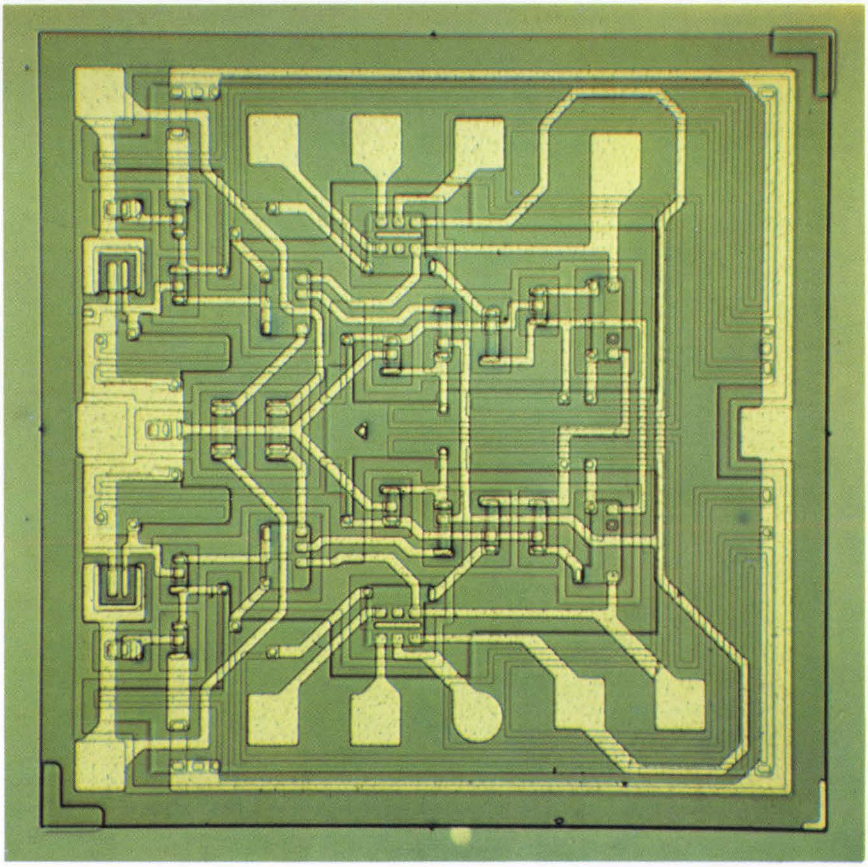


One form of input-coupled or current-sinking logic is based on diode-transistor logic (DTL). In the circuit at the top left, R_3 and C form a "dynamic battery" to set the gate threshold level. A pair of diodes replace the RC combination in the middle circuit and, below it, transistor Q_1 adds gain to boost the output voltage swing. At the top right, in another gain version, R_2 improves transient response and D_1 compensates for load variations. "Modified DTL" version at the lower right has pnp input transistors, no diodes.

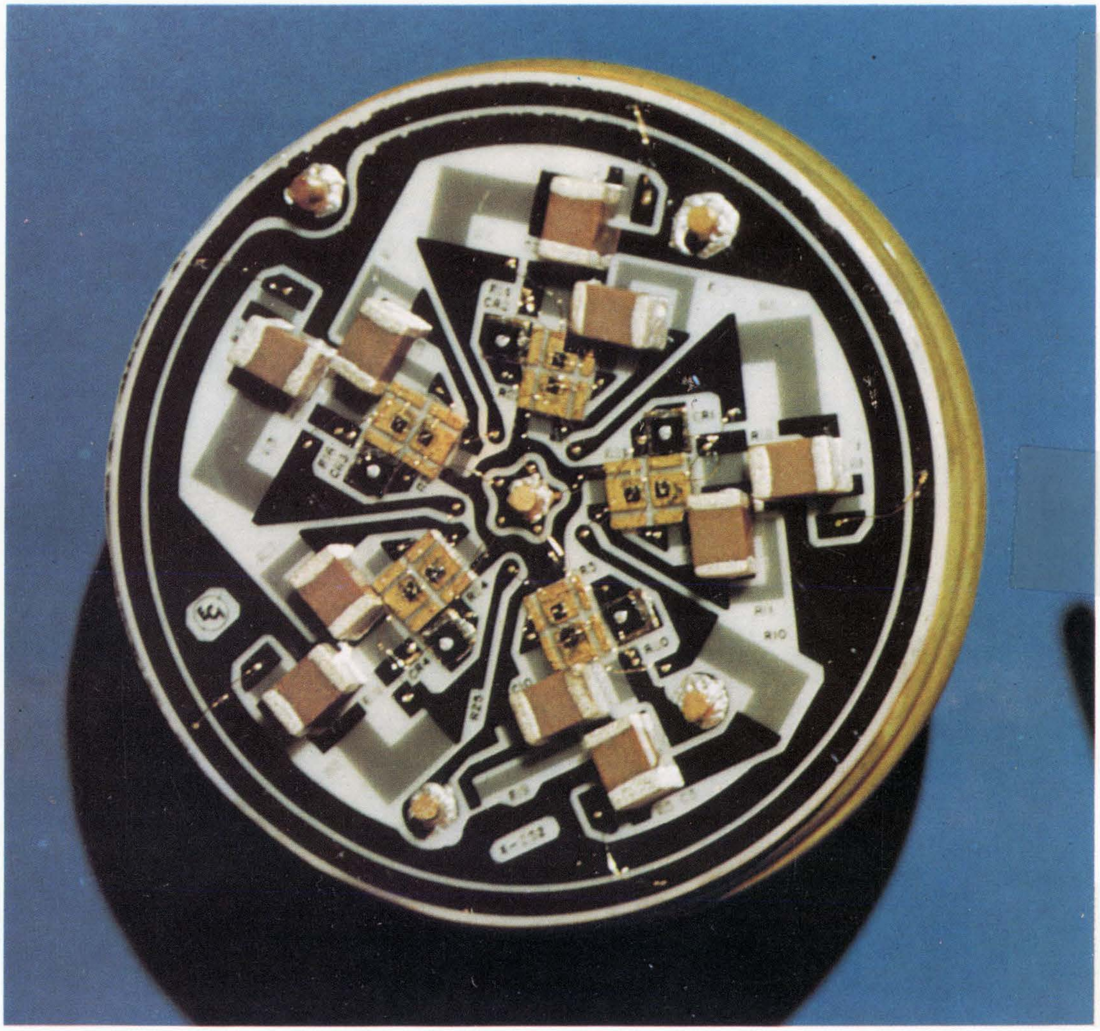
Flip-flops: designer's mainstay



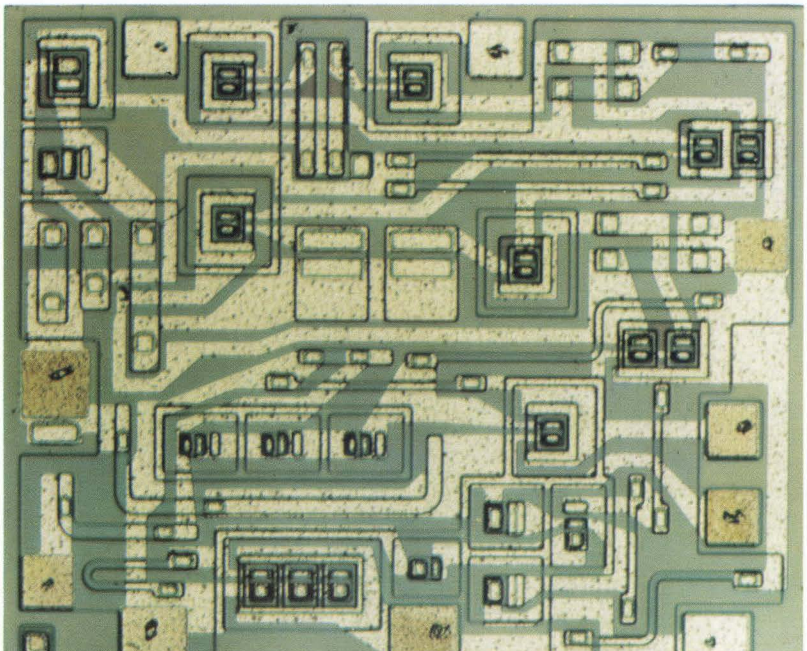
Dual J-K flip-flop contains 28 transistors, 38 resistors. The RTL device is a complete general-purpose storage element designed by Fairchild Semiconductor for industrial shift registers and binary counters.



Master-slave flip-flop in new low-power TTL line, series 54L, will be introduced by Texas Instruments at the IEEE show and convention.



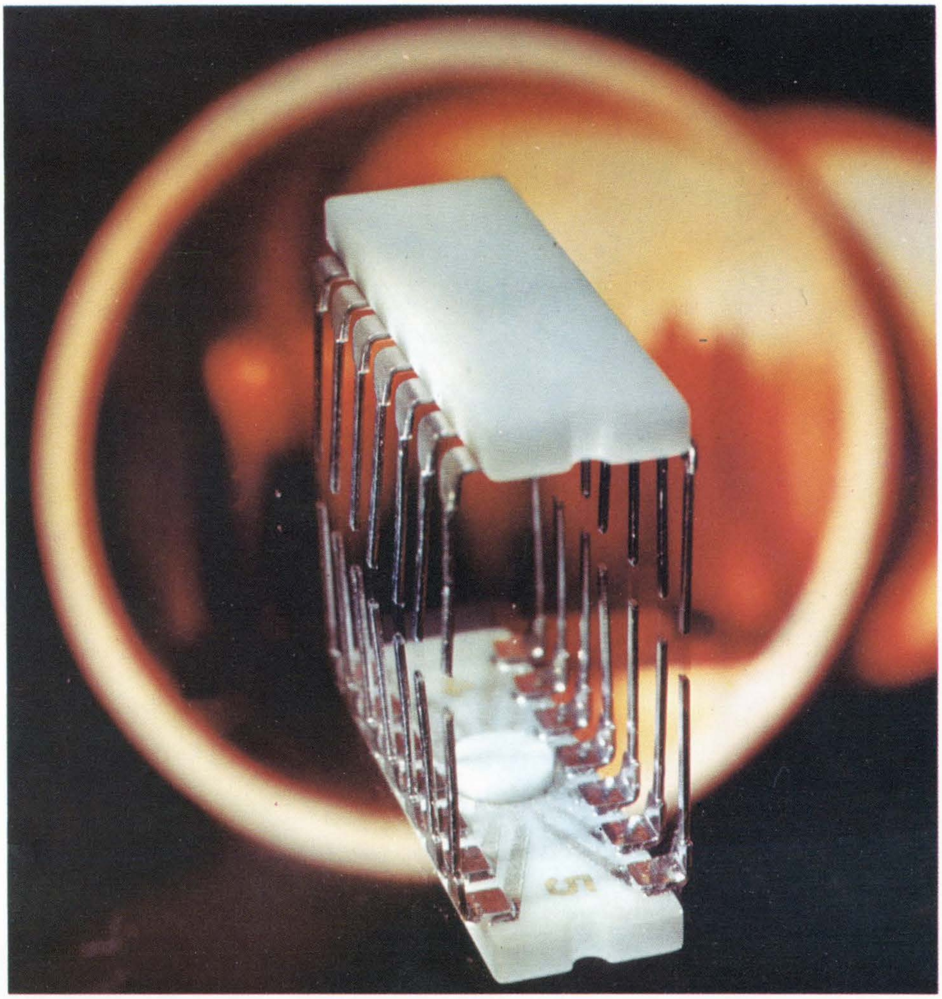
A divide-by-five ring counter has five current-mode switching stages, made in hybrid IC form by Electronic Communications Inc. for use in uhf digital communications system. The counter is used in pairs as a prescaler.

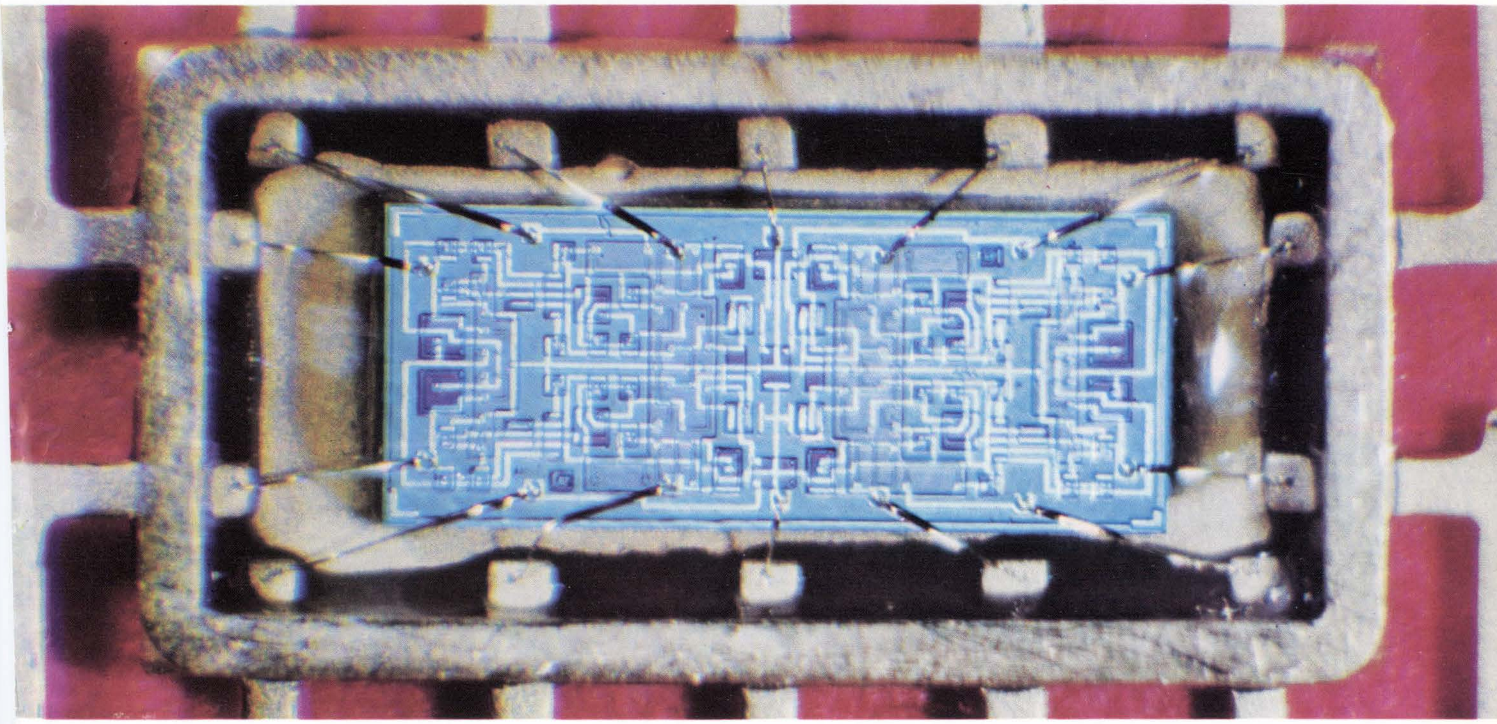


Modified-DTL, in which input diodes are replaced by transistors, forms the output of this monolithic sense amplifier. Built by Motorola Semiconductor for 0.5 μsec-cycle core memories, its high and low output levels are 5.9 volts and 0.35 volts, respectively.

Cracking the consumer and industrial markets

New ceramic dual in-line package containing DTL IC's will be exhibited by Fairchild at the IEEE show and convention. Circuit is contained on circular ceramic "button," bonded face down to join with fired-on lead pattern on underside of rectangular ceramic body. The package may help IC vendors reach avowed goal of supplying military-grade IC's at industrial and consumer price levels.

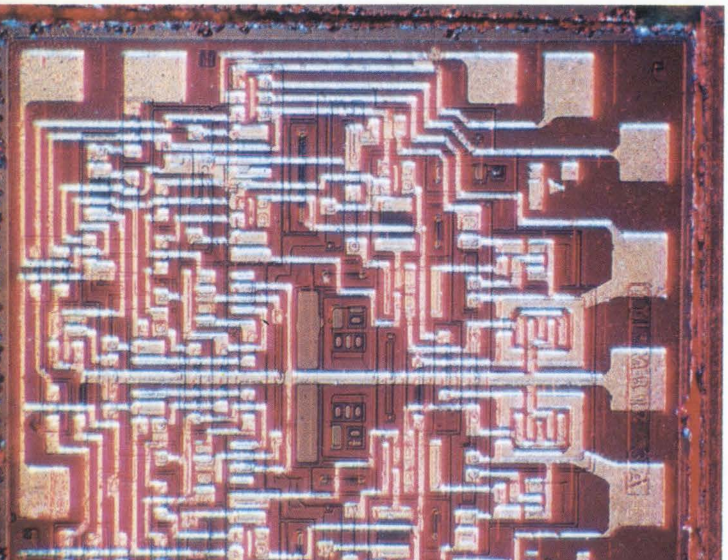




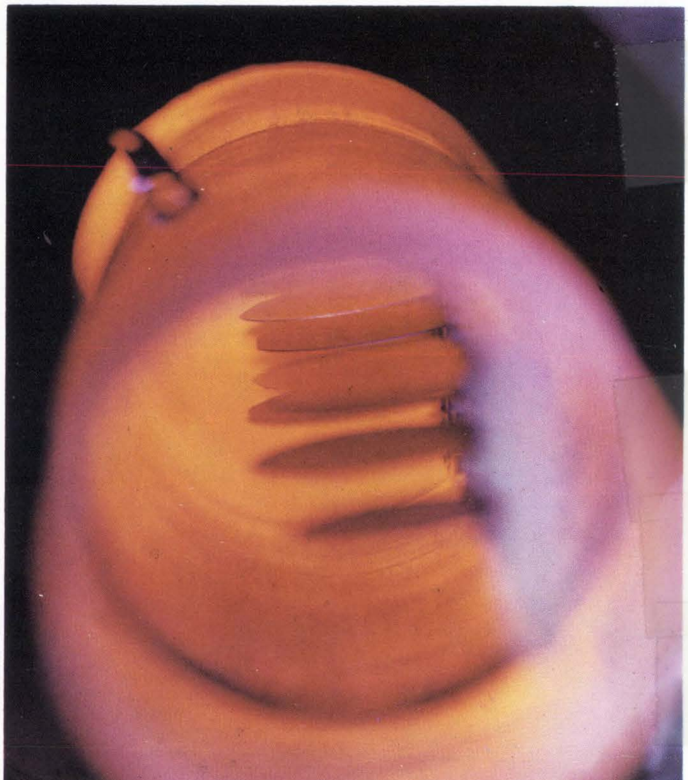
One of modified-DTL devices used in Cincinnati Milling Machine numerical control system is this dual J-K flip-flop, part of TI's series 73. Silicon slice contains total of 80 transistors, resistors, and capacitors.

Built-to-order digitals

Honeywell's Computer Control division designs its own digital IC's, fabricates and tests them before turning over design to outside vendor. Here a DTL device is mounted in a package in laboratory.



Rules of thumb in custom logic IC's like this one from Fairchild are: maximize functional circuits per unit area, minimize separate isolation areas, and use transistors in preference to passive elements.



Digital IC wafers undergo diffusion in Honeywell furnace.

label it, belatedly, complementary-transistor logic (CTL). The fan-out of the driving circuit is boosted by the pnp transistors. Q_3 is driven by Q_2 operating as a collector follower, and Q_1 provides extra gain, driving the succeeding stages through R_3 and permitting resistor tolerances up to 30%.

Low- or ZERO-level DTL output voltage is determined by the saturation voltage of the output transistor, and high-or ONE-level voltage is equal to supply voltage Vcc. Thus the voltage swing is basically large, leading to good noise immunity.

Of those logic types mentioned so far, DTL is unquestionably the most widely used.

TTL a comer

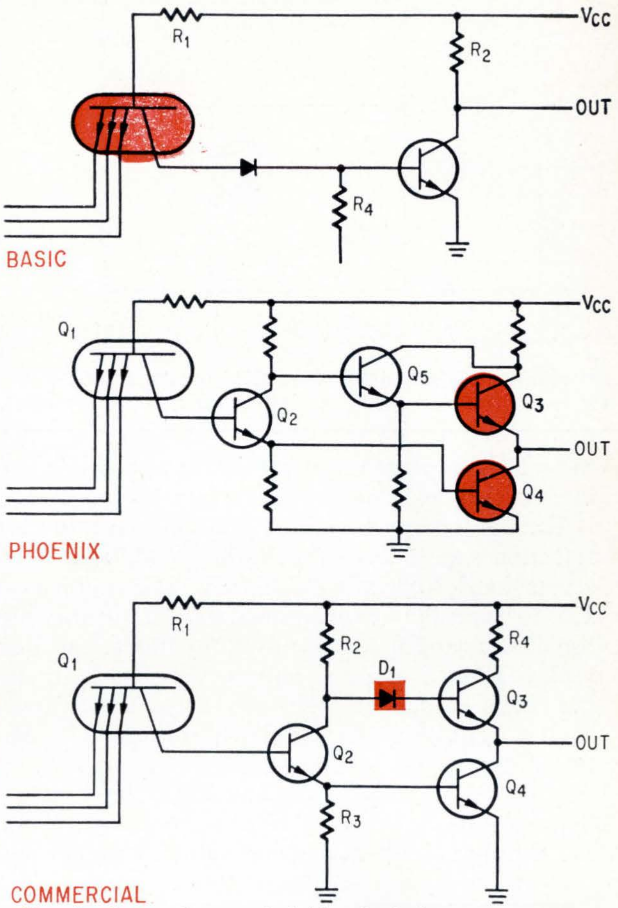
The logic type destined to become the workhorse of the industry, however, appears to be transistor-transistor logic (TTL), a direct descendant of DTL.

A shortcoming of DTL is that it is not fast enough for some applications. The input diode network and the first coupling diode of a DTL gate can be replaced by a multiple-emitter npn, top right. This decreases capacitance loading and as a result boosts speed. The resulting circuit is TTL (when first developed it was called transistor-coupled logic).

One of the early TTL circuits, dubbed the Phoenix gate because of its use by Litton Industries Inc. in the Phoenix missile, is shown at middle, right. In TTL, a low impedance path is developed through which Q_1 is discharged; after Q_1 is turned off, the collector of the multiple-emitter transistor effectively opens.

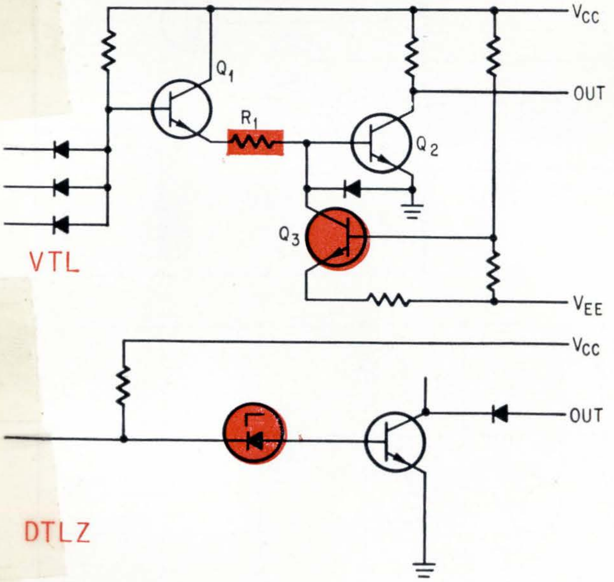
It is possible that high leakage of the multiple-emitter transistor may load a circuit excessively. To offset this, and to provide a charging current during both ON and OFF transient conditions under capacitive loading, the totem pole output stage is used. Totem pole refers to stacking Q_3 and Q_4; the output is thus driven through an active device during both rise- and fall-time, (through Q_3 and Q_4, respectively). Commercial versions of TTL are called high-level TTL because they provide a voltage swing of about 3 volts. Among them are the version produced by TI, Series 54, and the almost identical version shown above, made by the Sylvania Electronic Components Group, a division of the General Telephone & Electronics Corp., and the Transitron Electronic Corp. Note that the Darlington amplifier of the Phoenix gate has been omitted in favor of the single transistor Q_1. By avoiding the extra transistor and by altering the values of resistors, the manufacturers have reduced power dissipation

Input coupled logic: TTL

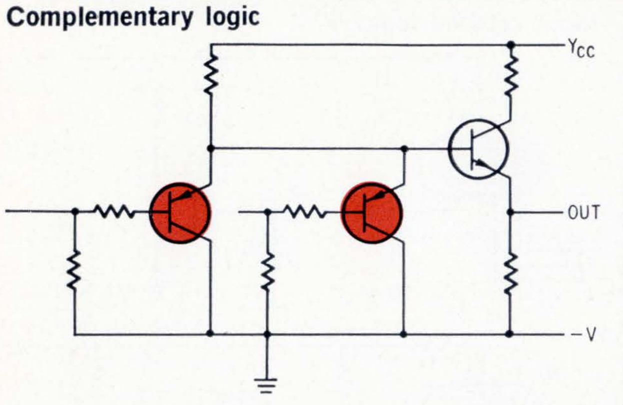


Popular form of current-sinking logic is transistor-coupled or transistor-transistor (TTL). Basic gate at the top shows how input diode network is replaced by multiple-emitter transistor at center, the Phoenix gate, with its totem pole output. Widely used commercial version at the bottom omits one transistor of the Phoenix gate to cut power dissipation.

DTL variations cut noise



Variable-threshold logic, at the top, in which supply voltages are set at high or low values to provide high or low noise rejection. R_1 replaces level-setting diodes of DTL, and Q_3 acts as constant-current source. Zener diode in the DTLZ circuit, below, replaces conventional diodes to boost noise threshold to about 6 v, but power and propagation delay zooms.



Complementary-transistor logic, CTL, needs current sink for low output level, current source for high-level output.

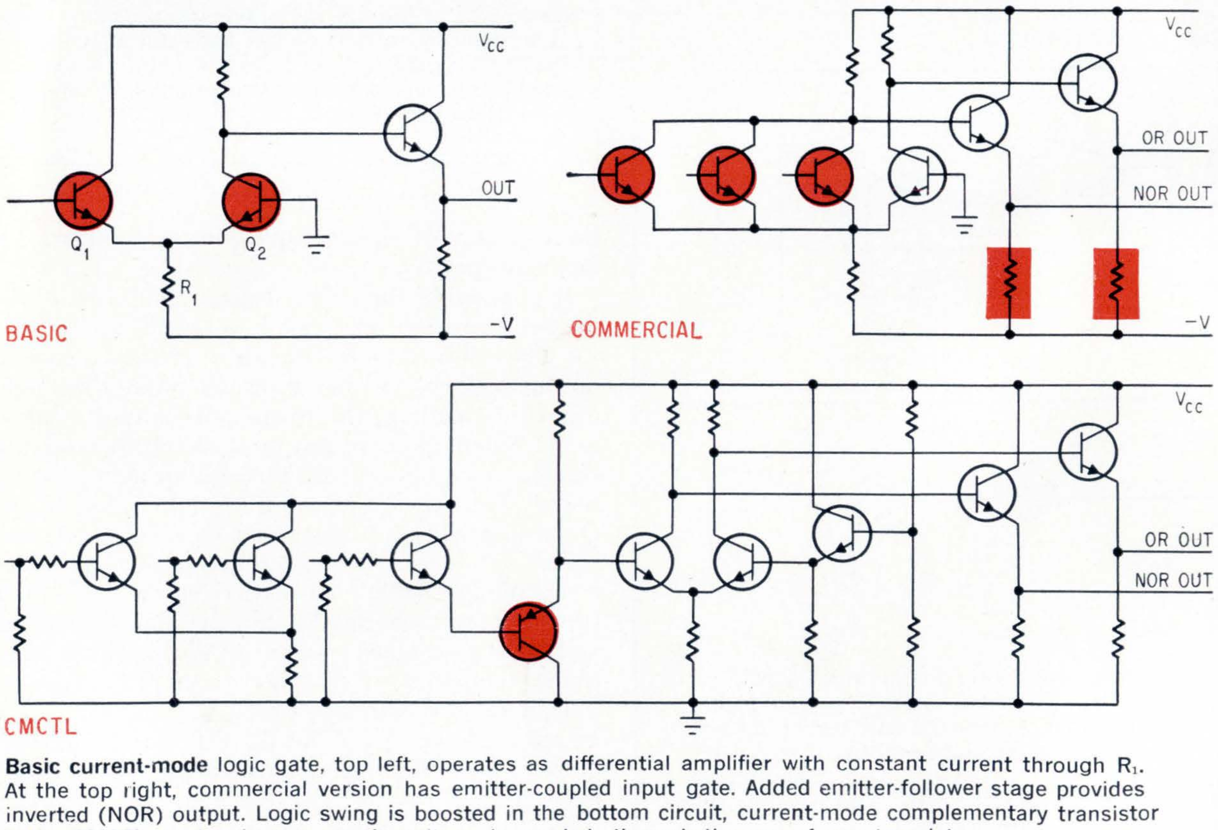
to as little as 10 mw per gate. Also, speed has been increased by making device geometries smaller.

For equipment demanding the optimum in noise rejection capability, variable-threshold logic (VTL) seems hard to beat. The circuit, shown on page 155, is basically a conventional DTL circuit in which the first coupling or level-setting diode has been replaced by a resistor, and in which a transistor has been added to serve as a constant-current source, replacing the pulldown resistor. The Motorola Inc.'s Semiconductor Products division developed the circuit. It provides a threshold voltage that can be selected within a range by setting the supply voltage at a given value. A higher supply voltage increases the current through the current-source transistor and the drop across it, which in turn boosts the threshold level.

A novel logic scheme was revealed last fall [Electronics, Nov. 28, 1966, p. 195] when AEG Telefunken of West Germany announced zener-diode transistor logic (DTLZ). The chief advantage of DTLZ is its high noise immunity. It is achieved by substituting a zener diode for the conventional level-setting diodes between the input diodes and the inverter stage, shown on page 155. In a conventional DTL circuit the threshold level—and thus the noise immunity across the two diodes—is about 1.2 volts. The drop across the zener diode, on the other hand, is about 6 volts, and noise threshold is boosted accordingly. The good noise performance is gained at a sacrifice in propagation delay and power dissipation. Telefunken sees applications of DTLZ in low-speed machine tool controls.

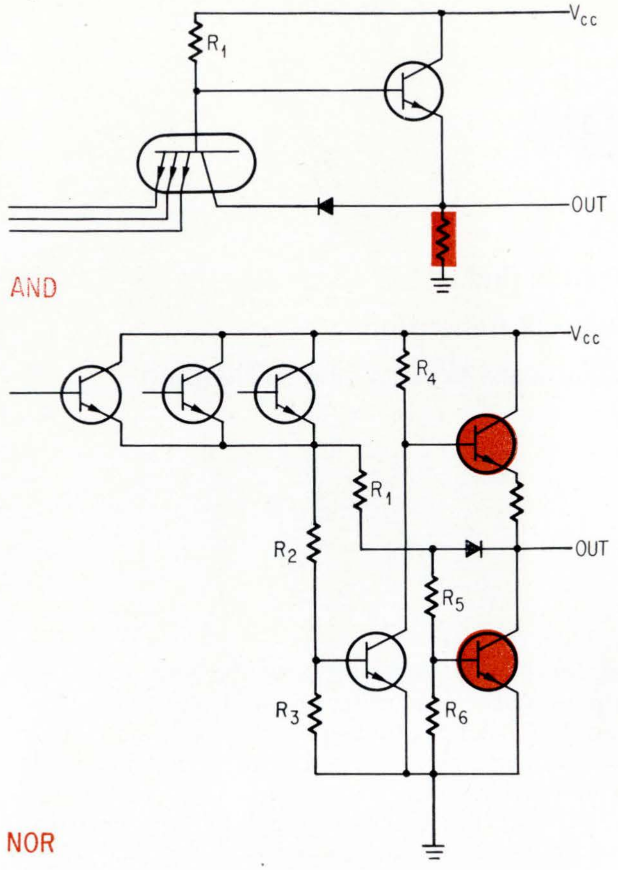
Currrent mode switching

The logic scheme that appears to have the greatest potential for high speeds is current-mode logic (CML). The significant feature of CML is its limited operating excursion which avoids both the cutoff and saturation regions. A current-mode differential amplifier and a constant-current source, shown below, form the basic circuit. If the input is high, Q_1 supplies the constant current through resistor R_1. Q_2 is shut off and the output goes high. Conversely, when the input goes low, Q_2 supplies cur-



Basic current-mode logic gate, top left, operates as differential amplifier with constant current through R_1. At the top right, commercial version has emitter-coupled input gate. Added emitter-follower stage provides inverted (NOR) output. Logic swing is boosted in the bottom circuit, current-mode complementary transistor logic, CMCTL, and only one supply voltage is needed, through the use of pnp transistor.

Hybrid method



AND gate, at the top, in "Utilogic" has noninverted emitter-follower output. NOR gate, at the bottom, has totem pole output, all npn transistors.

rent to R_1 and the output goes low.

Several transistors can be paralleled with transistor Q_1, forming an emitter-coupled npn gate at the input. The output will be the logic OR of the inputs or, if a resistor is placed in the common-collector circuit of the input and an emitter-follower stage added, as in the commercial version, illustrated on the opposite page, an inverted output (NOR) is provided.

CML is finding application in very high speed general-purpose computers. However its critics cite the need for multiple reference and power supply voltages and its relatively high power dissipation, particularly in lower speed applications.

Another deterrent to widespread use of CML is its incompatibility with all saturating types of logic.

One variation of CML is called current-mode complementary transistor logic (CMCTL). Its developers, Compagnie Europeene d'Automatisme et d' Electronique of France, claim very high speed, low package count and power consumption. The basic gate, opposite page, uses coupled emitters and a current-mode amplifier. The output is transmitted through emitter followers and the voltage level is restored by a current-mode amplifier. The circuit provides a logic swing of 1.1 volts and gives complementary logic outputs. Only one supply voltage is needed, and its tolerance need be no better than 10%.

Fairchild's complementary-transistor logic line (CTL or CTμL) can be classed as a current-mode type. Fairchild notes it was designed for use in simple circuit board or open transmission line systems. The inputs in the circuit, opposite page, require low voltage, a current sink to drive the output to its low level value, and a current source to drive it to its high level value. The pnp transistors, the company notes, have a low f_T of only about 30 Mhz, which helps avoid instability.

A problem encountered in some current-mode circuits, including CTL, is shifts in level due to a voltage gain of slightly less than unity. The result is an output voltage not quite equal to the input voltage, and after propagation of a signal through several stages, the logic level must be restored.

Hybrids

Not all designers believe that using a single logic scheme will necessarily provide the optimum system. The important thing, they point out, is to match logic levels, get the needed speed and keep power dissipation low.

Fortunately, there is good compatibility among saturating logic schemes. Fairchild Semiconductor has exploited this compatibility to pick and choose in order to come up with a line it calls compatible current-sinking logic (CCSL). The new line combines three families: TTL, DTL and low-power DTL. All are classed as current-sinking circuits, meaning circuits that accept current into their outputs from the circuits they drive. Each CCSL gate can drive or be driven by every other CCSL gate.

Signetics several years ago introduced a line of digital IC's called Utilogic.

Utilogic is a line built around a basic AND and a basic NOR circuit, displayed at top left. The AND has multiple-emitter inputs while the NOR has emitter-follower inputs. Output for the AND is an emitter-follower and, for the NOR, a totem pole arrangement. In the NOR circuit, the threshold levels are determined by the ratios of R_2/R_3 and R_5/R_6. The NOR gate will drive capacitive loads efficiently. Notice the similarity of the NOR gate to the TI Series 53 "modified DTL" line. Some engineers label it a variation of Series 53—one that does not require complementary transistors. Since the emitter-coupled input gate is npn, it performs the OR function for positive logic. Hence this is a DTL modification that performs NOR logic instead of the usual NAND logic.

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Understanding IC logic

Designers of commercial devices are often hard put to find the IC's they need. When they do locate them, full comprehension of how they work is imperative because specifications are sketchy and misleading

By Robert Sanford

Babcock Electronics Corp., Aerospace Division, Costa Mesa, Calif.

Integrated circuits may indeed revolutionize the electronics industry but not without some costly mistakes caused by the misapplication of devices that result in less than optimum equipment designs. Furthermore, IC manufacturers jump at the chance to produce devices in high volume for the computer market, but logic devices needed in smaller quantities are hard to come by. One case is the true d-c J-K flip-flop, which is not available—though many vendors offer "J-K" devices.

Much confusion might be averted if manufacturers would more clearly characterize and label the devices they put on the market. One manufacturer, for example, offers a "quad 2-input OR gate" that actually has three 2-input AND gates and one 3-input AND gate feeding into a NOR gate. In the very same line, the manufacturer lists a multiple-input AND gate that really is an AND gate without inversion.

In fairness to the IC manufacturer, it must be admitted that occasionally the device is hard to define in a few words. A simple IC containing just a gate and a transistor inverter can perform OR, NOR, AND, NAND, or inverter functions, for example.

The solution is to take a cautious view of IC labels. The user must arm himself with a knowledge of the functions that different types of logic circuits can perform. Then he can examine an IC logic diagram, or better yet, its detailed circuit schematic to determine what a particular device contains and what it can do.

Terminology

The basic function performed by npn current-sourcing logic types such as RTL, DCTL, and RCTL (see circuit schematics on page 150) is the NOR function, for positive logic. Positive logic means that the voltage level assigned to the ONE state is more positive than that assigned to the ZERO state. In the NOR function, if any input is in the ONE state, the output is in the ZERO state; all inputs must be in the ZERO state for the output to be in the ONE state. The NOR gate may also be viewed as an OR gate followed by an inverter.

The basic function performed by npn current-sinking logic types such as DTL and TTL (see schematic on page 150) is the NAND function, for positive logic. If any input is in the ZERO state, the output is in the ONE state; the output is ZERO only if all inputs are in the ONE state.

A point worth noting is that an inverting transistor stage can be tacked on to either type of gate to reinvert its logic: that is, a NOR gate becomes an OR gate or a NAND gate becomes an AND gate.

A gate which performs the AND function for positive logic performs the OR function for negative logic; and a gate that performs the NAND function for positive logic operates as a NOR gate for negative logic. Negative logic describes the situation in which the voltage level representing the ONE state is less positive than the level representing the ZERO state.

Many data sheets list NAND/NOR gates; a particular device will perform as either a NAND gate or as a NOR gate, depending solely on the logic rules used.

Before IC's, the computer industry was disposed strongly to the use of NOR logic. It was built in the form of direct-coupled transistor logic (DCTL), resistor-transistor logic (RTL), and resistor-capacitor transistor logic (RCTL). Several manufacturers offered discrete NOR packages, mostly RTL, because they were inexpensive; the computer manufacturers purchased one type of package, from which any system was built.

Early digital IC's were simply monolithic versions of one of the three NOR logic schemes. Eventually, RTL prevailed and many of those devices are still in use where low power consumption is important.

When monolithic diode-transistor logic (DTL) was introduced it copied discrete NAND circuitry, and began the present emphasis on NAND devices.

Easier than it looks

Any system can be built up from OR and NOT (NOR) circuits or from AND and NOT (NAND) circuits. A case in point is the Apollo program, which used NOR gates throughout in its first and second generation spaceborne guidance computers. Either scheme (NOR or NAND) uses inversion (NOT) in each gate. The inverter (a common-emitter amplifier circuit) provides power gain, which permits it to drive a number of other similar circuits. Thus it provides fan-out capability, or what is sometimes called logical gain. Furthermore, it serves as a logic-level restorer since its output is accurately determined by either its cutoff or saturation mode of operation, even though its input may range over wide values.

An ABC approach

Should the designer want to avoid a long, involved Boolean transformation, he may duplicate any natural AND-OR logic system using NAND circuits and inverters. NAND inputs are tied together or unused inputs are bussed to the positive supply or left open when an inverter is desired. An AND gate, for example, is made from a NAND followed by an inverter, above right. An OR is a NAND with an inverter ahead of each input, while an AND-OR combination is made from NAND's into another NAND. An OR-AND combination is more complex, requiring inverters working into NAND's, then into a NAND followed by another inverter. Fortunately, this combination rarely occurs in logic systems.

The AND-NOR function is available directly in several devices. A number of IC vendors provide such a device, page 160, with two 2-input AND gates into a NOR and call it an exclusive-OR gate.

A true exclusive OR provides a ONE output when one or the other but not both of its inputs is ONE. When the inputs are not of the same value a ONE output appears; similar inputs provide a ZERO. The AND-NOR device in question, on the other hand, provides the inverse; dissimilar inputs cause the ZERO output. Thus a better label would be "exclusive NOR." Furthermore, the device works only as an exclusive-OR if both inputs provide both regular and complementary signals, as in the diagram on page 160. If complementary signals are not available, two additional input inverters are required.

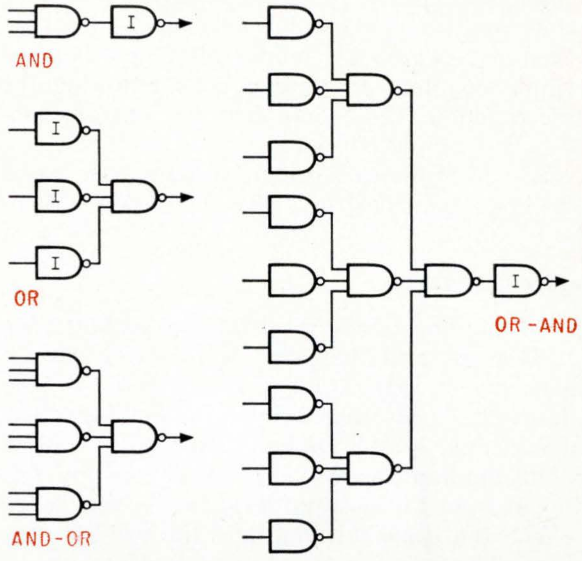
Fun with flip-flops

A flip-flop is essentially a pair of cross-coupled inverters in which a high output of one holds the output of the other low, and vice versa. A flip-flop remains in a stable state until externally triggered. Alone it is useless; its value is determined solely by its input gating. The simple flip-flop, page 160, is made from two NOR gates. The Q output is low and the $\overline{Q}$ output is high in the normal or ZERO state. The leading edge of a momentary positive pulse applied to either the S or P input turns the OFF side to ON, reversing the flip-flop. In this new state (the ONE state), Q is high and $\overline{Q}$ is low. A simple change in d-c level cannot be used as a trigger because it locks up the flip-flop against further changes; a pulse is a must. Reset to the ZERO state results from a pulse on the R or C lines.

While discrete-component flip-flops are a-c gated, IC flip-flops are normally d-c gated. A delay flip-flop is produced by adding a gating scheme like the one shown at the bottom of page 160. The basic flip-flop is shown as a simple rectangle. Complementary control levels are applied to the D inputs and the clock is normally low. A pulse on the clock line passes through the gate to which the higher control level is applied and changes the state of the flip-flop accordingly. If the flip-flop was already in that state, nothing happens. The d-c conditions applied to the control inputs appear at the outputs one clock pulse later, hence the name delay flip-flop.

If the clock line in the delay flip-flop is high or missing, the circuit reverts to the simple SET-RESET type. If the clock is present but the D inputs are both high or missing, the flip-flop is useless because it has an indeterminate state for each clock pulse. This is the outstanding disadvantage of a SET-RESET flip-flop when both inputs are applied simultaneously. The flip-flop does not toggle.

A universal approach



Using only NAND gates, such as in TTL circuitry, AND gate, OR gate, AND-OR, and OR-AND can be produced. For the AND, a NAND is followed by an inverter; in the OR, inverters precede a NAND; and AND-OR is made up entirely of NAND's; and the OR-AND is three stages of NAND's followed by an inverter.

Shortcomings

The simple SET-RESET flip-flop can be used in storage registers and in some control functions, but it is otherwise not very useful. Indeed, some SR flip-flops on the market are worse than useless, because they have an indeterminate stage for both

ONE's and the condition of both ZERO's is not allowed. The D flip-flop, on the other hand, is useful in both clocked and unclocked storage registers, in shift registers and, with sufficient D inputs, in clocked or synchronous counters. It cannot be used in ripple counters or other circuits requiring the toggle function. Most computer functions are handled by the simple D flip-flop.

Nearly all of the earlier logic systems were based on trailing-edge triggering, so many engineers consider it normal.

Trigger techniques

A d-c flip-flop is triggered by the leading edge and clamped until the pulse is removed. An a-c (capacitor-coupled) flip-flop is "cocked" by the leading edge and triggered by the trailing edge. Thus a positive level is applied for as long as desired and the flip-flop changes state when the input is switched from the positive level to the zero level. In effect, the capacitor translates the level change into a pulse.

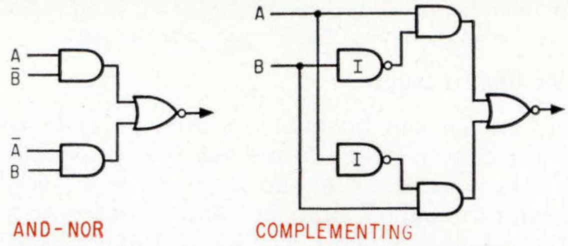
The diagram below, left, represents a true a-c J-K flip-flop. Note that the clock inputs of the a-c delay flip-flop are separated and labeled J and K. The D or control inputs have been externally connected back to the flip-flop outputs and are unlabeled. This is not the cross-coupling of the basic flip-flop. That cross-coupling is made inside the flip-flop box.

A J-K flip-flop is a SET-RESET flip-flop that has the additional capability of complementing itself if both inputs are applied at the same time. It has two separate inputs for SET and RESET, no clock or toggle input, and no other control inputs. If the two inputs are tied, the flip-flop becomes a toggle or complementing type; it is only in this sense that the d-c "J-K" flip-flops on the market today provide any J-K function. The additional control inputs are labeled J-K but are in reality only D and $\bar{D}$ inputs. When these inputs are used, the flip-flop does not operate as a J-K but is actually a D flip-flop. This point is of little importance in computer logic, since most computers are clocked systems. However, many control systems are unclocked and the available d-c "J-K's" require additional hardware and circuit trickery to make them perform the desired asynchronous control functions.

In the ZERO state of the true J-K flip-flop, the K input is gated OFF by the low output of Q, while the J input is not gated OFF because $\bar{Q}$ is high. An input on J changes the state to a ONE, reversing the condition of the input gates. At this point, only a K input will be effective, changing the flip-flop to the ZERO state.

Without the additional gates, the speed with

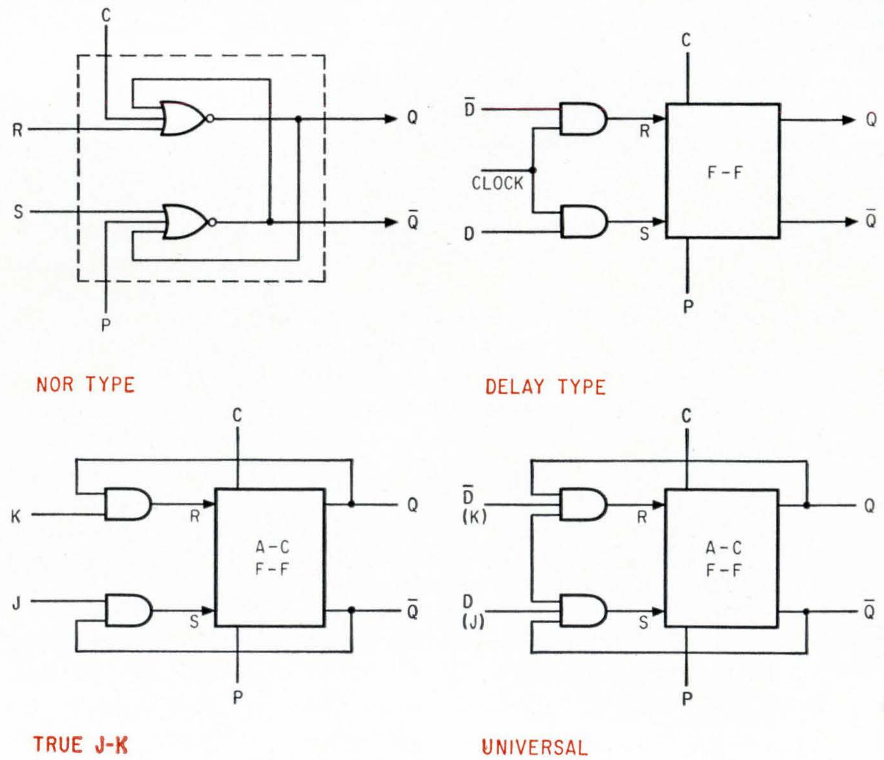
Exclusive-OR function



If the input and its complement are available, the AND-NOR gate (left) can provide the exclusive-OR function. If not, a pair of inverters will provide it.

Flip-flops

Two NOR gates make the simple set-reset flip-flop, top left. An auxiliary gating scheme, top right, turns it into a delay flip-flop. At bottom left, a "true" J-K flip-flop, and at bottom right, a "universal" flip-flop. The latter performs both J-K and delay functions.



which the a-c flip-flop can be SET and then RESET is limited by twice the transition time—the time required for a change of state—and by the width of the trigger pulses. Moreover, if both pulses are applied simultaneously, the flip-flop can't decide which state to assume. With the gates, however, the pulse width is not important because it is only the transition times of the trailing edges that count. If both signals are applied at the same time—either through coincident trailing edges or equal-width pulses—the flip-flop assumes the opposite state; it complements or toggles.

Universal circuit

If the flip-flop is modified by tying the J-K inputs to form a clock input, and additional control inputs are added, opposite page, an a-c "universal" flip-flop is formed. While similar in some respects to the D flip-flop, it has two differences. If the clock is high or missing, the D inputs become true J-K inputs that SET and RESET the flip-flop. If the D inputs are high or missing, the flip-flop toggles from a clock input. When additional inputs are added to the gates, this configuration is truly universal in application.

Unfortunately, not one single available d-c J-K integrated circuit flip-flop will perform the functions of the a-c universal circuit. They are, however, designed to perform the D logic function. And they will toggle if the D inputs are high or missing. They do not, however, perform the true unclocked J-K function. The essence of this is that "J" and "K" inputs of available d-c integrated circuit flip-flops are really only D and $\overline{D}$ inputs as far as functions go. The devices do have the additional capability of toggling but this is only one special use of the J-K function.

NAND not NOR

Most IC flip-flops are made from two cross-connected NAND gates rather than the NOR gates of the basic flip-flop, opposite page. The positive AND direct inputs are OR inputs for negative logic so most IC flip-flops SET and RESET on negative (toward ground) pulses from a normally high level. A few leading-edge flip-flops SET and RESET on positive pulses, however. Several devices can be used for other than their stated purposes. For example, one device labeled "two-phase SR clocked flip-flop" provides the D function, triggering on the leading edge of positive clock pulses. A second set of inputs provides SET and RESET functions for negative pulses. The device does not toggle.

Regardless of whether the direct SET (PRESET) and RESET (CLEAR) inputs require positive or negative pulses, the vast majority of IC firms offer so-

Using IC's: Trials and tribulations

While integrated-circuit manufacturers promote lines that are designed to eliminate all woes of the digital equipment designer, users express skepticism. Robert Sanford, author of the article, "Understanding IC logic," beginning on page 158, experiences frustration each time he begins work on a new logic system and finds that available IC's are woefully inadequate. Sanford, a senior digital engineer working on ECM systems for the Babcock Electronics Corp's Aerospace division, finds that unclocked asynchronous systems for the military don't always fit gracefully into the "computer scheme of things," where IC's are concerned.

No one series provides all the functions needed, he says, so most systems combine IC's from two or more lines. That's when the fun begins, Sanford reports, citing differences in logic levels, power supply requirements, fan-out, and input loading.

A pet peeve of Sanford's is the flip-flop. Most control flip-flops, he notes, are SET and RESET as opposed to toggle types—and this requires one-shots for pulse generators. A typical one-shot used by Sanford will set and reset a flip-flop made by another manufacturer, but it requires an additional inverter for use with flip-flops of its own line.

Frequently special logic schemes must be fabricated to circumvent the shortcomings of existing IC's. Designs could be simplified, Sanford notes, if the flip-flops were true J-K's that would respond to changes in level, instead of requiring trigger pulses.

William Rhoades, who wrote the article "Logic IC's don't live alone," starting on page 162, emphasizes that the IC must be considered as part of the over-all system. Equipment performance often rests more upon the interconnections than in the IC's themselves, reports Rhoades, who is a senior staff engineer in advanced techniques for the engineering division of the Hughes Aircraft Co. Rhoades is now evaluating high-speed IC logic circuits for general-purpose computer programs. Problems faced by digital system designers, Rhoades says, are turn-around time, cost of spares, and the time and complexity of field testing. If a true sequential test of a computer system were to be undertaken, one would not live long enough to see the end of the test, Rhoades points out. Furthermore, the test equipment in the field could be more complex than the system being tested.

How noise affects a system is another big problem. Both Sanford and Rhoades criticize the conventional ways that vendors characterize IC's for noise. Both deride the fictitious "switching point." Semiconductor junctions do not switch on and off like a light switch, Sanford points out. In a TTL gate, for example, any input voltage greater than 0.5 to 1.0 volt will cause partial conduction and a reduction of the output voltage from its ONE level. Usually the output transistor in a gate will be at the ZERO level when the input is above about 1.4 to 1.7 volts. Any input voltage between these limits will produce an indeterminate output voltage.

The real troublemaker is a-c noise—primarily switching spikes. But, Sanford says, the IC vendor is careful to avoid specifying a-c noise immunity. About all one can do, he says, is use large power busses—particularly for ground, clean up the power lines and use LC filters in the positive lead on each board—and hope.

called J-K flip-flops that toggle on the trailing edge of positive pulses, just like a-c flip-flops. This is accomplished through the use of a master-slave configuration. The leading edge of the clock pulse triggers a master flip-flop to the new state while gates prevent any change occurring in the slave flip-flop. On the trailing edge, the gates open and the condition of the master is transferred to the slave and the output. This permits "normal" logic and assists in the timing of clocked systems. Some devices exploit a charge-storage scheme where the pulse charges a capacitor (back-biased diode) and the trailing edge allows the charge to trigger the output flip-flop.

There are a few true J-K flip-flops manufactured in IC form but these are a-c (capacitor-coupled) flip-flops, having separate a-c inputs. One vendor offers a single flip-flop with separate a-c inputs. However, the same vendor sells two flip-flops in a dual package, each having an a-c clock input, single d-c J and K inputs, and a d-c RESET input; since that device offers no functions not available in d-c flip-flops, it is not a true J-K. Another vendor offers a "single-phase SRT triggered flip-flop" with separate a-c inputs. This permits true J-K operation when the steering (gate) inputs are connected back to the proper outputs, or D operation with the a-c inputs connected and the gate inputs used as D gates. Except for the limited cases in which separate a-c inputs allow true J-K operation, these a-c devices are not really useful because they do not provide enough gating functions.

Integrated electronics III

Logic IC's don't live alone

Their ultimate destination—the system—will affect their performance; better guidelines to selection are badly needed

By W.T. Rhoades

Hughes Aircraft Co., Fullerton, Calif.

The designer faced with picking the best digital integrated circuits must first know the system problems that restrict his choices. A familiarity with the causes underlying crosstalk, ground noise, mismatch of lines, capacitance loading, and power distribution permit him to exploit a few handy figures of merit in making a decision. [See "Criteria for circuit selection, page 164].

Noise confuses

Though noise margin is a key parameter of a logic circuit, the many ways it is specified makes it perhaps the least accurate parameter for comparing IC gates. Noise margin is best defined as the magnitude of the smallest extraneous input signal which, when added to the worst-case input level, causes an error in the following chain of logic circuits. The popular definition says it is the magnitude of input signal which causes the output of the gate to shift into an "uncertainty region." The weakness there is that the uncertainty region is itself uncertain—it can be defined by threshold points or by shapes of worst-case d-c and a-c transfer curves, and sometimes as the region in which gain is greater than unity.

Uncertainties encountered in measuring the transfer characteristics of single gates arise from variations in the characteristic from gate to gate, as well as from transfer characteristics having a slope that changes at several points. A technique that makes these factors insignificant is to measure the transfer curve across a pair of gates.[1] The technique, which is consistent with the definition of noise margin given above, provides a correct result but doesn't necessarily lead to the optimum noise margin. Where this is required, a technique such as "charge over threshold," to be described in a future article, is recommended.

Another important parameter is noise immunity, defined as the minimum noise margin divided by the maximum logic swing. Noise immunity dictates the types of IC interconnections. Gates having a noise immunity under 20% require shielded structures such as coaxial or strip lines. Noise immunity for typical gates, operating without a hysteresis effect, is about 20% to 30%.

Spurious signals

In a transmission network designed to connect digital IC's together in a logic system, coupling between nearby signal paths can raise havoc. For example, a signal passed through one transmission line can produce spurious signals at the terminations of adjacent lines. The spurious signals, called crosstalk, can be classified in terms of the ways in which coupling occurs: common impedance, electrostatic, and electromagnetic.

Factors that combine to make analysis of crosstalk difficult are:

- Interaction is usually not just between two but among many circuits of a transmission complex.
- The distributed, rather than lumped, nature of the inductances and capacitances of the circuits involved.

Nevertheless, there are precautions that can be taken to reduce crosstalk. For example, where two or more loads share a common line impedance such as in power distribution, a solution is to run separate lines to each load, or reduce the impedance common to both.[2]

When a line connecting two IC's is cut by magnetic lines of force generated by a nearby current-carrying conductor, an unwanted voltage will be induced.

Below 10 kilohertz, shielding, to be effective, must be done with ferromagnetic materials. Decreasing the length of the coupled lines is usually the most effective way to reduce crosstalk. Finally, changing the circuit parameters—such as increasing the signal-source impedance, decreasing the signal-load impedance, and decreasing the magnitude and frequency of the currents generating the field—may reduce coupling.

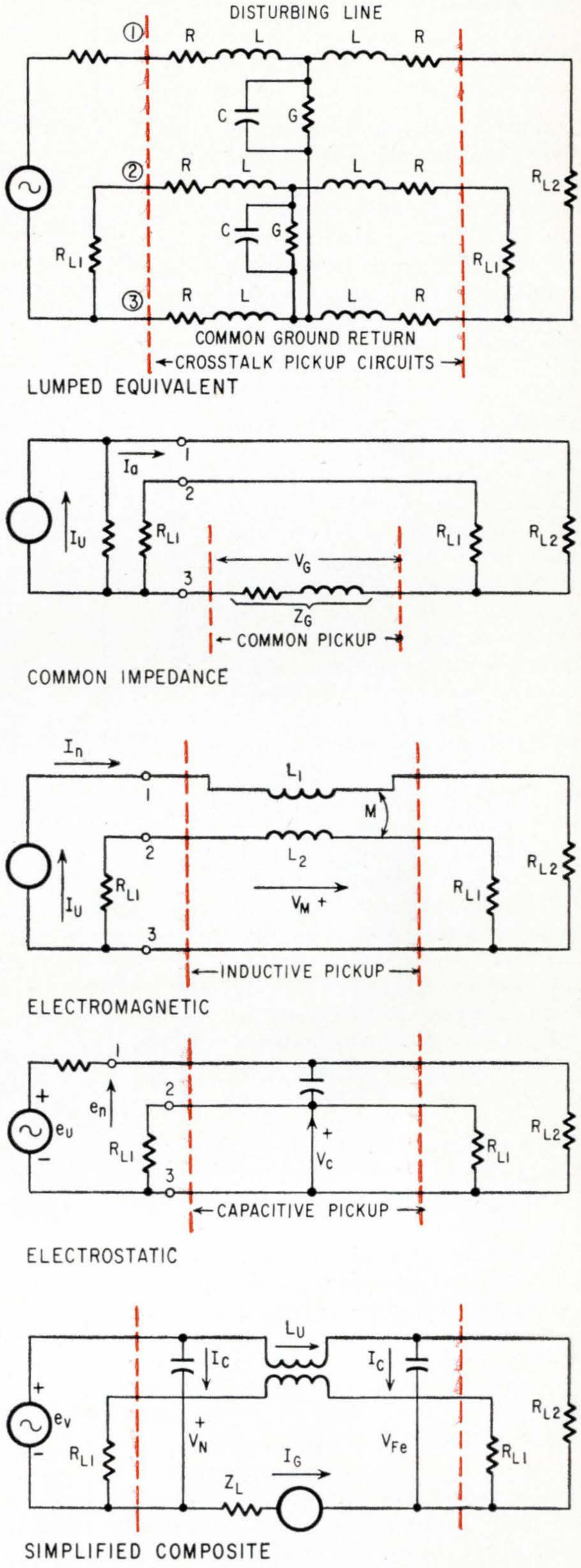
Electrostatic coupling

When two lines differ in potential, capacitive coupling can exist. The coupling current will result in a voltage drop in the signal load. An electrically conductive shield reduces the stray coupling, bypassing it to ground.

Unfortunately, the capacitances of the shield to ground are across the load and may be significant. If the shield is ungrounded and its potential is varied with the signal voltage, part of the capacitance is eliminated but the shielding effect is reduced.

Other ways to reduce capacitive coupling are standard: increase the distance between lines, decrease the dielectric constant between lines, and decrease the diameter and length of the conductors. The best choice is usually to reduce length, since the relationship of capacitance to spacing and diameter is logarithmic, and the dielectric constant is low to begin with. Helpful circuit changes include reducing voltage differences between close wires,

Crosstalk circuits



Equivalent circuit for a multiconductor system, top, accounts for common impedance, capacitive and inductive crosstalk. Next three diagrams show separate equivalent circuits for the three crosstalk sources, and the bottom circuit represents the simplified composite equivalent.

Criteria for logic circuit selection

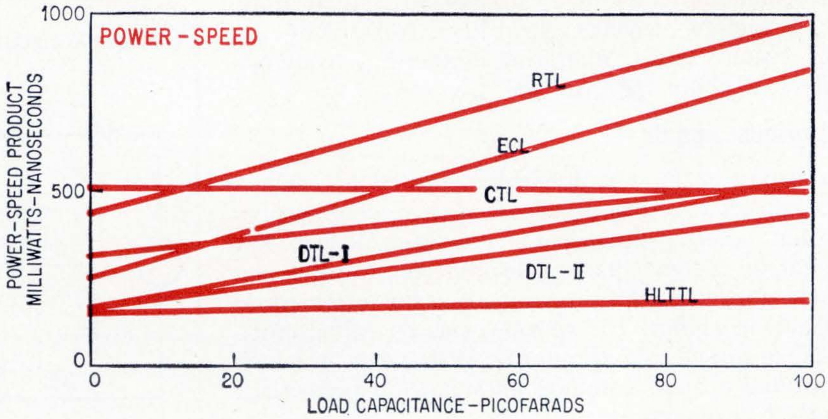
Integrated circuits for nonmatched designs can be selected on the basis of four figures of merit recommended by the author, aided by more conventional parameters such as circuit delay, power dissipation, and signal noise margin. The four suggested parameters are power-speed product, power efficiency, capacitance factor, and inductance factor.

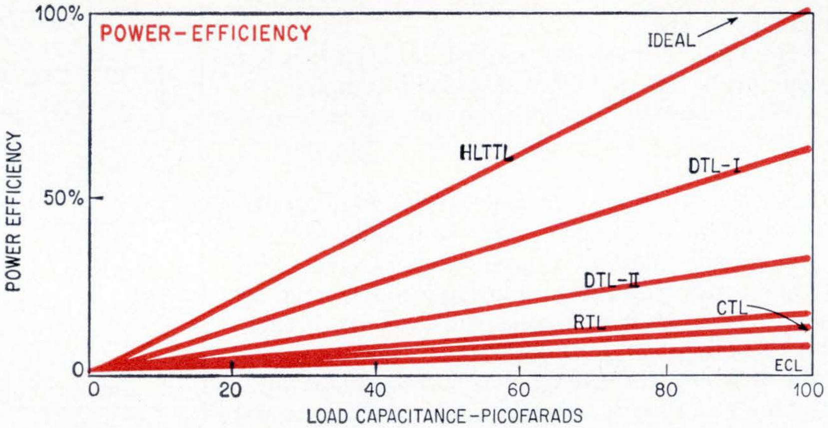
The first, power-speed product, is compared in the graph for variout logic types as a function of load capacitance. The power-speed product is determined for an integrated circuit by multiplying its propagation delay, t_c, by its power dissipation. One wants a low power-speed product, of course. Note that some curves cross, leading to the conclusion that a scheme may have to be selected with the particular load capacitance range in mind. For example, above 18 pf ECL has a higher power-speed product than CTL; below 18 pf, ECL is superior.

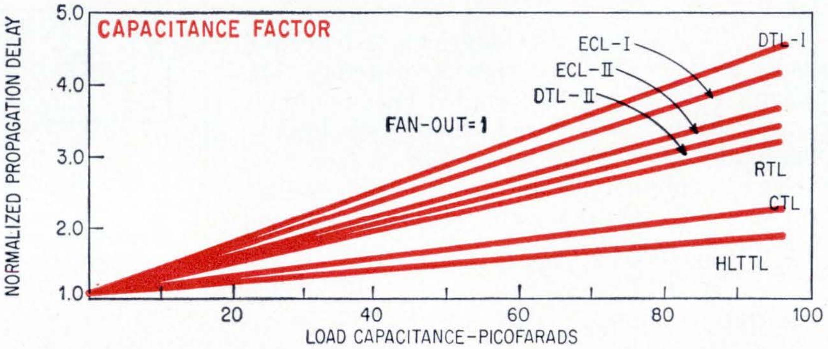
A second criteria, power efficiency, is defined as the ratio of propagation power (see page 165) to the total power drawn by the circuit. Power efficiency for six different gates is compared in the second set of curves, which shows that all gates have very low efficiency when the load capacitance is small.

The third figure of merit is capacitance factor, which is a measure of the immunity of a gate to capacitance loading. The third set of curves shows capacitance factor not directly but as the slope of the propagation delay versus load capacitance curves for a variety of logic types. The ideal capacitance factor would be zero, and would be represented by a flat curve. In the curves given, ECL-I and DTLI refers to devices made in a conventional way, whereas ECL-II and DTL-II are devices made with dielectric isolation between elements. [Inductance factor is described on page 165.]

The table compares the more conventional parameters for different lines of logic circuits, listed in order of propagation delay. Micropower IC's have been omitted from the table, as have certain other logic types aimed at special performance, such as variable threshold logic (VTL) which was designed to provide optimum noise margin.







Logic parameters compared

Logic type	Circuit delay (nsec)	Average power dissi-pation (mW)	Typical signal noise margin (mV) (25°)	Fan out
ECL	0.7	50	80	10
ECL	1.5	90	250	10
ECL	5	40	250	10
DTL	6	10	650	5
RTL	8	4	100	5
HL-TTL	8	18	1,000	20
HL-TTL	13	10	1,000	20
DTL	25	8	750	8
RTL	35	3	150	5
RCTL	130	2	200	5
MOS	500	15	3,000	5

lowering frequency and signal-source impedance and signal-load impedance.

Multiconductor systems can be studied through the equivalent circuit on page 163 representing two lines sharing a common ground return.[3] In that circuit, R, L, C, and G are distributed parameters per unit length.

The common impedance, capacitive, and magnetic crosstalk sources for multiconductor systems can be represented separately, as in the three diagrams on page 163. The composite equivalent circuit at the bottom shows how the crosstalk pickup voltages differ at the near and far ends of the circuit. The dominant crosstalk mode can be found by either measuring the polarity of the voltage on the coupled line or through calculation. If $M_P/C_P >> R_{L1}\ R_{L2}$, the inductive mode predominates, whereas if $M_P/C_P << R_{L1}\ R_{L2}$, the capacitive mode is dominant, and the appropriate equivalent circuit can be used. In the above expressions, M_P is mutual inductance and C_P is capacitive coupling.

More noise

Ground noise margin is the voltage that may be applied at the ground connection without causing the circuit to malfunction. It is usually measured by increasing the static ground voltage on a single gate until the logic fails to operate properly. By sweeping the ground both positive and negative while the input voltage, V_{in}, is set at the operating logic levels, the change in the output voltage can be observed as a function of ground noise.

A more accurate method of testing ground noise also makes use of a pair of gates. V_{in} is set at the worst-case logic levels, and ground voltage is increased on both gates—in the worst-case direction —until the output changes state.

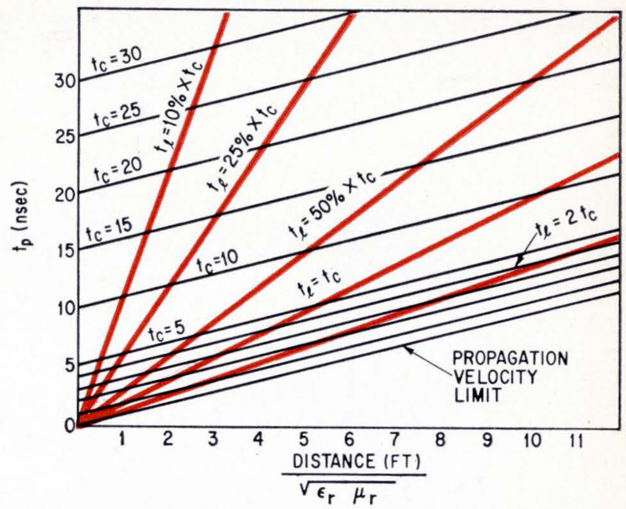
With ground noise margin known, one must determine how much ground noise will be developed. Ground noise is the sum of the voltage developed due to series inductance in the ground paths and the d-c drops. The latter voltages are often negligible, although they cannot be overlooked in high current circuits such as CML or in large-scale integration. Thermal effects also plague very high speed systems.[4]

A-c voltages developed in the ground path can be determined from the rate of change of current in the ground path and its inductance. The former, a function of the IC, is called the inductance factor. It is high in HL-TTL gates because of the totem-pole output and modifications of HL-TTL are sought to reduce it.

One can compare the permissible inductance dictated by noise margin of the circuit itself with that which would result from the use of specific transmission line formats. The table on the next page can be used to compute the latter.

Propagation delay

Two important sources of delay in a logic system are circuit delay, t_c, and delay caused by the media used to interconnect the circuits, t_l. Circuit delay,



Trade off between system logic delay, t_p, and interconnection lengths between IC's. Delay resulting from IC is t_c, while delay caused by the interconnecting media is t_l. The line lengths are normalized for relative permittivity and permeability of unity.

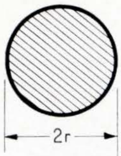
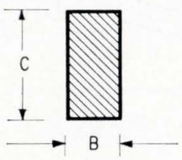
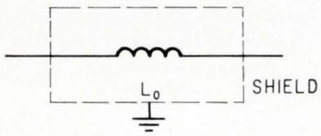
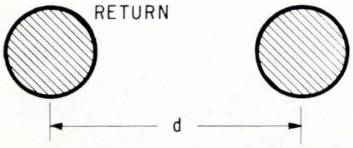
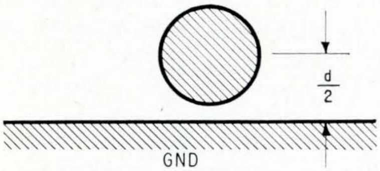
meaning propagation delay due to the IC alone, is usually expressed on IC data sheets as t_p, but we reserve t_p for the propagation delay (per logic decision) resulting from the circuit and its interconnections in a system; we call this "system logic delay." The trade off between the system logic delay and the interconnection lengths can be determined with the aid of the universal chart directly above. The chart is applicable to a matched signal transmission system. Its abscissa is the allowable line length normalized for relative permittivity and permeability of unity, so that allowable line lengths are reduced for media having constants greater than unity. The graph is general in that dividing or multiplying the abscissa by a scale factor divides or multiplies the ordinate and lines of constant t_c by the same factor.

It is important to recognize that t_c is not only constrained by t_p and t_l but it is also a function of the circuit design and loading. It is useful to introduce the concept of propagation power, P_p, and examine the thermal problems related to it. Propagation power is the absolute minimum rate of energy dissipation required to propagate logical information at the slowest permissible rate throughout a system. An ideal logic element would draw no power when it is not switching, and only propagation power when it is switching. Standby power is considered wasted, although it may be required to make the logic element work properly.

Consider a case in which the load R_L, and source impedance R_S are very large compared to the line impedance, Z_O. Propagation power can be found experimentally by measuring t_c as a function of load capacitance, C_L. Due to fixed propagation power available from the logic circuit, t_c increases as a function of some power of C_L (i.e., $C_L^{1/n}$ with $n > 0$, where larger values of n indicate greater propagation power capacity). In our example

$$P_p = (\Delta e)^2 C_L / 2t_p$$

Guide to calculating transmission line inductance

CROSS SECTION	INDUCTANCE L IN NANOHENRIES/ FOOT (ALL DIMENSIONS IN INCHES)	COMMENT
	$5.1\ell\left[\log_e \frac{2\ell}{B+C} - 1/2 + 0.22 \frac{\mu}{4}\right]$	FOR 10 AWG (0.1019 INCH IN DIA.) L = 373 nh/FT. - 4/0 AWG (0.46 INCH IN DIA.), L = 238 nh/FT
	$5.1\ell\left[\log_e\left(\frac{2\ell}{B+C}\right) + 1/2 + 0.22 \frac{B+C}{L}\right]$	FOR 1.5 X 1/4 INCHES, L = 227 nh/FT
	$L_o\left[1 - 2/3 \frac{V_c}{V_t} \frac{\mu o}{K}\right]$	FOR 1.5 X 1/4 INCHES, SHIELDED BAR, L = 74.3 nh/FT
	$10.2\left[\log_e \frac{d}{r} - \frac{d}{\ell} + \mu\delta\right]$	FOR AWG, AT 0.010 INCH SPACING BETWEEN WIRES L = 8.6 nh/FT
	SAME AS RETURN LINE	FOR 10 AWG, AT 0.005 INCH 4 ABOVE GROUND, L = 8.6 nh/FT

Specific transmission line formats will yield these values of inductance per foot. In the last six cases in the table, μ is assumed to be that of air, and no fringing is assumed.

where Δe is the logic voltage swing and t_p is the maximum allowable logic delay with $t_1 = 0$.

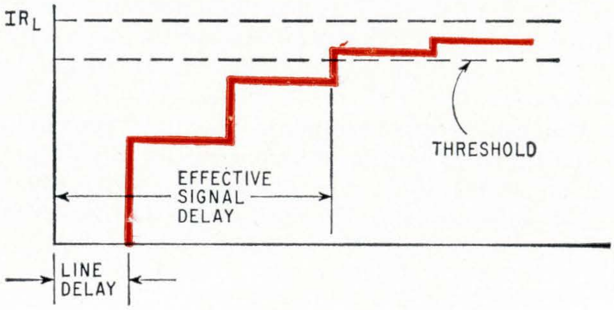
On the other hand, for a load that is matched to the line impedances the necessary propagation power is

$$P_p = (\Delta e)^2/Z_o'$$

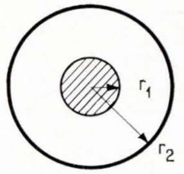
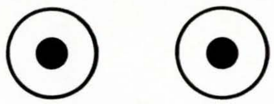
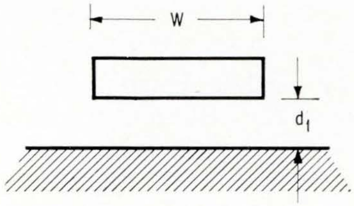
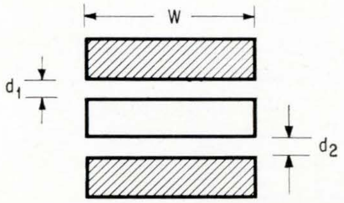
where Z_o' is the characteristic impedance.

In a matched system, one may have to increase the propagation power by a factor of 20. This usually boosts the power dissipation in the circuit due to poor power efficiency. A nonmatched system is advisable with available IC's. In such a system, the effective delay must, of course, be less than the required system delay. With large-scale integration, one can achieve system delays below one nanosecond under nonmatched conditions. In the nonmatched case the line will reach a stable value after several successive reflections have occurred. The effective signal delay will exceed the line delay, as illustrated at the right.

For example, if a gate drives 10 others, each of which has an input capacitance of 3.0 pf, the gates alone account for 30 pf. Assume that a 6-nsec increase in circuit delay can be tolerated and the specified logic delay can still be met; assume also a capacitance derating factor for the IC gate of 0.1 nsec/pf. The allowable added capacitance would then be 6 nsec divided by 0.1 nsec/pf or 60 pf. The gates contribute 30 pf, allowing 30 pf more for the line. The fan-out of 10 results in 11 connections; if each connection adds 1.4 pf, only 14.6 pf



In nonmatched system, line reaches stable value after several reflections. Curve shows how effective delay of signal is greater than line delay alone.

CROSS SECTION	INDUCTANCE L IN NANOHENRIES/ FOOT (ALL DIMENSIONS IN INCHES)	COMMENT
	$140 \log_{10} \frac{r_2}{r_1}$	FOR 10 AWG, AT 0.005 INCH SPACING L = 2.8 nh/FT
TWISTED PAIR 	SAME FORM AS THE COAXIAL LINE, BUT THE VALUES FOR THE ARGUMENT OF THE LOG FACTOR IS A FUNCTION OF TWISTS/FOOT	FOR 24 AWG, 19 STRAND TEFLON INSULATED, EE, 60 TWISTS/FT, L = 140 nh/FT
	$385 \frac{d_1}{W}$	FOR 0.75 INCH BY 0.002 INCH SPACING L = 1.02 nh/FT
	$\frac{385}{W} \frac{d_1 d_2}{d_1+d_2}$	FOR 0.75 INCH BY 0.002 INCH SPACING L = 0.51 nh/FT

is permitted for the line. The table at the right gives typical capacitance values per unit length of various types of unmatched lines, which are used to calculate allowable line lengths.

High-speed rules

For high-speed systems in which the effective delay must equal the line delay, fan-out methods can be a problem. For one thing, good matching is a must. Two popular techniques are the radial method, on the next page, and the tapped method, below it. In the radial approach, all inputs to the logic circuits must be matched to the transmission line. Also, the driver must drive an impedance of Zo/n, where n is the fan-out. Such an impedance can be undesirably low if n is large. Then too, a separate line is used for each load. This method is recommended only for n equal to one.

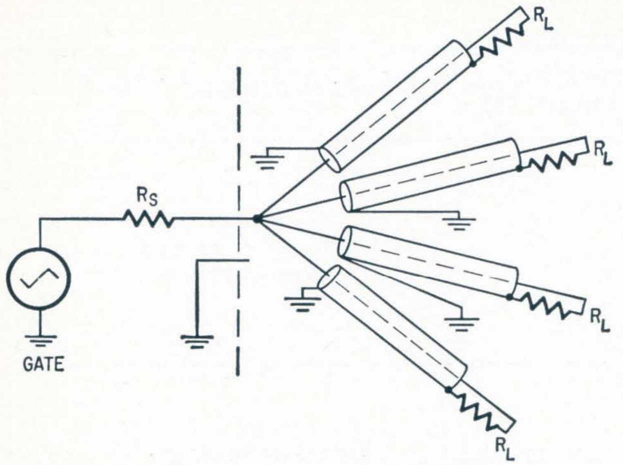
The tapped method requires very high impedance loads to prevent undue line loading.

A third method, the tree method, is recommended when $1<n<5$ since it provides matching at every point in the line. It also drives loads located in different directions (like the radial method). Yet it requires a smaller number of lines than the radial method and, for reasonable fan-outs, the driver output impedance need not be unusually low. If there are just two tree members, the driving gate may be placed anywhere along the line.

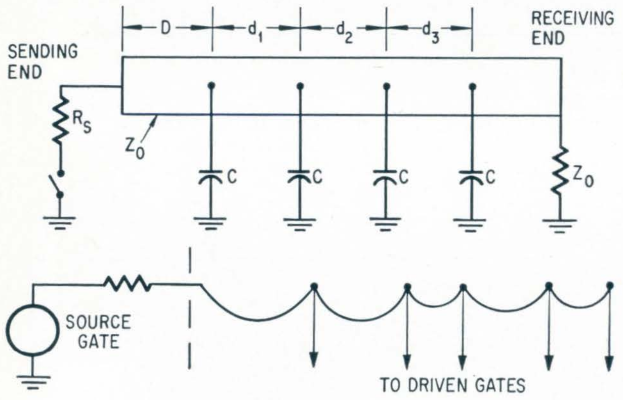
The radial method is superior in the case of ex-

Capacitance for various transmission lines

Type of line	Typical capacitance per inch (pf)
Microcoaxial	2.5
Microstrip	1.0
Strip line	1.79
Multilaminate	1.20
Flat flexible wiring	0.6
Twisted pair	1.10
Point-to-point	0.4
Conventional etch	0.5



In the radial fan-out method, inputs to the logic circuits must be matched to the transmission line.

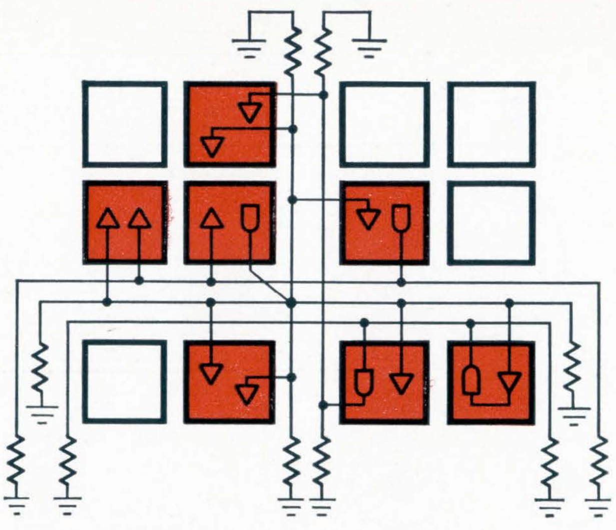


Tapped or daisy-chain fan-out technique requires high impedances to match the logic circuits.

tremely high fan-outs to loads having higher impedance than the line. The loads must also be lumped. If the loads cannot be lumped, the tapped method with controlled spacing between the lines is recommended. In this instance, one chooses the highest possible line impedance, tapping the loads at intervals, and treating the entire tapped line as a low-impedance artificial line. If the spacing between lines is greater than one inch, the tap locations can be found using time domain reflectometry; if the spacing is less than an inch, a computer-aided approach can be used.

Cut it short

One can both save space and reduce power by keeping leads short and doing as much wiring as possible within the circuit card or module. This could be extended to the IC itself, though this requires cooperation with the IC vendor at the conceptual stage, and suggests the use of multiple chips in a single package or large-scale arrays. In the tree method, one might elect to drive both horizontal and vertical lines that fan out to flatpacks, above right. In this case, the longest run within the module will probably be under 1.5 inches, and unmatched conditions are permissible. If a gate outside the module is connected to a single horizontal or vertical line in the module, however, it must drive a line impedance of $Z_0/2$. When circuits adjacent to both horizontal and vertical lines are to be driven by one gate, the driver sees an impedance of $Z_0/4$.



In this example of tree method, one gate is seen to drive both horizontal and vertical lines fanning out to flatpacks. All lines are terminated in characteristic impedance.

In practice, such low impedance levels are difficult to achieve without very high power dissipation, particularly when the propagation delay is below 5 nsec. An even more serious problem occurs when the line is required to turn a corner; the reflection which occurs at the corner can be prevented by matching techniques but it creates very difficult fabrication problems.

The dynamic impedance, not the static impedance, of a digital IC must be matched to the line or the load when using the tree method. Transition and diffusion capacitances, for example, can play a significant role in the impedance matching. In one typical case of four emitter-coupled logic flip-flops in a planar configuration, the average impedance of the load was 17.6 ohms during the transient, not the 1-kilohm value expected from static measurements. The transition and diffusion capacitances of the flip-flop caused the dynamic impedance to be low during the transient.

The flip-flop essentially slows down due to the deterioration of the input waveform. This is detected easily with time-domain reflectometry techniques, whereas with steady-state measurements, it would be virtually impossible to measure.

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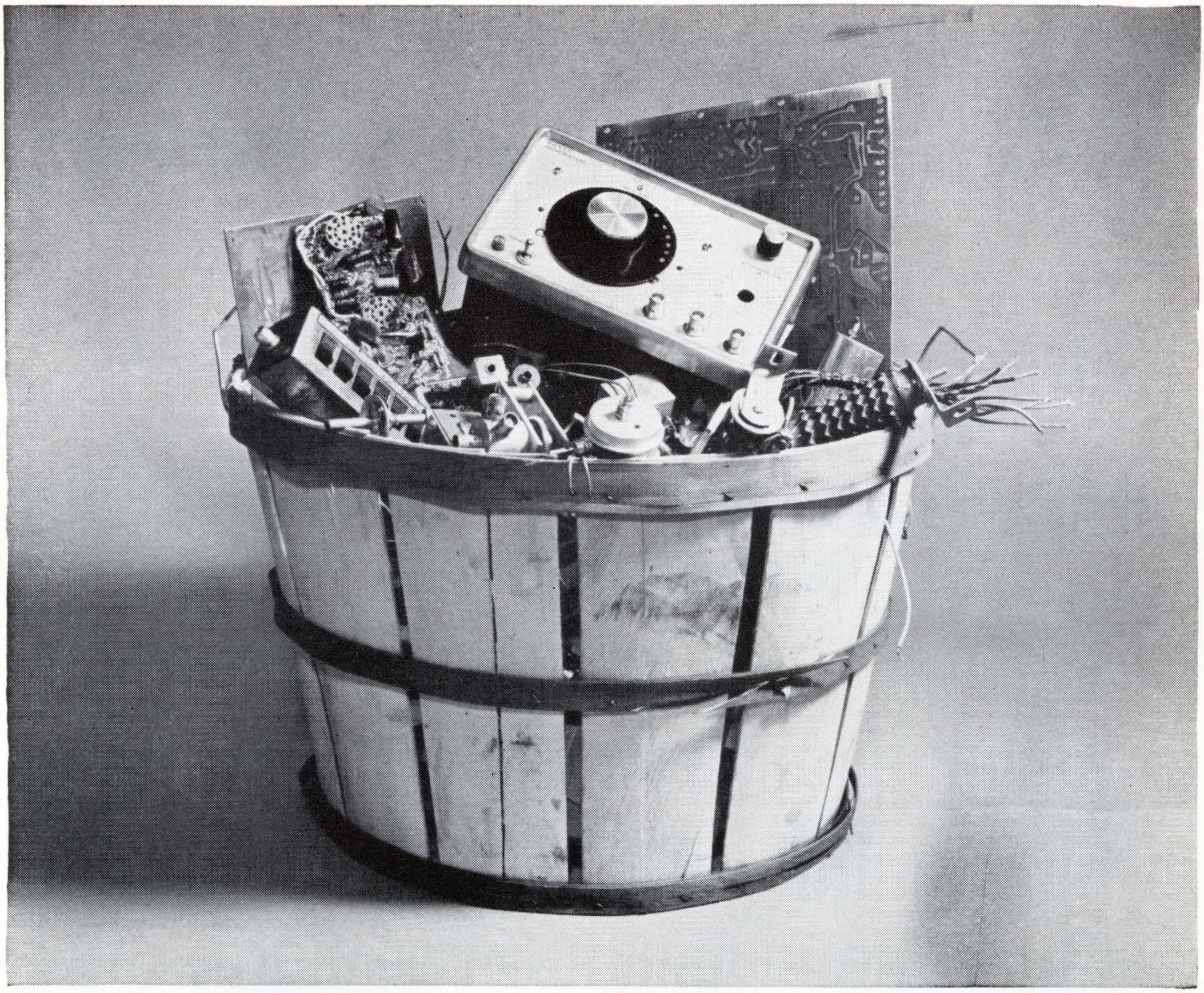

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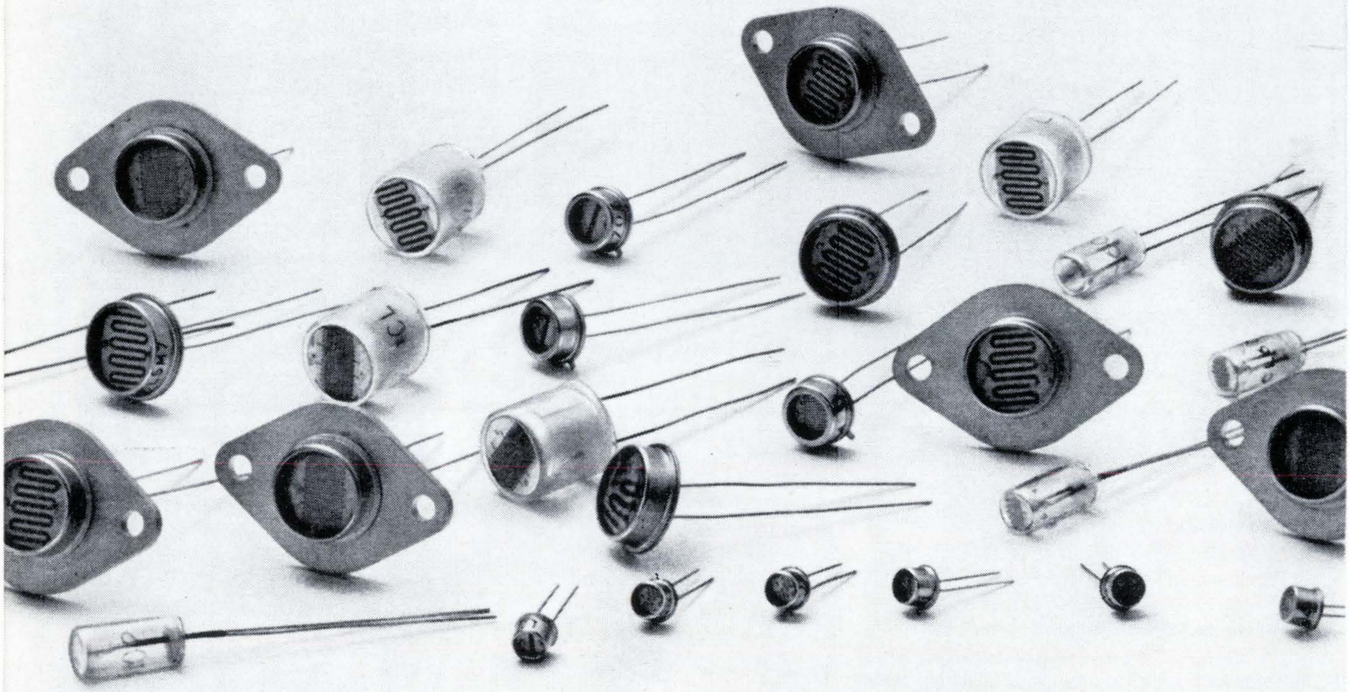

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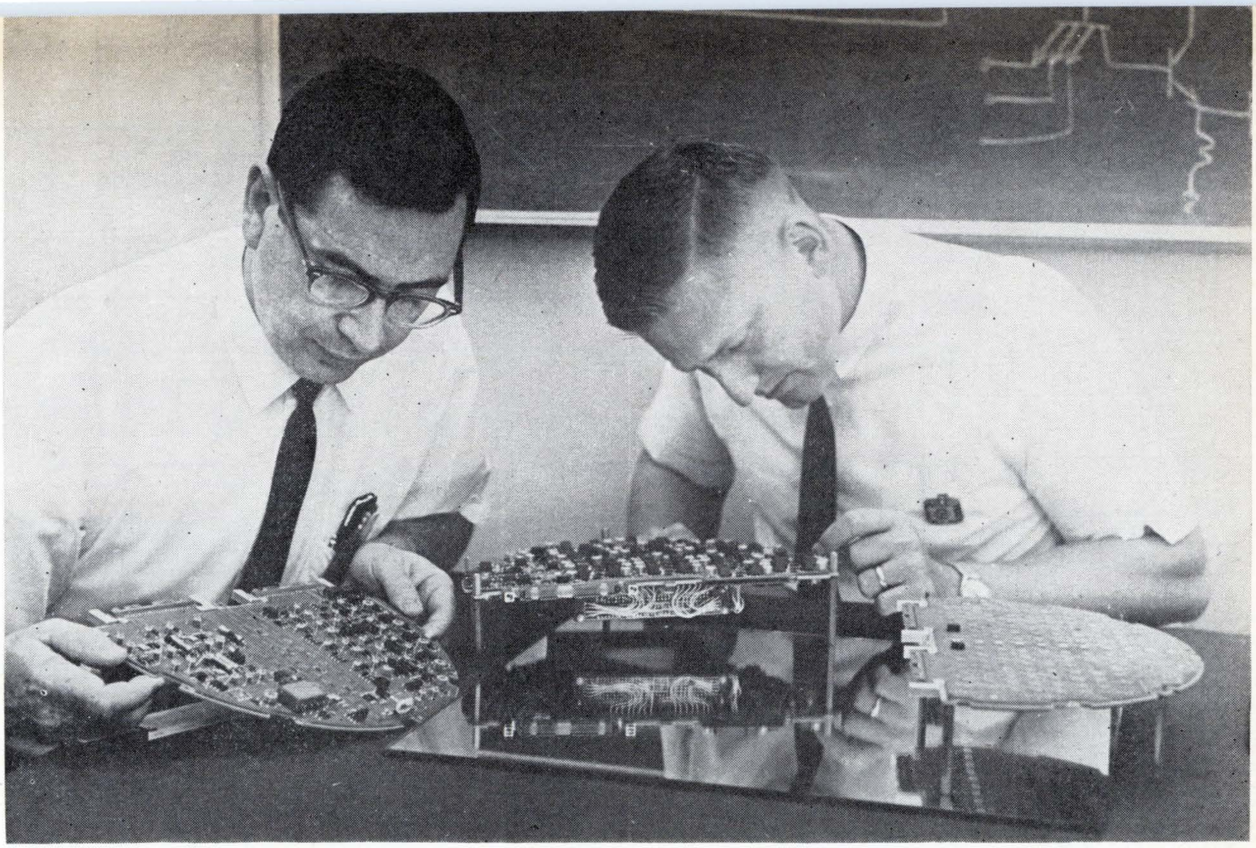


Three subassemblies constitute IBM's new mass production computer for varied aerospace applications.

Computers

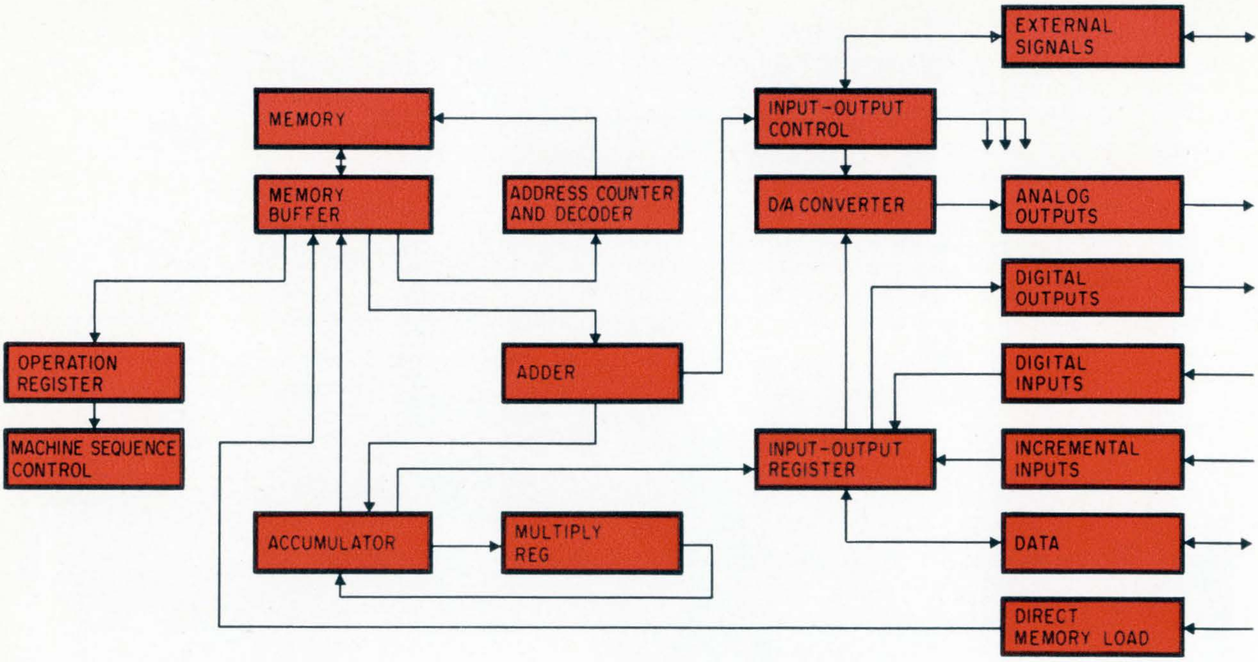
The airborne 4 Pi computer: IBM aims at aerospace guidance

A low-cost computer now being mass-produced promises to replace traditional computers in guided missiles. Intriguing organization and the use of IC's contribute to its attractiveness

By William N. Carroll and Frederick F. Jenny
International Business Machines Corp., Owego, N.Y.

General-purpose digital computers have heretofore been too expensive and too large for use in expendable aerospace applications such as in the guidance system of a missile. But now they can compete with the special-purpose machines that have traditionally been used in such vehicles. The widespread availability of varied monolithic integrated circuits, new packaging techniques and high-speed core memories makes the competition possible. Mass production of logic circuits has cut the cost of such a general-purpose computer and the inclusion of IC's has reduced the size of the machine sharply.

Although special-purpose analog, hybrid analog and digital, and incremental computers have all been used in aerospace vehicles, the military would prefer a general-purpose machine instead because



This tactical-missile computer resembles many other computers and therein lies its special advantage. Previously computers for such applications were specifically designed.

the special-purpose one always requires unique design, and special software, testing and reliability data, and is difficult to reprogram. The Air Force has dropped special-purpose machines entirely in ground support applications, preferring off-the-shelf machines of general-purpose design because they have better reliability [Electronics, Sept. 19, 1966, p. 201].

An engineering model of a general-purpose machine, designed especially for aerospace use, has been built and evaluated by the International Business Machines Corp. as part of IBM's series 4 Pi program, which is as comprehensive in aerospace applications as IBM's System 360 is on the ground. The basic design of this machine will solve the kind of problems encountered in missile guidance, although it can be used in other applications with the addition of special input-output channels and different packaging. Such versions would be suitable for aircraft control and navigation.

IBM has built the 4 Pi machines with integrated circuits, but the logic organization can be easily implemented with large functional arrays when large-scale integration becomes feasible.

System architecture

Because the missile system imposes unusual requirements of size, weight, power, cost and maintainability, the computer design must be a compromise of system organization, instruction set and circuit layout. In addition, the design must be easy to modify because the over-all system will probably change during development.

Analysis of the guidance problem showed that system accuracies could be met with a 16-bit data word and that an erasable memory with direct access and a relatively small capacity was required. Instructions of both 8-bit and 16-bit lengths economize still further on the memory size, over a uniform 16-bit instruction format. Thus all data and instructions fit in a memory of only 1,024 eight-bit words.

Instructions are stored anywhere in the memory. Data is stored only in one block of 256 words, and the block is divided into four 64-word sectors. The sectors economize on the memory-addressing hardware, although this makes the programing awkward when data from different sectors is required.

A part of the 1,024-word main memory may be wired as an optional read-only memory. When so

Missile guidance computer characteristics

Type of computer......	General-purpose processor with specialized input-output
Mode of operation.....	Serial arithmetic parallel program serial input-output
Arithmetic notation....	Fixed point
Instruction word length	8 or 16 bits
Data word length......	15 bits and sign
Number of instructions	15
Arithmetic speeds	
Addition............	12 μsec
subtraction..........	12 μsec
Multiplication........	140 μsec
Memory capacity......	1,024 8-bit words
Memory cycle time.....	4 μsec
Input-output-control...	6 inputs 8 outputs
Incremental counters..	3
Data channels.........	One, serial
Channel speed.........	100 khz
Weight.................	10 pounds
Volume................	0.27 cubic feet
Power..................	32 watts
Reliability.............	14,000 hours or more

wired, the read-only portion stores programs and subroutines that have been completely debugged. Instructions in the read-only memory aren't changed by temporary malfunctions or unusual conditions that arise during missile storage, testing or flight. In space vehicles particularly, the read-only memory is useful because it occupies little space and is highly reliable. In the larger models of the 4 Pi series [Electronics, Oct. 31, 1966, p. 42], and in general-purpose computers like IBM's System 360, the read-only memory controls the execution of programs but does not itself contain program instructions; the programer is not concerned with the read-only memory.

The set contains only eight instructions, each consisting of an operation code and a single address. All instructions have the same execution time except the multiply and shift instructions. Two of the eight instructions can be coded to perform different operations: the process input-output can initiate 31 different operations, and the transfer can cause either conditional or unconditional transfers (execution out of normal sequence) or a change in the memory sector being addressed.

Memory design

The core array is a single plane automatically fabricated and tested, containing 1,024 eight-bit words, expandable to 2,048 words. Additional planes can be stacked to build larger memories, up to 16,384 words. The larger memories, however, will not fit on a single page. Drive and sense electronics consist of monolithic and discrete components. The memory system cycle is 2.5 microseconds, but each active cycle is followed by a 1.5-μsec idle period to reduce power consumption; the total cycle is therefore 4 μsec.

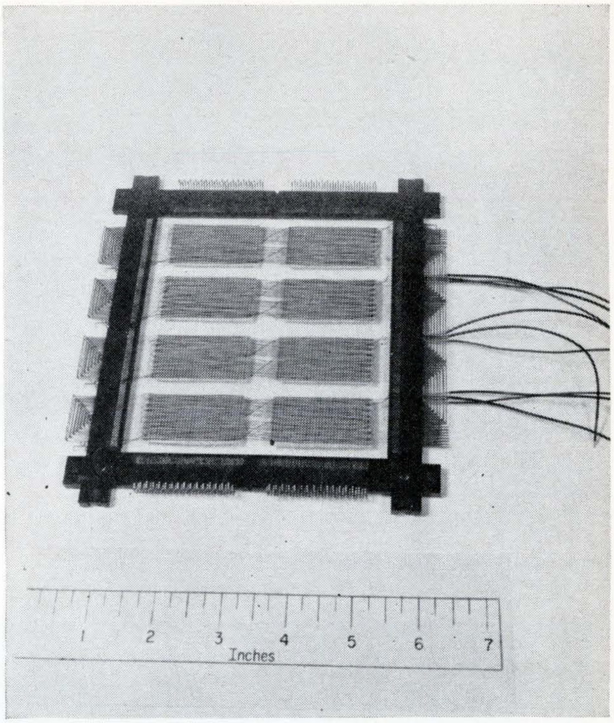
The read-only memory is identical to a normal memory except that cores are removed from those locations which contain zeros. This arrangement has several advantages. The memory construction is essentially similar to a conventional system and can be fabricated on existing automatic equipment. Data can be written into as well as read from the memory during development, thereby allowing flexibility in the programing design. The memory with appropriate cores missing is truly unalterable, and cannot be affected by electrical transients or erroneous addressing. The same drive and sense circuitry can be used as with the normal memory; the memory addressing is also the same.

A memory of this type presents certain difficulties. For example, cores with hysteresis loops that are not square could generate unwanted outputs caused by noise from the slanting top of the square. To reduce this hazard the timing of the memory drivers is staggered and extra cores on the drive lines compensate for the noise.

Sensing and controlling

The input-output section of the guidance computer performs important functions:

- It decodes, buffers and amplifies control outputs and decodes and gates control inputs.
- It monitors the guidance processor, signals the occurrence of any program or power malfunctions and keeps track of real time.
- It accumulates input signals from the accelerometers for later processing, and works with external equipment during initialization and retargeting procedures.
- It assists in the alignment and torquing of the inertial platform and other control functions.
- It controls the sequence of power on-off to various subassemblies.



Memory array used in the tactical-missile computer is a single core plane that can hold 1,024 eight-bit words.

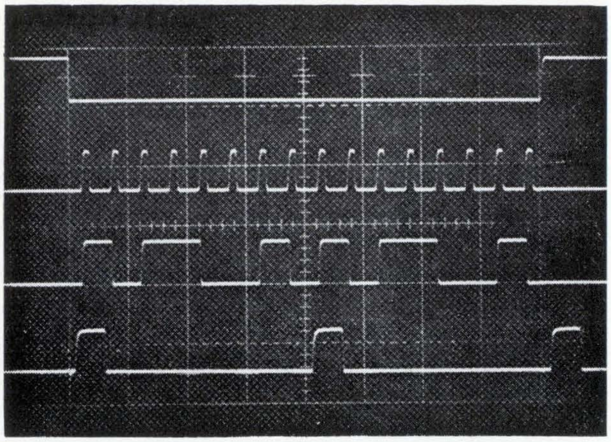
The specialized nature of these tasks require a mixture of digital and analog circuits using both discrete components and IC's in flatpacks. However, all circuits are mounted on a single multilayer board, as shown in the bottom table, p. 175.

All digital transmission line circuitry, all control circuitry, and most digital-analog conversion circuits are IC's packaged in 14-lead flatpacks. In most cases, analog IC's proved too costly to use.

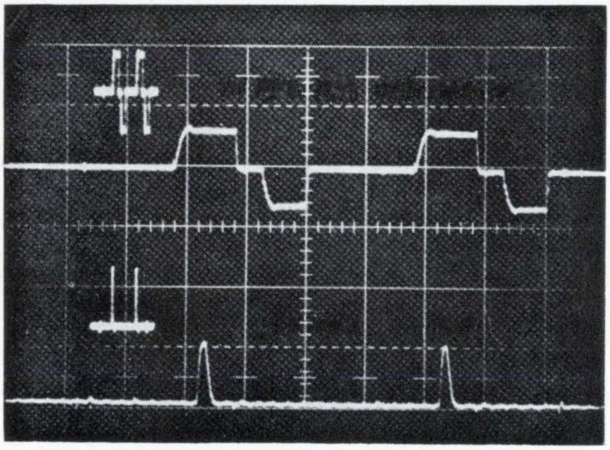
A major consideration with the multilayer boards

How fast the 4π works

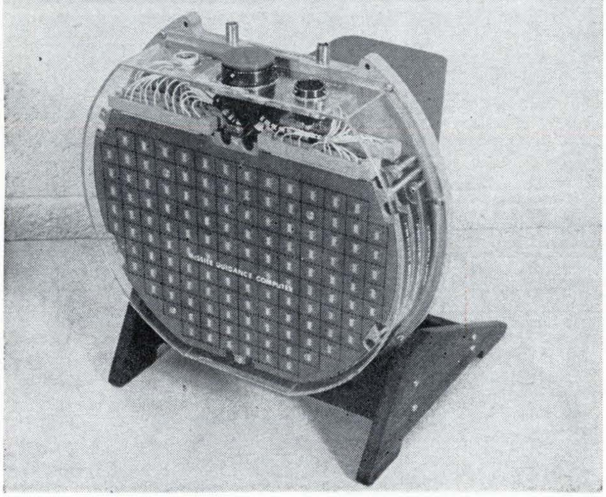
Instruction set	Time (μsec)
Clear and add	12
Add	12
Subtract	12
Multiply	140
Store	12
Shift (left or right up to 16 places)	20
Process input-output (31 codes)	12
Transfer (6 codes)	12



Data and timing waveforms from the computer are, from the top down, the instruction-execution cycle, the serial add shift operation, data from the accumulator, and the main computer timing pulse, once every 4 microseconds. The scales are 1 μsec per division horizontally, and 5 volts per division vertically.



Memory input and output waveforms show the drive current on the top trace and the sense amplifier voltage on the bottom. The vertical scales are respectively 0.5 ampere per division and 3 volts per division; both horizontal scales are 1 microsecond per division.



Three subassemblies are visible in this mockup of the computer. They are the central processor, the memory, and the input-output. The round shape is the cross section of the missile in which the computer will be used.

in the input-output subassembly was in designing them so the necessary voltages are provided to the various circuits, crosstalk is avoided between them, and at the same time the board design is kept simple. The logic circuits need only one power supply, +5 volts; power drivers, amplifiers and other special circuits, some of which are hybrid IC's or discrete-component circuits, sometimes require two or three voltages. But the board contains only a ground plane and one other voltage supply plane. The voltage plane is subdivided, one voltage connected to each subdivision, and the cans and flatpacks arranged on the surface of the board so that the necessary voltages are available and also that low-level logic circuits are well separated from high-current power drivers delivering as much as three amperes.

Three plates and a harness

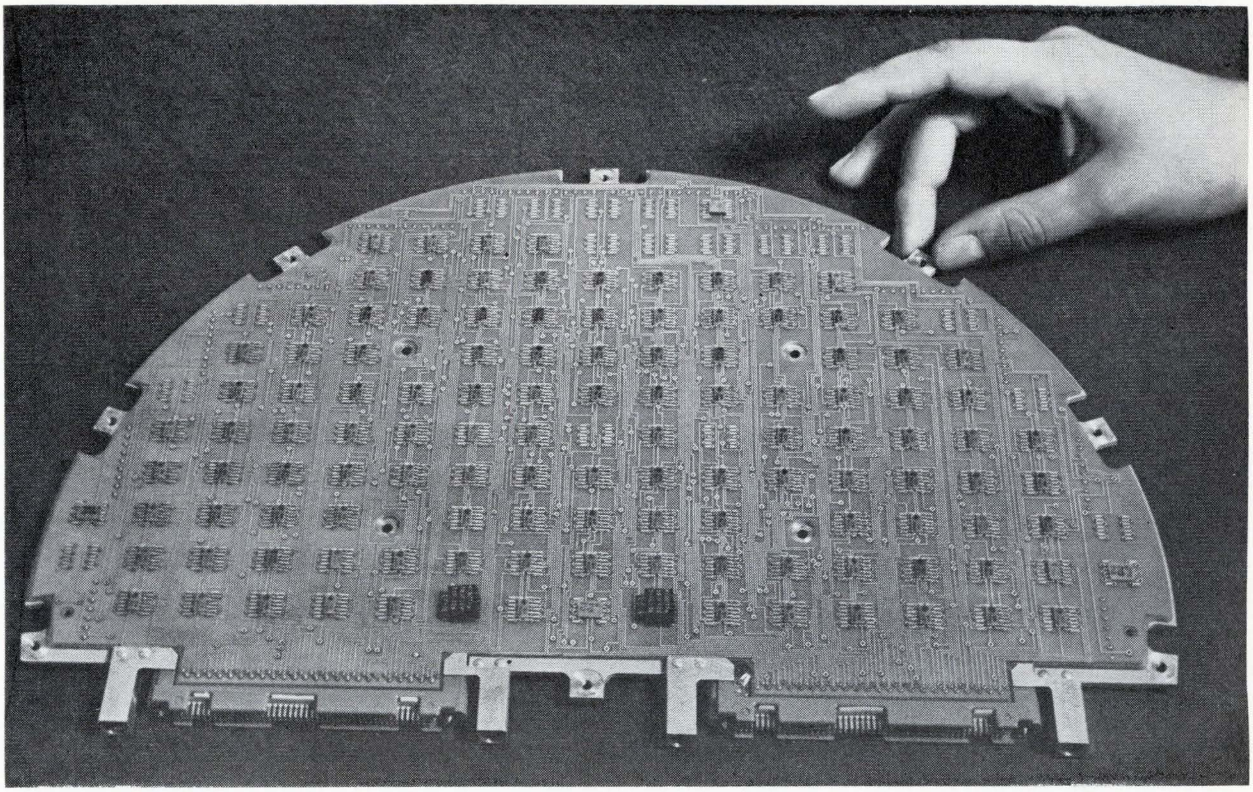
The computer, below left, contains three major subassemblies: the central processor, the memory, and the input-output. Each semicircular subassembly is made of two simple multilayer boards and a supporting aluminum plate that is both mechanical support and thermal conductor which is brazed to a cold plate. The shape of the computer is compatible with a specific missile configuration that is classified. Integrated-circuit flatpacks and discrete components are soldered to specified land patterns on the multilayer boards. The boards themselves contain two signal-wiring layers, one voltage distribution plane and one ground plane. All signal connections within a board are 0.010 inch wide and 0.025 inch apart. The two boards are insulated from and bonded to the aluminum supporting plates to form a page. Three pages make up the entire computer.

Putting all electronics associated with major sections of the computer on a single page minimizes the number of interpage wires and connectors and eliminates the need for a costly and complex backpanel. A simple wiring harness is used.

The unit is cooled by conduction through the page mountings to a cold plate; air at an inlet temperature of 70°F ±10° (21°C ±5°) cools the plate before the missile is launched. During the missile's relatively short flight, the calculated temperature rise is less than 1°F per minute.

The temperature specifications for the inertial platform are 30° to 60°C, and this range was chosen for the computer as well. Within this range, the memory power supplies do not need controls to vary their output with temperature, a significant cost reduction. Point-to-point temperature variation within the computer can be considerably greater. The monolithic IC's have a temperature range of 0° to 70°C. These circuits require temperature regulating controls, but the controls are cheaper than the extra cost of circuits with a wider range.

The memory subassembly is mounted closest to the cold plate because of its restricted temperature limits, while the other two subassemblies can be



Flatpack mounting and wiring details are visible in this view of the arithmetic and control subassembly.

placed next to the memory with either one in the middle. The entire unit is sealed with a O-ring gasket to keep out excessive humidity and dirt.

Heart of the computer

The central processor subassembly is a general-purpose unit that performs the basic arithmetic and control functions. The two multilayer boards making up this subassembly contain 243 standard 14-lead flatpacks. The basic structure of the board avoids signal crosstalk and provides some power supply decoupling; additional discrete decoupling capacitors are mounted around the page assembly. Connections between boards are provided by 100 feed-through pins along the edge of the boards. Two 98-pin connectors are mounted on the flat edge of the subassembly for connections to the memory, input-output pages, and external guidance equipment.

The computer is built with seven types of transistor-transistor logic (TTL) circuits. One consideration in the choice of an IC family was its applicability to other programs, since purchase in large volume saves money.

The logic requirements of the computer suggested a few additions to the standard TTL line, the most significant of which was two flip-flops on one flatpack. Sixty-three of these dual flip-flops are used in the design as registers, shifters and counters.

What lies ahead

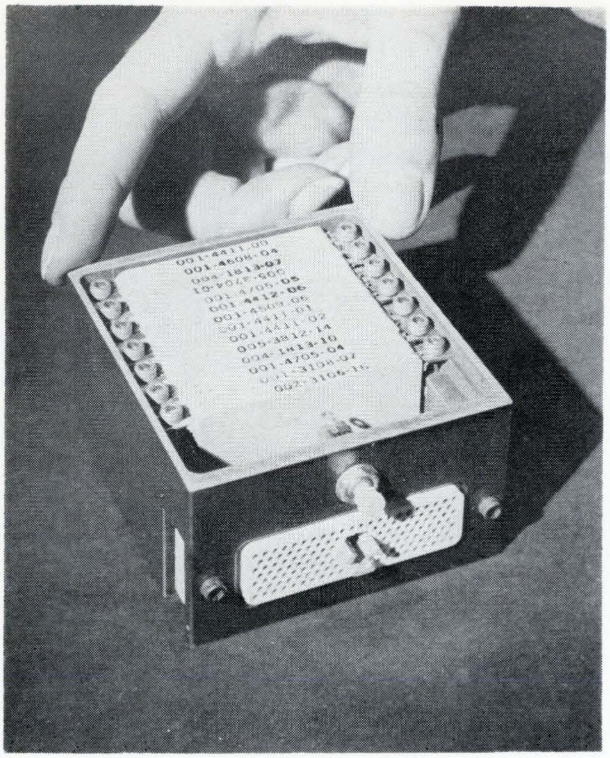
The logic circuits now used are nonfunctionally

T^2L circuit characteristics

Circuit delay (maximum)	25 nanoseconds
Power consumption (average)	10 milliwatts per gate
Power supply	5 volts ±10%
Fan-in	8
Fan-out	10
Signal levels, nominal	0 and +5 V
Noise margins (minimum)	400 millivolts
Temperature range	0 to 70° C

Counting the components

	Processor	Memory	Input-Output	Total
Integrated circuit flatpacks	243	56	34	333
Discrete semiconductor flatpacks	....	80	...	80
Transistors	....	76	59	135
Diodes	....	109	39	148
Resistors	....	288	98	386
Capacitors	12	79	33	124
Miscellaneous	....	68	1	69



Data-flow model of a digital computer built from multicircuit monolithic chips attached to thin-film interconnection networks.

packaged—that is, gates and storage elements are individually packaged in 14-lead flatpacks. Future missile guidance computers will unquestionably be built from large-scale functional monolithic circuits, to attain even lower cost and higher reliability. The repetitive nature of the processor design permits a functional packaging approach that could be implemented in either of two ways:

- Multicircuit monolithic chips can be attached to thin-film[1, 2] interconnection networks on a passive substrate, which is integrally packaged in a pluggable, hermetically sealed package. This hybrid approach offers a good potential for handling specialized analog and memory electronic requirements.

A data flow model employing these techniques is in the photo shown above. More than 2,500 components occupy less than 16 cubic inches including the thin-film panels, chassis, backpanel, and connector.

- Large-scale integration (LSI) techniques[3] [Electronics, Feb. 20, p 123] with monolithic and thin-film process steps on an active substrate are packaged in large flatpacks containing 28 or more planar flat leads. Metal-oxide semiconductor devices with either fixed or programable interconnection patterns or bipolar transistor circuit cells with a fixed interconnection pattern appear feasible at this time.

The hybrid approach offers short-term advantages, since both the monolithic chips and interconnection networks can be individually pretested prior to integration. This approach does not rely on the nearly perfect yields that LSI would require.

Nevertheless, several Government agencies and private firms are trying to develop LSI with the ultimate goal being perhaps a "computer on a chip."[4] Current photomasking techniques permit as many as 1,200 to 1,800 gates to be fabricated on a single wafer. Typical aerospace computers require about 1,500 gates; therefore it seems numerically possible to build an entire computer on a single chip of silicon. However, current yields of circuit cells and film interconnections are too low to achieve the desired results; and packaging, interconnections, and thermal technology are not yet far enough along to make a single-wafer computer practical. At one semiconductor company, planners talk about putting 40,000 gates on a slice someday. Then a slice would have more than enough good gates for an aerospace computer.

In our opinion, large-scale integration of assemblies will be an evolutionary process. Arrays with 20 to 30 circuits per module will become common first; modules containing 200 circuits or more will be developed later.

These functional modules will require significantly fewer expensive operations than semiconductor manufacture now requires, such as testing, dicing and encapsulation. They will also make possible substantial size reduction, which will permit the inclusion of more circuits for greater capability in a given size. They will be substantially more reliable than the present circuits because of the reduced number of connectors, solder joints and wiring paths in the computer.

Other technological advances that will affect future missile guidance computer development are advances in memory, including electrically-alterable read-only memories, strap-down guidance systems that will require higher computer performance, high-density printed circuits and multilayer boards, and thick-film or thin-film microminiature passive components.

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2. Max Bialer, Lt. Albin A. Hastbacka and T.J. Matcovich, "Chips are down in new way to build large microsystems," Electronics, Oct. 4, 1965, p. 102.

3. F.F. Jenny, D.H. Bergeron, T.R. Lawson Jr. and A.E. Lessor Jr., "High-density packaging employing monolithic and thin-film interconnection techniques," IBM Technical Report TR22.214, Nov. 9, 1965.

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The authors

William N. Carroll is program manager for small computer products development and is responsible for the small processor end of the 4 Pi line.

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ANALOG MONOLOGUE

On Means for Modelling, Measuring, Manipulating, & Much Else

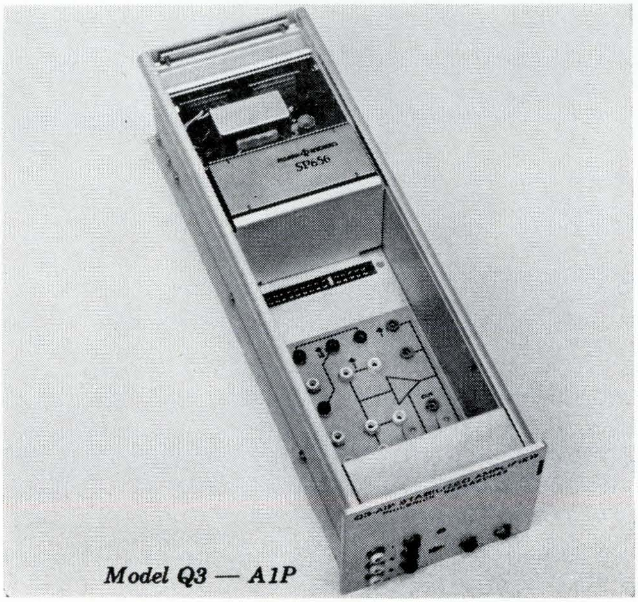
Volume 1, No. 4

A SHORTER PATH TO PRACTICAL ELECTRONIC MEASUREMENTS

One requirement is common to all scientific research . . . threads through all development engineering . . . marks every empirical exercise — *the need to measure.* Our interest in this arises from the fact that electronic circuits (often with transducers) are generally the most practical means for measuring and recording parameters. Moreover, an increasing number of practical and economical electronic measuring circuits employ Operational Amplifiers — our specialty in analog computing devices since before 1946, and as a circuit component since their introduction as such in 1952.

During the past twenty years, we have been privileged to work closely with specialists in many disciplines, helping them to design and build literally thousands of different kinds of circuits — instruments, signal "conditioners", and data "processors" and others ad infinitum. We have learned that our "opposite numbers" in Chemistry, Metallurgy, Aerodynamics, Hydraulics, Mathematics, Stress Analysis, Physics, Thermodynamics, etc., are generally enthusiastic about what Analog Operational circuits *can do*, but almost totally disinterested in *how* they can be made to do it . . . and that is pretty much as it should be. To each his own.

We have observed that a major deterrent to more widespread use of the powerful Analog Way (of sensitive, accurate measurement and data processing) has been the time, effort, and considerable skill required to convert the circuit diagram into a complete, functioning instrument. Now we have found a way to speed and simplify that process. We call it the *Universal Operational Module* (U.O.M.): One such module, the Q3-A1P, is shown here.



Model Q3 — A1P

The Q3-A1P consists of a unique mechanical structure, in which are mounted a high-performance, chopper-stabilized Operational Amplifier, a compatible power supply, and an "Operating Deck", on which is located a cluster of conveniently-disposed, clearly-labeled jacks, for interconnecting input and feedback components with the amplifier and its supply. The structure also provides connectors and space for auxiliary networks, for input and output cables, and a front panel with duplicate input/output terminations. With a Q3-A1P and a few simple pluggable components (i.e., resistors, capacitors, etc.) any one of literally thousands of useful circuits — complete and ready to use — may be realized . . . *minutes after it is conceived,* without punching a hole, or soldering a wire.

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The Q3-modular packaging system which includes a variety of universal operational modules, some of which are listed in Table 1, permits concentration on the *important* things — What and Why, instead of How.

TABLE 1

Q3-A1P	Compact, self-powered, chopper-stabilized amplifier complete with patch panel and accessory socket.
Q3-A2P	As above, but using a low noise, low current-offset, differential amplifier.
Q3-J1P	A switch-programmable, self-powered integrator-differentiator.
Q3-M1P	A switch-programmable, self-powered unit capable of performing non-linear functions such as multiplying, dividing, squaring and rooting.
Q3-M2P	As above, less switches, programmable via a patch panel.

These universal operational modules (U.O.M.'s) consist of a standard Q3 series package, equipped with a carefully optimized interface facility to permit the combination of amplifiers, networks, components, and power supplies into highly-flexible, universal analog devices.

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Tv show of the century: A travelogue with no atmosphere

Apollo astronauts will use a lightweight television camera to send back pictures of their trip and of the moon's surface

By Stanley Lebar and Charles P. Hoffman
Aerospace Division, Westinghouse Electric Corp., Baltimore

More "vast wasteland" is in store for television viewers—the surface of the moon. Apollo astronauts will use a highly sensitive, lightweight camera to send tv signals from their spacecraft and the moon back to earth, where some of the scenes will be retransmitted by conventional television stations to a living-room audience. Also, scientists and engineers viewing live, real-time tv images will follow nearly every phase of the three-man mission.

Integrated circuits make up 80% of the camera's electronics. A rugged unit, small enough to be held in one hand, the camera uses an improved version of a recently developed tube to operate in the brightness of the lunar day and in near-darkness, when the only illumination is light reflected from the earth—a light range from 0.007 to 12.600 foot-lamberts. The lower limit of this range would be equivalent on earth to the light from a quarter-moon, the highest limit to the light from an overhead sun on a clear summer day. Although lenses will be interchanged to optimize light sensitivity, the camera won't require any internal adjustments.

Only one camera will be taken on the trip, a unit designed for a 99.9% probability of success over the 360-hour duration of the mission. Completed models have already been delivered to the National Aeronautics and Space Administration. They are built to operate in the severe vacuum environment of the moon at temperatures ranging from 250° to —300° F; passive cooling will hold camera temperature between 0° and 116° F. The camera is also designed to operate in the humid and corrosive atmosphere of the spacecraft without endangering the astronauts.

The authors

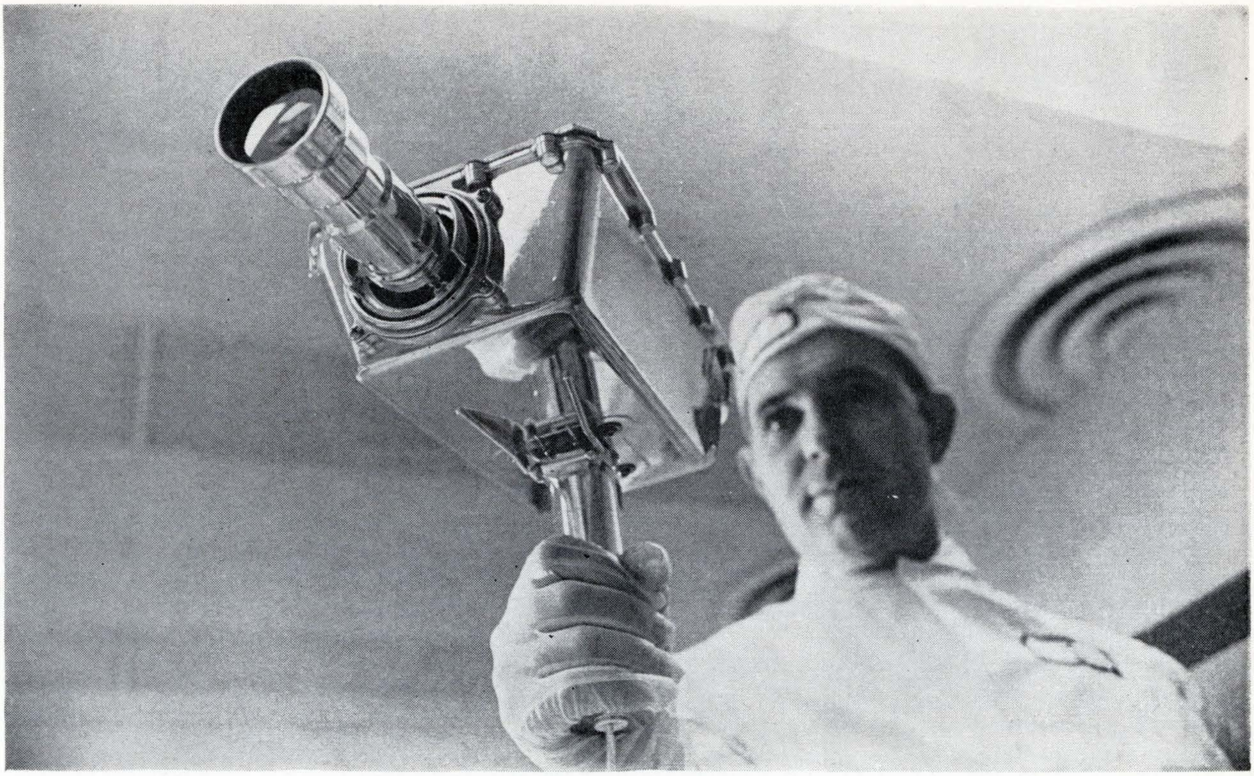
Stanley Lebar manages the Apollo lunar tv program. A 14-year veteran with Westinghouse, he has worked in the fields of optical instrumentation, waveguide and antenna systems, missile fuzes, and space systems. The manager of several programs over the past 10 years, he received his BSEE degree from the University of Missouri in 1950.

Charles Hoffman, engineering manager of the Apollo camera program, has been active in the design of radar and electro-optical systems. For his work on an integrated-circuit version of an infrared search-track system he received the "Outstanding Engineer Award" from the Maryland IEEE chapter. He received a BEE degree from Johns Hopkins University.

Making the scene

The only external camera control is a switch to change operation from slow to fast scan. For high-resolution scientific studies, the camera will be mounted on a tripod and will scan the scene at a rate of 5/8 frame per second with 1,280 lines per frame. Where lower resolution is needed—for example, to monitor the astronauts' movements—the camera can be hand-held and will scan the scene at 10 frames per second with 320 lines per frame. Unlike the conventional broadcast television format, the lines won't be interlaced.

After touchdown on the moon's surface and erection of an S-band antenna, the astronauts will connect a combination handle-electrical connector to the camera; the handle can be engaged or disengaged in a vacuum without the contacts welding together. The handle is hooked up to a 100-foot cable that will supply the camera with d-c power from the Lunar Excursion Module (LEM) and will



Apollo television camera with telephoto lens attached is held by Westinghouse engineer. Handle also serves as an electrical connector that can be engaged and disengaged without the contacts welding in the moon's vacuum environment. Cable in handle carries d-c voltages to camera and video output to transmitter in the spacecraft. All the electronics are mounted on the top plate. Bottom pan is an enclosure. Thick casing is for protection from meteors.

also connect the camera's video output with the module's S-band transmitter. After selecting a lens appropriate to the light conditions and the scene to be viewed, an astronaut will switch to the desired scan mode. He will use the edges of the camera as an aiming sight.

The heart of the Apollo camera is a sensitive image tube that combines a variable-gain light intensifier with a secondary electron conduction (SEC) target.[1,2] This target produces gain and stores the image that is subsequently scanned by the tube's electron beam gun. Although the tube is slightly less sensitive than an image orthicon, the electronics for reading out the stored image are as simple as those of a vidicon tube. With fast response, the SEC tube's video output signal at low light level reproduces objects in motion without smearing—unlike the video output of vidicon and image orthicon tubes. At the same time, the SEC target can store and integrate signal information over a relatively long time period, a factor that contributes to the tube's slow-scan capability and sensitivity.

Optical system

The Apollo camera, built by the Westinghouse Electric Corp.'s Defense and Space Center, is provided with four interchangeable lenses of fixed focal length. A wide-angle lens will be used primarily for pictures inside the command module, while a telephoto lens will be used to view the earth and moon during the trip back and forth. Two general-purpose lenses will be used on the moon's surface, one during the lunar day and the other during periods of darkness.

The lenses focus light onto the electrostatic diode image intensifier's photocathode, which emits electrons in proportion to the incident light level. A faster lens—one with a larger aperture—collects more light and thus increases the number of emitted electrons. S-20 photocathode material is used in this tube because its quantum efficiency is relatively high and uniform over visible wave lengths.

The potential difference between the photocathode and the SEC target accelerates the emitted electrons and the intensifier's electronic optics focus the image onto the SEC target.

Depending on the incident light level, an automatic control circuit varies the accelerating potential so that electrons hitting the target have energies ranging from 2,000 to 8,000 electron volts, with the higher energy level corresponding to low light levels. In this way, the tube is able to accommodate a wide range of illumination while maintaining a relatively constant signal output.

The SEC target releases secondary electrons in proportion to the number and energy of the impinging electrons. These secondary electrons are collected by a thin aluminum plate that is at a higher potential than the target material. As a result, each point on the face of the target becomes positively charged in proportion to the incident light level.

The operation of reading the stored image out of the SEC target is similar to that in a vidicon tube. When the electron gun scans across the target, it

Apollo camera's system parameters

Power consumption	6.5 watts with 24- to 32-v d-c primary source
Weight	7.25 lbs.
Video bandwidth	2 hz to 500 khz
Scene illumination (requires lens change)	0.007 to 12,600 foot-lamberts
ALC/AGC control range	Greater than 1,000:1
Scan parameters	
Mode 1	10 frames/sec, 320 lines/frame noninterlaced
Mode 2	0.625 frames/sec, 1,280 lines/frame noninterlaced
Aspect ratio	4:3
Faceplate image size	0.5 x 0.375 inch
Resolution (limiting)	500 tv lines in picture height
Signal-to-noise ratio	28 db, minimum
Operating temperature	0° to +116F with passive cooling
Linearity	2%

neutralizes the charge and brings the target potential back to ground level. This change in charge results in a current pulse that is coupled to an external resistor. The voltage developed across the resistor is the video signal.

The tube's image intensifier and 1-inch hybrid vidicon gun are especially rugged but are otherwise of conventional design. Because the gun is electrostatically focused, it requires only simple external circuitry. Although a magnetically focused gun would improve the tube's resolution, the focus coil would appreciably increase weight and power requirements.

Thermally balancing the package

Except for the unregulated d-c supply from the spacecraft, the camera is a self-contained unit. The SEC tube and deflection surface provide the basic conversion from optical to electrical signals, while a combined automatic light-level control and gain control (ALC/AGC) maintains a constant video output even as light levels change. Video amplifiers boost the signal and mix it with sync signals and blanking pulses developed in the synchronizer.

The amount of surface area needed to maintain thermal balance at lunar noon determines the camera's size and weight. Besides having the appropriate cooling properties for lunar operation, the surface finish must withstand the corrosive atmosphere of the spacecraft. The finish used will hold the camera's surface-temperature below 120° F during lunar day if the top surface can reflect into deep space. For night operations on the moon, camera temperature may drop as low as —44° F. However, 27 square inches of silver shields can be attached to the unit's top surface to prevent radiation of heat outward and hold the low temperature to 0° F, improving reliability.

Integrated circuits for reliability

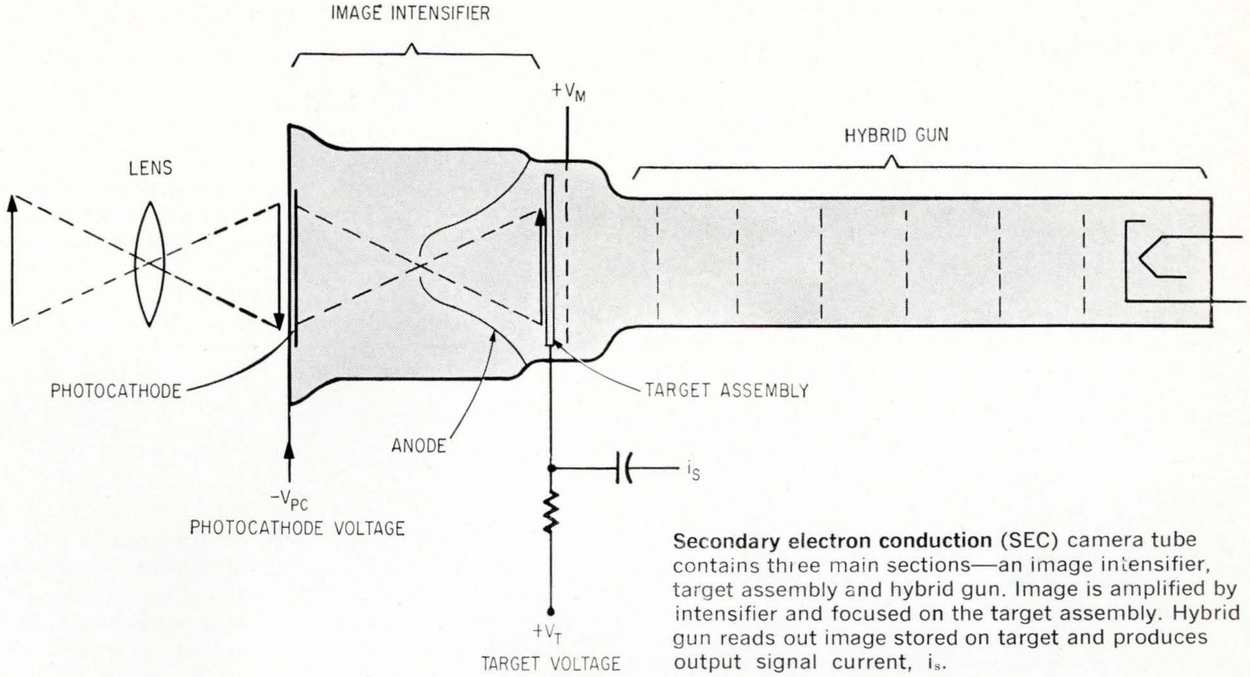
Reliability was also the prime factor directing the choice of integrated circuits for most of the camera's electronics, though size, weight, power-consumption and cost reductions were also considerations. Of the 43 integrated circuits used, 24 are of different types and 19 of these types were designed especially for the camera.

The custom circuits are of both monolithic silicon and multiple-chip hybrid designs. Of the 19 custom units, Westinghouse built 11—the ones deemed most likely to change with improvements in the SEC tube. A monolithic silicon chip contains all the active components except for pnp and field effect transistors. Those components that couldn't be built with integrated circuits—large capacitors and chokes, for example—had to be wired in.

Since the synchronizer requires the largest number of integrated circuits—12 flip-flop packages and 7 gate packages—it was essential to use devices with low power-switching capability. Two higher-power AND-gate units form the interface between the synchronizer sweeps and the mixer in the video

Comparison of tv cameras

	SEC	Vidicon	Image orthicon
Low light level in foot-lamberts (for S/N = 20 db	10^{-3}	10^{-1}	10^{-5}
Lag	No	Yes	Yes
Power	6.5 watts	6.5 watts	15 watts
Weight	7.25 lbs.	4.5 lbs.	25 lbs.
Size	160 in.^{3}	80 in.^{3}	400 in.^{3}
Complexity	Slightly more than vidicon	Simple	Complex
Dynamic range	40 db	40 db	30 db



Secondary electron conduction (SEC) camera tube contains three main sections—an image intensifier, target assembly and hybrid gun. Image is amplified by intensifier and focused on the target assembly. Hybrid gun reads out image stored on target and produces output signal current, i_s.

circuit. Hybrid circuits were used in the mixer, sweeps and power supply.

Whether made by Westinghouse or purchased from outside vendors, the circuits have had to meet specifications far in excess of the environmental stresses they are liable to encounter.

Design constraints

For transmission of pictures back to earth, the camera's video output frequency-modulates the S-band transmitter. The signals will be transmitted in analog form because NASA studies have shown that such a system requires only one fourth the bandwidth of a digital transmission scheme. Since power is limited, the bandwidth has to be restricted to 500 kilohertz.

To prevent excessive deviation of transmitter frequency, the video signal must be less than 2.1 volts when working into 100 ohms. The sync burst format used puts both the sync amplitude and the video signal above a reference black level. In this way, both the sync and picture information can have a full 2-volt swing and thus deviate the transmitter the full 500 khz. In comparison, the amplitude-modulated format of commercial tv would prevent full deviation because video information is on one side of a fixed black level and the sync information is on the other.

As in commercial tv, the vertical sync pulses in the Apollo system are serrated at the horizontal line frequency to maintain horizontal sync in the receiver during the vertical sync pulses.

Scan modes

The 10-frames-per-second, 320-line scan format —the primary mode in the Apollo camera—affords good vertical resolution and adequate display of motion. In telecasting fast actions—a man quickly raising his arm, for instance—there is breakup or smear at frame rates below 15 frames per second, and this breakup is quite pronounced at 10 frames per second. However, because the astronauts will move slowly in the spacecraft and on the lunar surface, the rendition of motion at the slower rate is acceptable.

The resolution is actually lower than the number of lines. A 500-khz transmitter bandwidth would theoretically limit the maximum resolution to 210 lines, but because the filter in the video amplifier section has a frequency response that rolls off gradually, the resolution is equivalent to that of a 250-line system.

The high resolution offered by the slower scan mode—5⁄8 frame per second with 1,280 vertical lines—is limited by the camera's aperture response.

Signal controls

The combined control of the photocathode and video gain by the ALC-AGC circuit compensates for a 65-db change in light level in about 2 seconds. Over this wide dynamic range, the signal-to-noise ratio will change only about 20 db. Not shown in the schematic diagram on page 185 are transistors that electronically switch the input level, detector time constants and threshold levels when changing operation modes.

The first step in controlling the signals is to produce a d-c signal proportional to the video signal. This conversion starts in detector Z_1. D_1 and C_1 will clamp to a fraction of a positive voltage (black level) that is generated by the blanking pulse at the end of each sweep. In this camera, R_1 is usually set so that the clamping level is about 1.5 volts. This fixes the minimum peak-to-peak video signal that must appear before D_2 begins to conduct. The video output (white signal) is a negative-polarity

The target

The Apollo camera's advantages are related to the unique characteristics of the tube's secondary electron conduction (SEC) target. The target consists of three sections:

- A thin supporting layer of aluminum oxide.
- A thin conducting layer of aluminum that acts as the signal plate and which becomes more transparent to accelerated electrons as their energies exceed 2,000 electron volts.
- A layer of an insulating material such as low-density potassium chloride (KCl) to produce the secondary electrons.

The signal plate is held at positive potential with respect to the KCl target material, which is at ground potential when there is no charge on it. Therefore, there is a field across the KCl.

When the signal-plate voltage isn't too high, it is characteristic of such materials as KCl that conduction involves secondary electrons traveling through the interparticle volume of the material, rather than electrons moving in the conduction band. Under the influence of the electric field, therefore, most of the secondary electrons pass through the KCl and are collected by the signal plate, resulting in a large charge distribution on the target's surface. Thus the target has high gain, where gain is defined as the ratio of the charge produced on the target to the total charge of the incident electrons.

Furthermore, the slow decay of conduction-band electrons isn't a factor in neutralizing the charge during the readout process. There is no lag, therefore, as in the semiconductor targets employed in vidicon tubes; the target is almost completely neutralized in every scan.

At the same time, the target has a high resistivity—usually greater than 10^{17} ohm-cm. Although the target's capacitance is only a few hundred picofarads, the resulting RC time constant for a charge to leak off the target allows the target to accumulate charge during long exposure times.

The resistivity isn't a factor in readout, because the time constant during this process is determined by the "beam resistance"—typically on the order of 10^6 ohms.

Because of the target's high resistivity, there is no measurable dark current to contribute noise. That is, if no light is incident on the tube, there is no current flow in the target. System noise is determined by the noise figure of the preamplifier stage at the tube's output and by how well the system is shielded from spurious internal signals and external noise sources.

To maximize the charge buildup, and thus increase sensitivity, the tube is operated with the highest target voltage—about 25 volts—producing high-quality images. The granularity of the SEC target becomes apparent at very high target voltages.

Because the target has capacitance, the peak signal current varies directly with the exposure time. The longer the time, the greater the charge buildup and the greater the output current. Similarly, the larger the target area, the greater the signal output.

The signal current, which will vary inversely to the readout time, is approximated by

$$i_s = \frac{\Delta Q}{\Delta t_r}$$

where i_s is the signal current, ΔQ is the charge and Δt_r is the readout time. If the scan rate is reduced, the readout time increases at every point on the target and the peak signal current decreases.

waveform and will thus make D_2 conduct when the absolute value of the negative level is greater than the voltage established by R_1. Signals passed by D_2 are smoothed in the integrator circuit R_3, R_2 and C_2.

Since reflections from the LEM will produce wide variations in light level, the ALC/AGC loops must respond very rapidly to bright spots. The loops' time constant—2.2 seconds—is fast enough to correct the gain for bright spots as small as 5% to 10% of the over-all picture area.

After integration, the d-c voltage is divided and amplified to control the photocathode and AGC attenuator loops. The control element in both these loops isn't activated until a certain threshold is reached; the threshold level in the AGC portion of the tube is close to 0 volts.

When the light level is about 4 db below the saturation point of the tube, the ALC threshold is exceeded. As the light level increases, the ALC circuit reduces the d-c supply voltage into the photocathode supply from 15 to 3 volts. This changes the photocathode voltage from —8 kilovolts to —2 kilovolts, extending the tube's range.

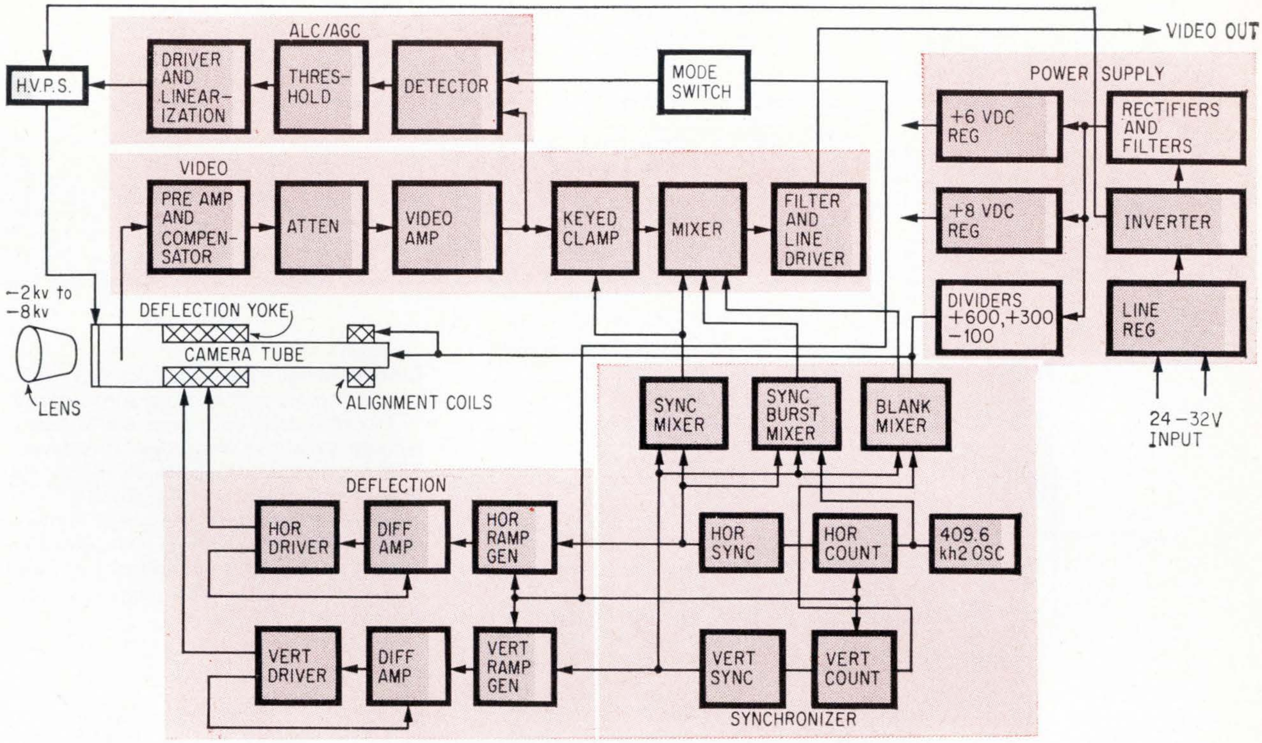
The ALC threshold is exceeded when diode D_3 starts to conduct. The point at which this happens is determined by the voltage on C_2 and the settings of potentiometers R_4 and R_5. R_5 is set to activate the AGC loop near 0 volts, while R_4 is set to actuate the ALC loop when the AGC regulation starts to deteriorate, and to provide a smooth transition between the two control loops.

Of the other integrated circuits, Z_4 includes components to set the threshold for the ALC circuit and the resistors needed for the three differential amplifiers. A correction network, Z_4, supplies differential amplifier Z_5 with a nonlinear signal that corrects for the nonlinear characteristic of the photocathode. Amplifier Z_6 is a low-output impedance circuit that drives the high voltage supply.

Video amplifiers

The video unit consists of the preamplifier that boosts the camera tube's output, two post-amplifiers, and the mixer that combines the video with the sync and blanking pulses. The mixer is a high-impedance source that produces 2 ± 0.1 volts across 100 ohms or 1 ± 0.05 volts across 50 ohms. The final output is the composite video waveform shown on page 186.

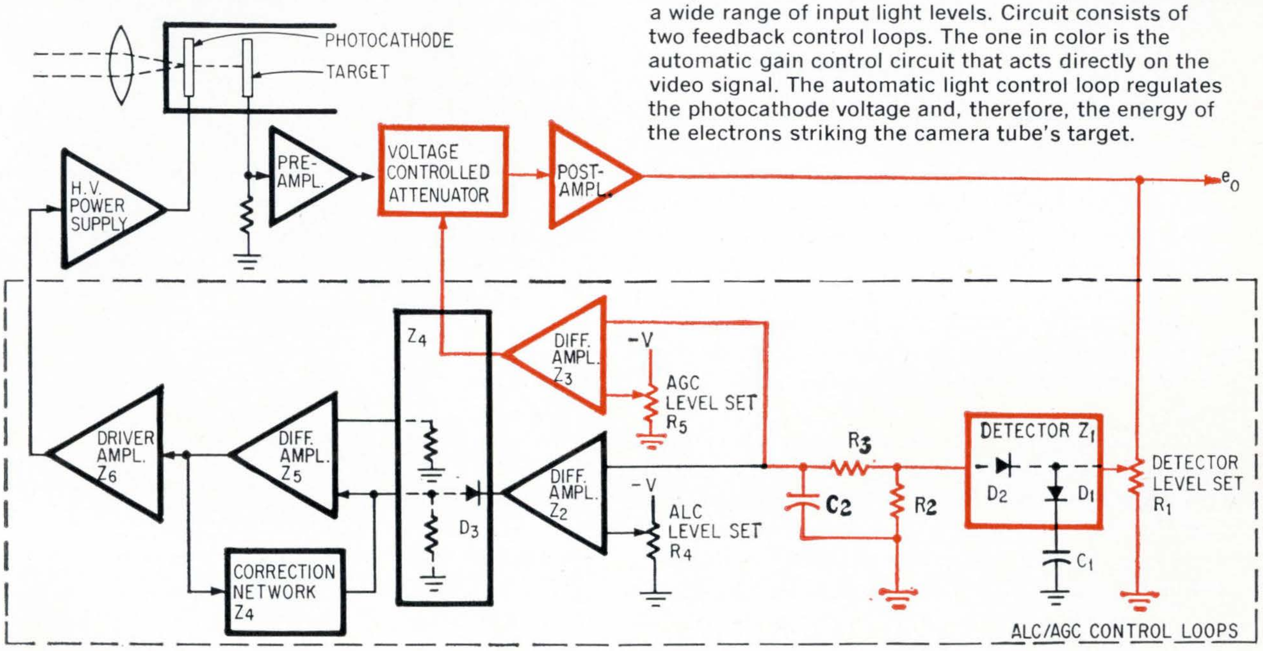
The over-all bandwidth is 2 hertz to 500 khz, with the upper frequency limit being the result of power allocations in the S-band transmitter. A filter between mixer and output stages reduces the signal 20 db per octave at frequencies above 500 khz.



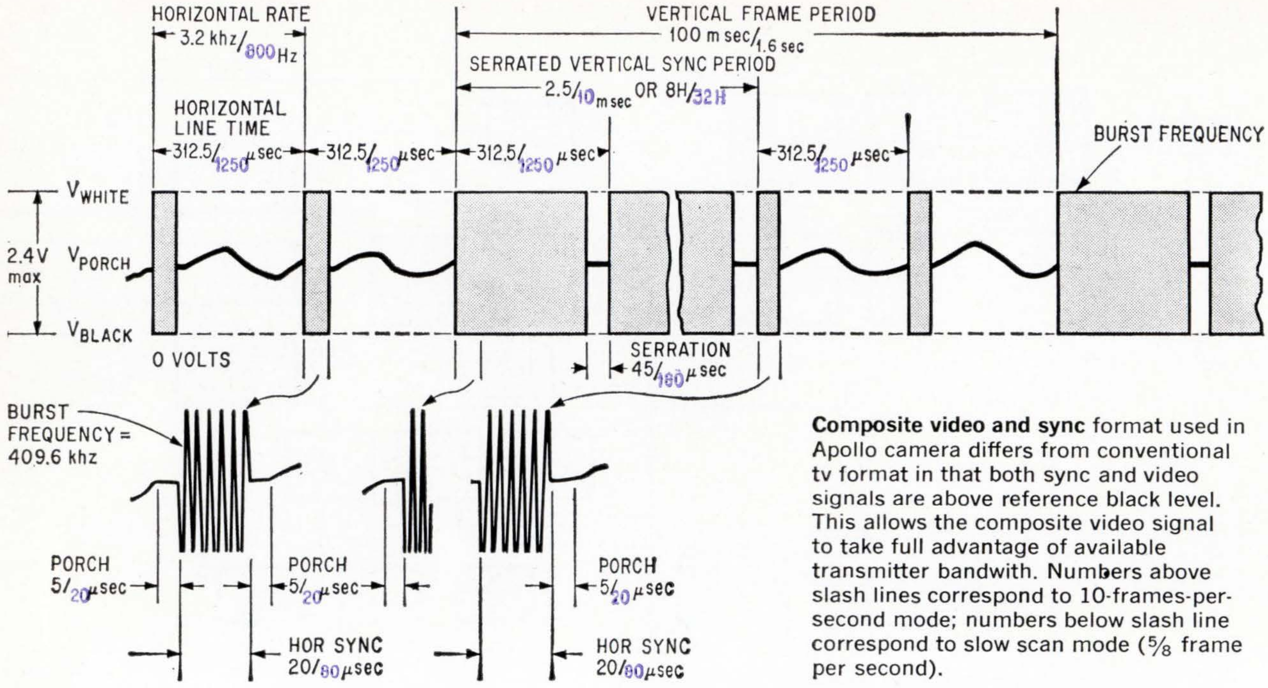
Camera's five major sections are shown in color in the block diagram above. Shaded portions indicate the percentage of integrated circuitry. Deflection circuits generate the waveforms to scan the tube. Camera's signal is controlled by the automatic light control and automatic gain control (ALC/AGC) circuit. Video signal is fed to S-band transmitter after amplification and mixing with synchronizing and blanking signals.

The 2-hz limitation is fixed by the amount of "droop" allowed in the slow scan mode. Droop is a change in amplitude caused by the loss of low-frequency components in the brightness signal; when viewing a uniform white scene, droop will cause the picture to have varying shades of gray. The 2-hz limitation is a compromise between acceptable droop and the increased size of the coupling capacitors that the amplifiers would otherwise require to improve the low-frequency response.

Three basically similar monolithic integrated circuits are used for the preamplifiers and post-amplifiers. The preamplifier is designed to compensate for the reduced frequency response that would be caused by the capacitance in the camera's target. The SEC camera tube has no detectable dark current, so low-noise performance is improved by reducing the noise in the preamplifier. A discrete



ALC/AGC control circuit holds video output constant over a wide range of input light levels. Circuit consists of two feedback control loops. The one in color is the automatic gain control circuit that acts directly on the video signal. The automatic light control loop regulates the photocathode voltage and, therefore, the energy of the electrons striking the camera tube's target.



Composite video and sync format used in Apollo camera differs from conventional tv format in that both sync and video signals are above reference black level. This allows the composite video signal to take full advantage of available transmitter bandwith. Numbers above slash lines correspond to 10-frames-per-second mode; numbers below slash line correspond to slow scan mode (5/8 frame per second).

field effect transistor is added to the input of the preamplifier to increase the input impedance and to reduce the equivalent-noise current from 0.5 nanoamperes to below 0.3 na.

Deflection circuits

Vertical and horizontal synchronizing pulses trigger ramp generators in the deflection circuits. The resulting sawtooth waveform drives one side of a differential amplifier stage while a feedback voltage developed by passing the yoke current through a small resistor drives the other. This amplifier drives a Class-B amplifier, which in turn drives the deflection yoke.

In conventional cameras, a resonant circuit drives the deflection yokes. This is possible at the higher scan rates of conventional units because the resonant circuits are small and economical. For slow scan applications, however, the reactance components would become excessively large and difficult to stabilize with temperature.

The Class-B amplifier in the Apollo camera can operate over a wide range of scan frequencies and is exceptionally good for slow scanning. The circuit has good stability and linearity, and the output is independent of temperature variations because a feedback circuit provides a low closed-loop gain of about 1.5-to-2 for the driver-differential amplifier combination. By changing a few components that control the timing and the output loading, the basic design serves for both horizontal and vertical sweeps.

To achieve great stability, the camera's synchronizer utilizes a crystal-controlled binary counter with gating and feedback to provide outputs for both the slow and fast scan modes. The oscillator, which operates at 409.6 khz ± 0.02%, utilizes a custom-designed monolithic circuit. Flip-flops or gates are contained in 13 other monolithic circuits.

The synchronizing pulse to the deflection circuits is a negative-going one of 4 to 5 volts. For the 10-frames-per-second mode, the horizontal sync pulses are 20 microseconds wide at a repetition rate of 3.2 khz; for the slower mode, the pulses are 80 μsec wide at 10 hz or 40,120 μsec wide at 5/8 hz.

Sync bursts of 409.6 khz with serrations, blanking pulses and sync pulses are also supplied to the mixer in the video circuit to produce a composite video signal that modulates the transmitter.

Other applications

A natural extension of the initial lunar-landing application would be the combination of an Apollo-type camera with a telescope to provide an unmanned lunar observatory. Signals from the earth could control the direction of the telescope.

Further, the SEC tube is available at this time for commercial uses. Among the applications being considered are:

- A rugged portable color camera for commercial broadcasting.
- A surveillance camera for security or industrial applications where there are fluctuating or extremely low light levels.

The camera may also find a place aboard ships and aircraft and at observatories and laboratories.

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2. A series of papers on SEC, advances in electronics and electron physics, Vol. 22A, 1966, Academic Press, pp. 219-291.

The Apollo lunar tv camera has been developed for the National Aeronautics and Space Administration under contract NAS 9-3548 out of the Manned Space Center, Houston, Texas.

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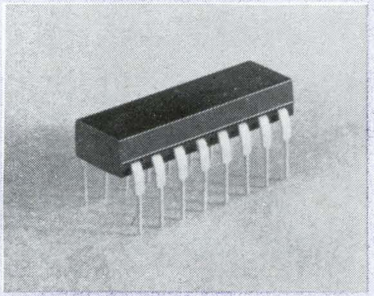

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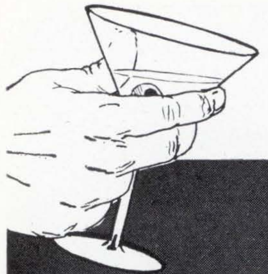

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From fundamentals clean FM, high stability, low FM noise, electronic fine tune, for communications, telemetry, FM broadcast.

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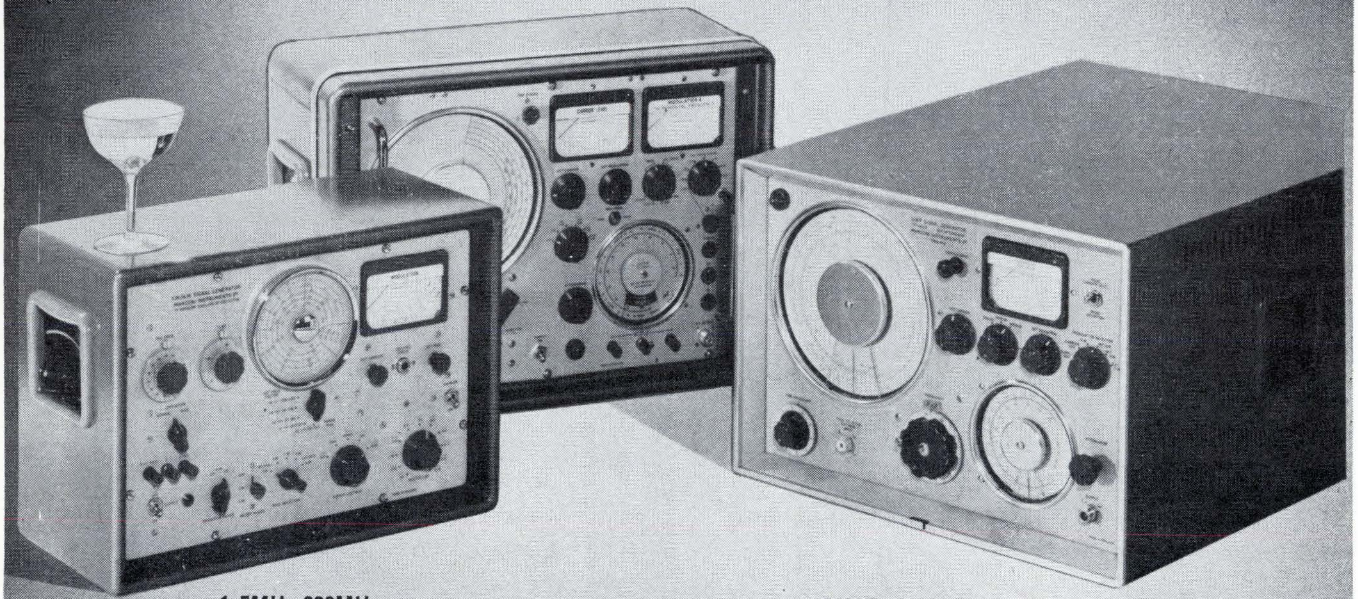

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A multiplier generator used in FM/AM broadcast, stereo and FM/AM communications, wide range, good AM and FM.

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A tuned line covers channels 14 thru 83 for FM sound, also telemetry, with FM deviation to ±300KHz, mod. rates to 100KHz.

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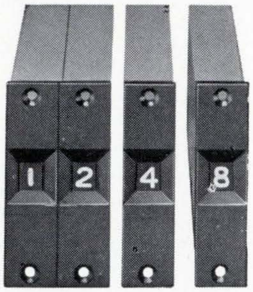
Circle 189 on reader service card

DURANT'S NEWEST!

Preview the latest in count/control advancements at IEEE, Booth 2H48-50



49600 UNISYSTEM®

New, single-level predetermining count/control system developed to meet the need for a small, inexpensive digital counter or timer. It provides direct digital reading, eliminating dial interpolation. Ideal for installation on control panels for machine tools, textile machinery, wire, machinery, metering and scaling equipment. This exceptionally compact unit is available as a standard unit equipped with 2, 3 or 4 Unipulser decades. Design permits it to be used equally well as a desk or panel mount without change. Important advantages include ease of presetting and resetting (panel or remote) . . . set-up and wiring simplicity . . . pre-determined visual setting is always retained. Count life and reset life proven for over 100 million counts. Count speed up to 30 cps. 115V — 230V, 50-60 cycles.

For more information circle No. 502 on Reader Service Card

6 YE SERIES ELECTRIC COUNTERS

These new 6 figure electric units have been developed for instrument or control systems, office machinery, data processing equipment where long life and high count speeds are required. Reset is optional, manual push-button or electric, with entire mechanism housed within the case. The 6 YE Series is available for base or panel mounting, providing permanent tamper-proof installation without extraneous hardware.

High accuracy and reliability are assured by an exclusive Durant drive feature: the power impulse cocks, power release counts, resulting in a uniform indexing force and smooth counting action.

Count speed is 2400 cpm DC — 1800 cpm AC (rectified). Models available for 115V, 230V AC or DC — other voltages on request.

For more information circle No. 504 on Reader Service Card

BCD UNIPULSER®

Durant Unipulsers are now compatible with count/control equipment using binary coded decimal systems. They are especially suited for use in data processing equipment, medical instrumentation, business machinery and more.

BCD Unipulsers use the 0-1-2-4-8 code and hook up easily with only 5 wires using standard connectors. Drive and visual readout is digital. Electrical readout is automatically encoded from digital to binary, eliminating the need and expense of code converters.

Important advantages include high count speed (40 cps), large readable figures, high current carrying capacity, and long life (proven for over 100 million counts). The BCD Unipulsers are the latest addition to the growing line of Durant decade modules, permitting you to count or control practically anything; hours, minutes, units, ounces, pounds, etc.

They are available in three models — 400 BCD non-polarized, 401 BCD with a common negative, 402 BCD with a common positive.

For more information circle No. 503 on Reader Service Card

DIGITAL CLOCK – ELECTRICAL READOUT

Hours, minutes, seconds or decimal combinations of any time period can be readout visually and electrically by this highly dependable unit. It can be used in data reduction systems . . . for controlling batching where timed mixing is important . . . to aid in computing piece rate in all production processes . . . for use in all types of data or material handling where a time base is required.

Three, four, five and six digit models are available as shown or without cabinet for 9½" panel or 19" relay rack mounting. 115V or 230V AC, 50 or 60 cycle. Prices start at $280.00.

For more information circle No. 505 on Reader Service Card

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Circle 191 on reader service card→

PROGRESS REPORT

ALSIMAG®

SMALL PRECISION CERAMICS "AS FIRED"

Five years ago we made guarded statements about meeting certain precision requirements with "as fired" ceramics in some configurations. Volume production of small alumina ceramics to close tolerances was the key to many electronic advances. There has been continual pressure for ever-smaller ceramics to still closer tolerances.

About once a year we have reported and illustrated our current abilities in this field. Each year progress has been made. It is based on hard won experience, employee training programs, specialized equipment and ability to control more variables.

Throughout most of this period our fast growing deliveries have not been satisfactory to us or to our customers. Now we feel that our staff of specially trained people plus our greatly enlarged production areas in both our Chattanooga and Laurens plants enable us to handle new volume requirements in agreed production time.

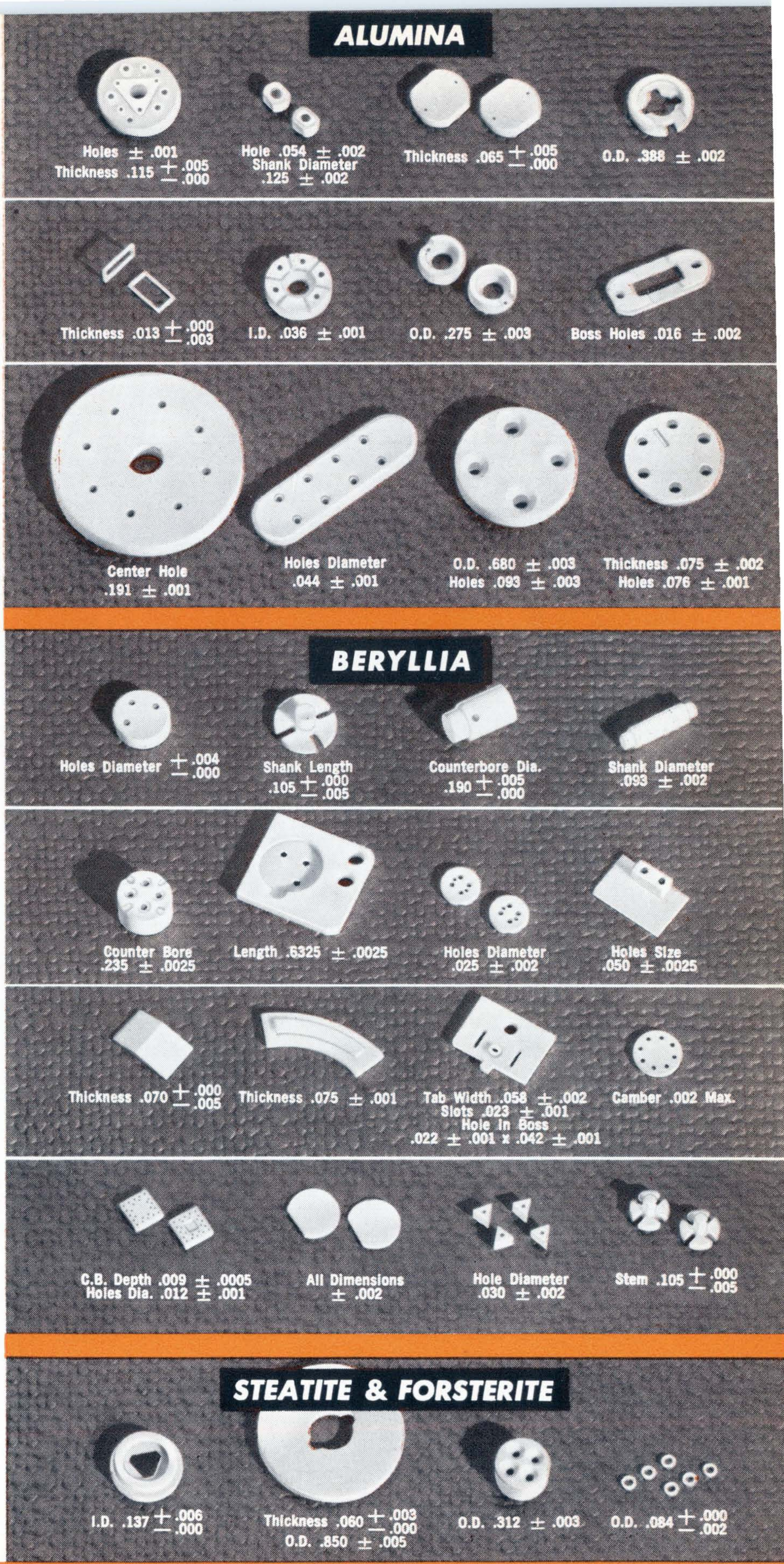
DELIVERIES

We will be glad to discuss your requirements and show you the current state of the art in precision alumina, steatite, Forsterite and beryllia ceramics.

PROGRESS IN BERYLLIA

It is often said that close tolerances on beryllia ceramics are difficult if not impossible. Small precision beryllia components are being processed regularly and in volume by American Lava. The favorable characteristics of beryllia, including its remarkable heat conduction, are thus available for a whole new range of applications.

Parts illustrated approximately actual size.



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American Lava Corporation 3M COMPANY

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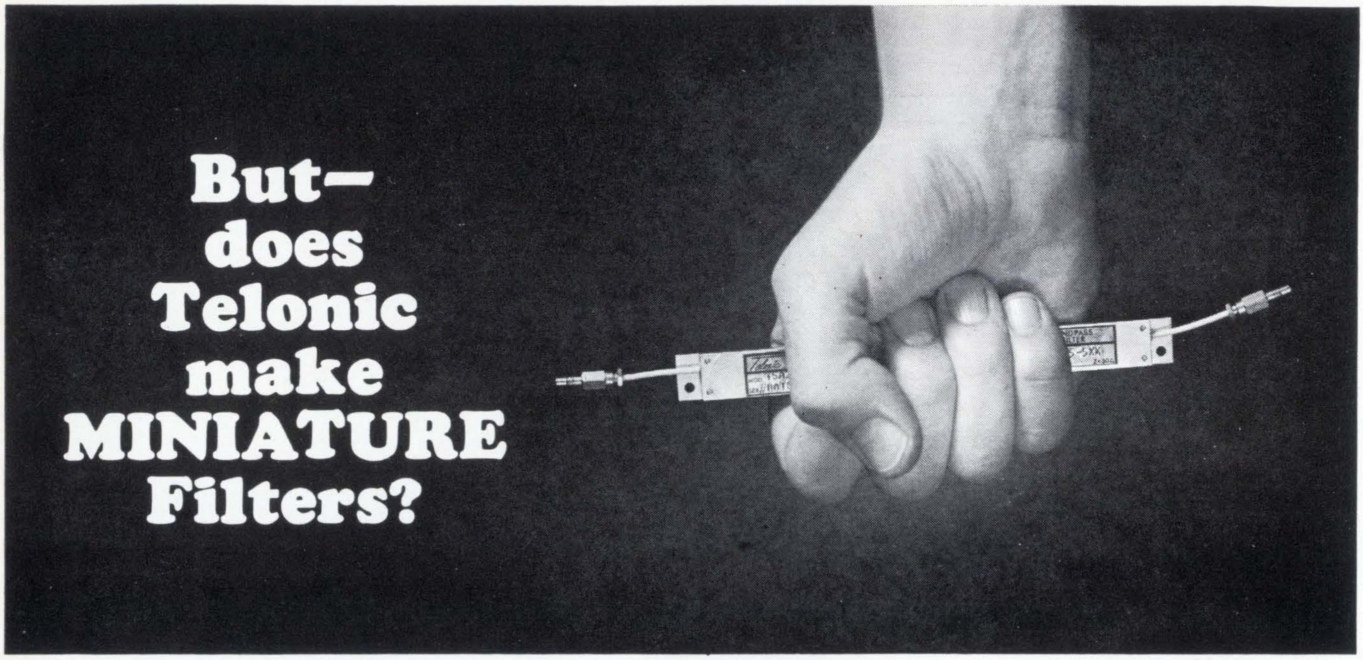

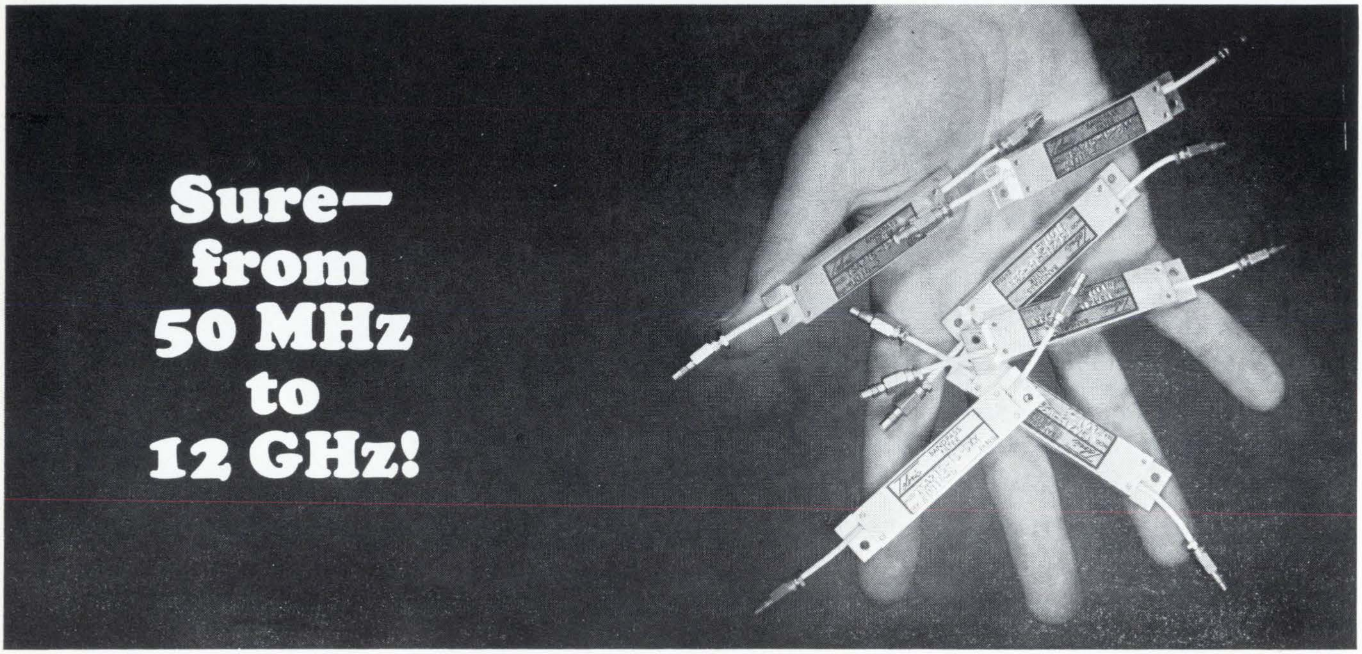

In fact, Telonic has made miniature filters longer than anyone in the business—miniature bandpass and lowpass in tubular, cavity, and interdigital types, with frequency coverage to 12 GHz.

The tabulation below indicates the extensive selection available to the design engineer. All series may be specified with OSM, BRM, Sealectro, or Micon connectors or cables and terminals.

Series	Configuration	Type	Frequency Range (Cut-off or Passband)
TLP	Tubular	Lowpass	100 MHz - 2750 MHz
TLR	Tubular	Lowpass	1000 MHz - 2750 MHz
TBP	Tubular	Bandpass	100 MHz - 2400 MHz
TCA	Cavity	Bandpass	1000 MHz - 3000 MHz
TCG	Cavity	Bandpass	2000 MHz - 6000 MHz
TCB	Cavity	Bandpass	1000 MHz - 2400 MHz
TCH	Cavity	Bandpass	6000 MHz - 12000 MHz
TIF	Interdigital	Bandpass	1000 MHz - 6000 MHz
TTA	Tunable Cavity	Bandpass	48 MHz - 4000 MHz
TSA	(Subminiature)	Bandpass	100 MHz - 1000 MHz

See Telonic at IEEE, Booths 2G02-2G10

If size is critical in your requirements, you won't have any trouble finding the filter to fit from Telonic's new catalog, C-101. It covers 20 basic series, shows insertion loss, attenuation, length, and connector types for an infinite number of filter variations.

But, if size **isn't** critical, then just consider Telonic filters for their performance—that's where they're very, very big. Now you hardly need a second source.

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Complete choice, including sub-miniature, fast recovery and high-power types. All popular configurations.

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Circle 193 on reader service card

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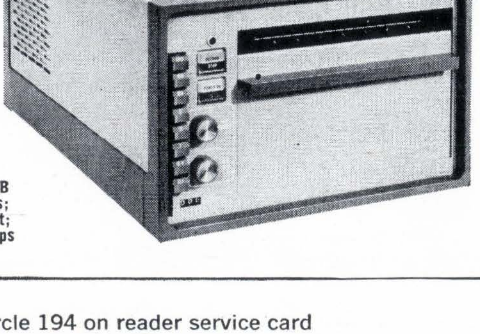
If you want a copy of the score, write or phone your nearest Midwestern **office.**



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36 channels;
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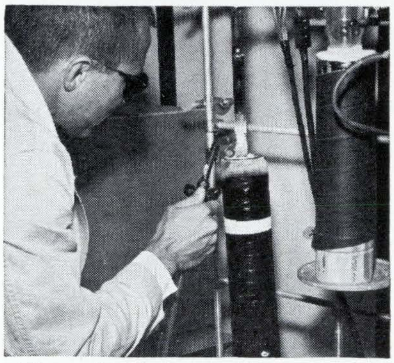
QUARTZ, LUCALOX® AND ELECTRONIC GLASS . . . SELECTED BY THE ELECTRONICS INDUSTRY TO MEET THE UNCOMMON CHALLENGE

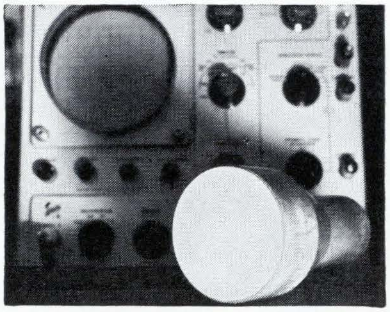
It's so hot it's freezing. This statement comes close to reality at Hughes Aircraft's Santa Barbara Research Center. They use G-E Type 204 fused quartz prepared for application in infrared detectors. In the process, a quartz tube is partially filled with semiconductor materials and evacuated. It is then torch-sealed at 1800°C



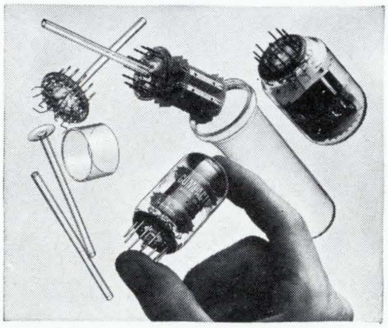
while one half inch away the same quartz tube is cooled by liquid nitrogen to –196°C. In half an inch, G-E fused quartz accepts a temperature gradient of 1994°C. Remember this fantastic capability of G-E quartz as you, in your own field, seek solutions to the uncommon challenge.

Circle 575 on reader service card

Ceramic-to-metal seals posed no problems for RCA when G-E Lucalox® ceramic was selected as the faceplate material in its multiplier phototube. This Lucalox application, a unique development in scintillation counters, not only simplifies nuclear detection systems but also makes scintillation counting more accurate. Why? The answer is in the high purity of Lucalox; its freedom from radioactive elements. Elimination of conventional graded seals results in sturdier construction which in turn reduces tube failures. Perhaps this evidence of Lucalox's ability to meet demanding ceramic-to-metal seal requirements will point the way to solving one of your problems in your industry. Translucent Lucalox®, 99% alpha alumina, has unique transmission characteristics for numerous applications.



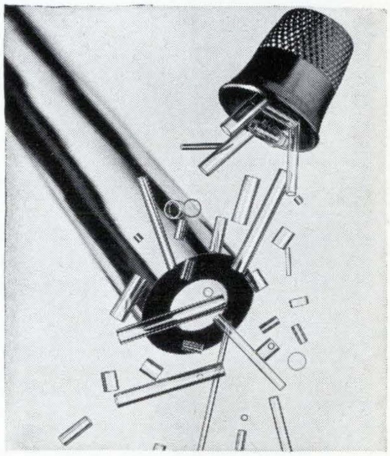
Circle 576 on reader service card



Over 100,000,000 have been made, so there must be something special about the G-E Compactron tube. There is. One Compactron, as produced by the G. E. Tube Dept., can do the work of up to three conventional vacuum tubes. But right here, we at the Lamp Glass Dept. think the Compactron can be used to illustrate our own capability in selecting specific glass types for specific applications. We provided three types for the Compactron: Type 008 lime glass, best for close tolerance forming of bulbs; Type 012 lead glass, best for preventing glass electrolysis in stems; Type 001 glass, best for close tolerance cutting of tubulations, in this case ± 0.5 mm. If you want electronic glass to do something for you, call us. We have the types and we know when to use which one.

Circle 577 on reader service card

Drawing .010 inch tube from one-inch lead glass stock is the artistry performed by Hanibal Glass in Santa Ana. Hanibal produces about 100,000,000 assorted tubes monthly, used as seals for electronic circuitry components. Seals of G-E Type 012 lead glass are virtually



inert, durable, stand up to heat and humidity and have excellent dielectric properties. Why does Hanibal use General Electric glass? Because tubing won't draw to .010 acceptably unless the one-inch raw stock has uniformity in wall thickness and weight. Quality control, as delivered by the Lamp Glass Dept., turns out to be the key to this advanced application of a versatile material you might give more thought to. Electronic glass.

Circle 578 on reader service card

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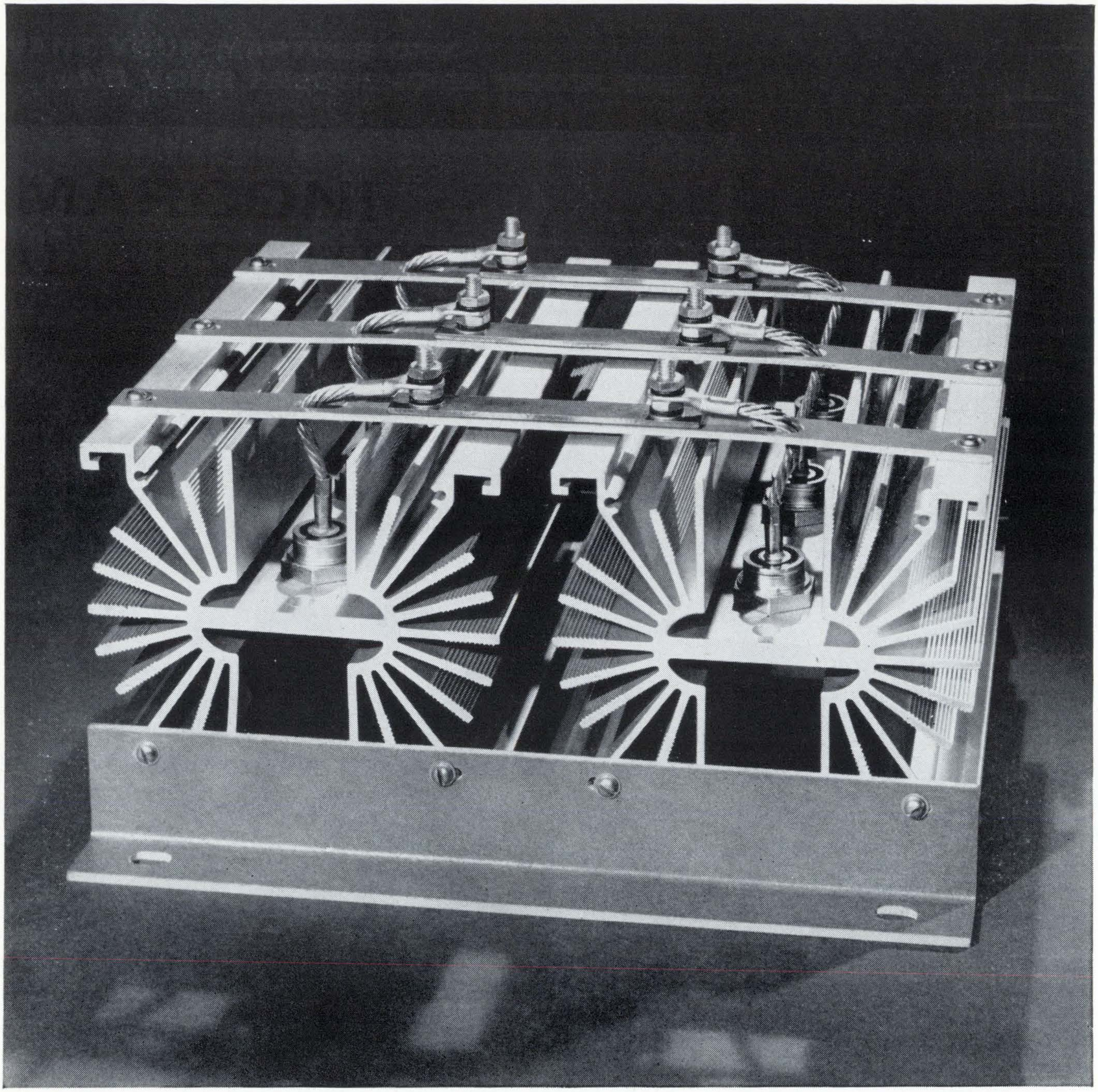

What's here besides Silicon Rectifiers and Aluminum Heat Sinks?

KNOW-HOW!

This 190 volt, 210 amp, three phase bridge rectifier stack is just six silicon rectifiers bolted into two aluminum extrusions. Simple? Of course it's simple, after somebody has determined the size permitted by the environment and somebody has evaluated dissipation to arrive at an effective heat sink configuration and somebody has surmounted the problem of transients that are always present where high voltage is employed. Not to mention the somebody responsible for producing the silicon rectifiers.

All these somebodies are Tung-Sol engineers. It is because of their know-how that Tung-Sol builds so many highly reliable silicon rectifier stack assemblies for so many companies. And we usually save them money when we do it.

Perhaps we can do the same for you? Why not write, describing your requirements? Our recommendations will place you under no obligation.

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Circle 197 on reader service card

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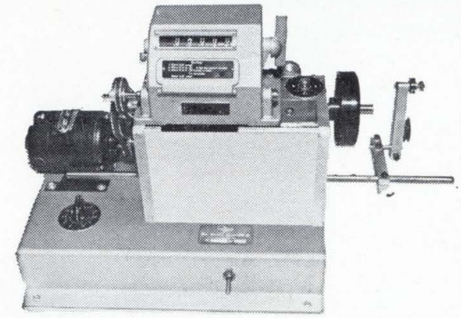
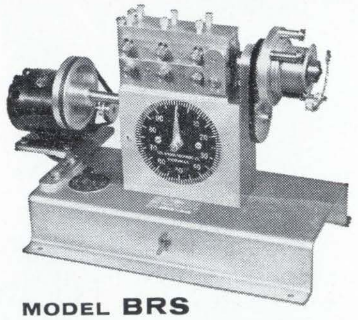


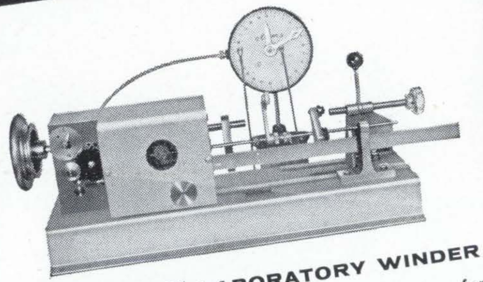
MODEL CS BOBBIN WINDER

Pictured is the current version of our most popular bobbin winder having increased capacities. A complete line of single and multiple units is available.



MODEL BRS PRECISION STRIP WINDER

This is one of a group of single-layer machines to wind on continuous or precut strips or mandrels of various shapes.

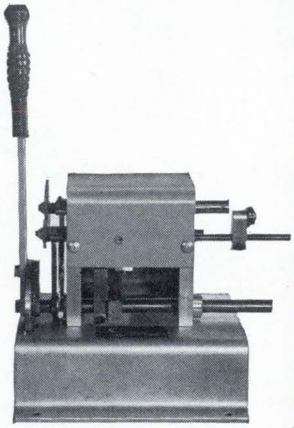


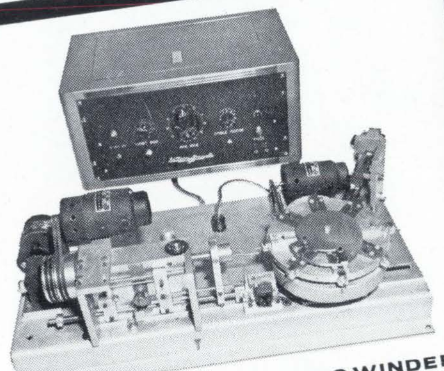
MODEL WX LABORATORY WINDER

The world's most versatile winding machine for all types of radio frequency coils as well as bobbins, transformers, resistors, etc. Features continuous gain or feed adjustment and our exclusive adjustable cam.

MODEL MP HAND WINDER

Coils with up to 60 turns produced in a single stroke of the lever.





MODEL CK-SL AUTOMATIC WINDER

The machine illustrated produces more than 20 completed coils a minute without operator attention. This is one of a large family of completely automatic or semi-automatic machines.

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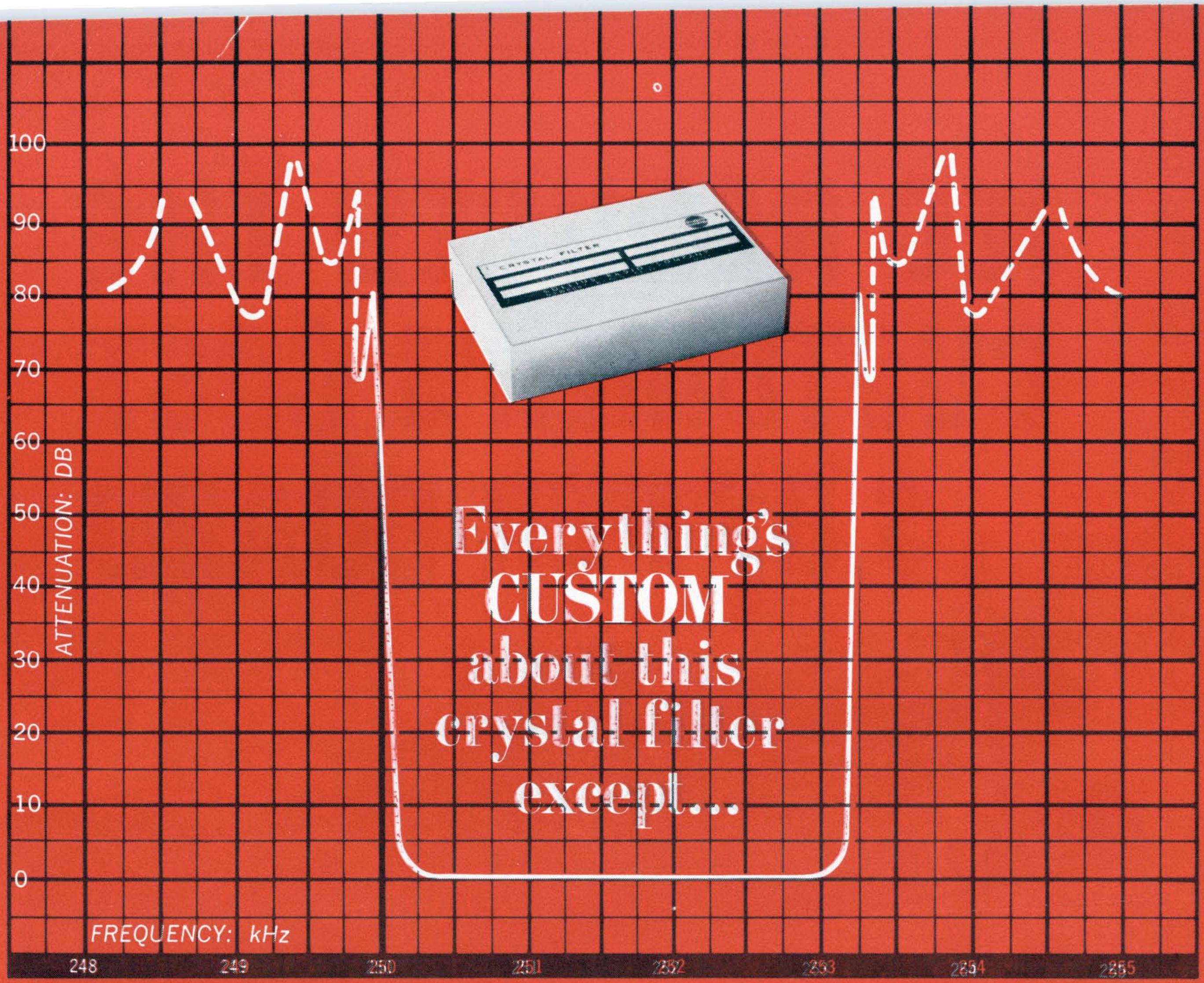

production, price, and delivery—they're STANDARD

Collins' prototype crystal filters with the response illustrated above are now available in the 100-kHz to 500-kHz region both in upper and lower sideband designs and to the following specifications:

Bandwidth at 1 db:	2780 Hz.
Bandwidth at 60 db:	3300 Hz.
Carrier rejection:	60 db min.
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Collins' crystal filters meet most narrow band needs (from 5 kHz to 20 MHz) in designs such as Butterworth, Tchebycheff, and Linear Phase. Prototypes to your specifications are generally available in four to six weeks. Collins' crystal filter capability is expanding rapidly. Send your specifications for design analysis. As one of the largest suppliers, Collins satisfies delivery requirements for all major programs.

Collins' entire filter product line covers the practical spectrum from 1 kHz to 100 MHz, offering LC and mechanical filters for applications where crystal filters are not suitable. If an advantage can be obtained in performance, price, or delivery through LC or mechanical filters, Collins is in a position to recommend these filters rather than crystal filters.

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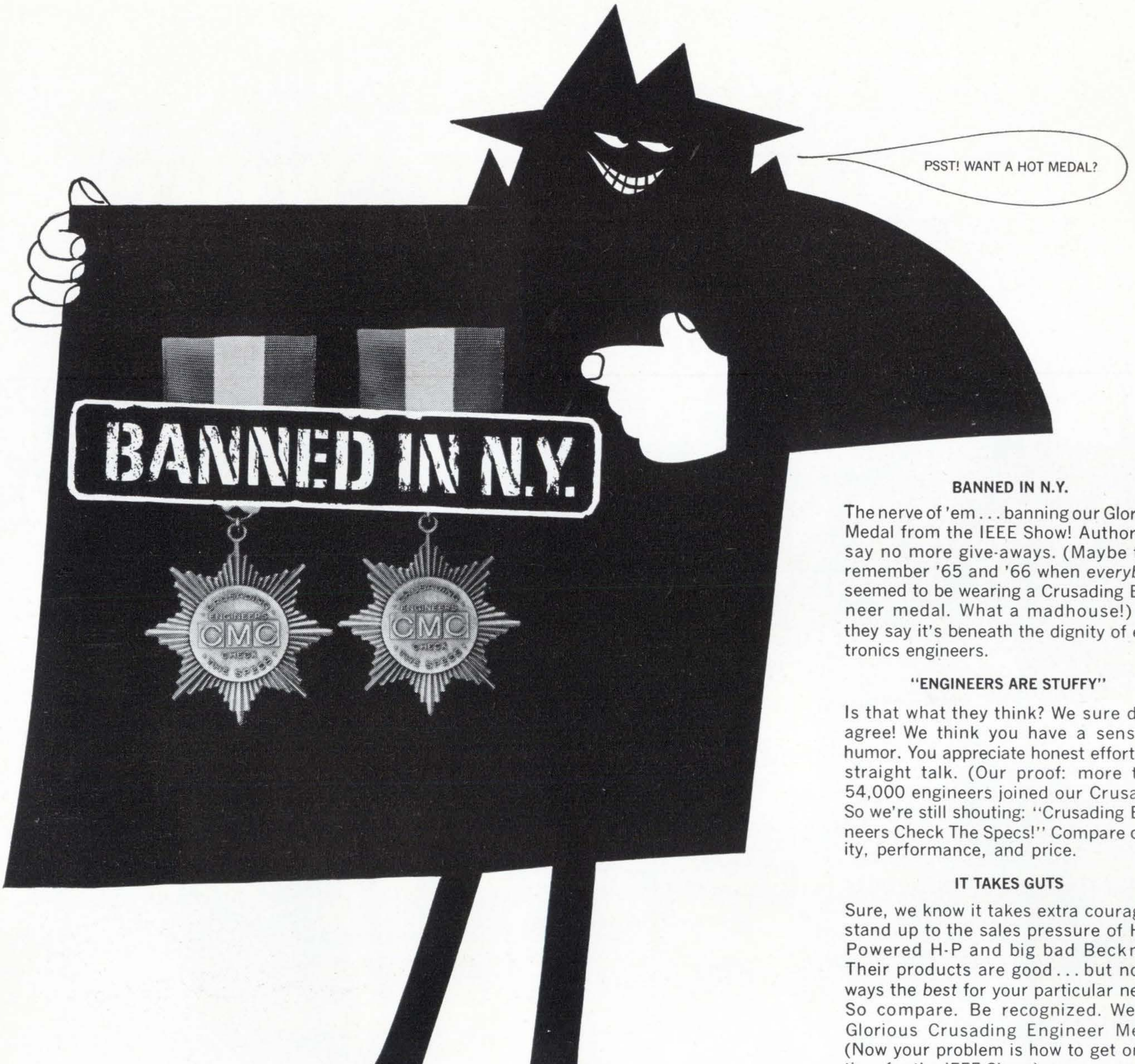
Circle 201 on reader service card



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The nerve of 'em . . . banning our Glorious Medal from the IEEE Show! Authorities say no more give-aways. (Maybe they remember '65 and '66 when *everybody* seemed to be wearing a Crusading Engineer medal. What a madhouse!) But they say it's beneath the dignity of electronics engineers.

"ENGINEERS ARE STUFFY"

Is that what they think? We sure don't agree! We think you have a sense of humor. You appreciate honest effort and straight talk. (Our proof: more than 54,000 engineers joined our Crusade.) So we're still shouting: "Crusading Engineers Check The Specs!" Compare quality, performance, and price.

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Sure, we know it takes extra courage to stand up to the sales pressure of High-Powered H-P and big bad Beckman. Their products are good . . . but not always the *best* for your particular needs. So compare. Be recognized. Wear a Glorious Crusading Engineer Medal. (Now your problem is how to get one in time for the IEEE Show.)

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NO-SHOW?

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Then, next time you talk to an H-P or Beckman salesman, wear your medal. You'll see grown men cry.

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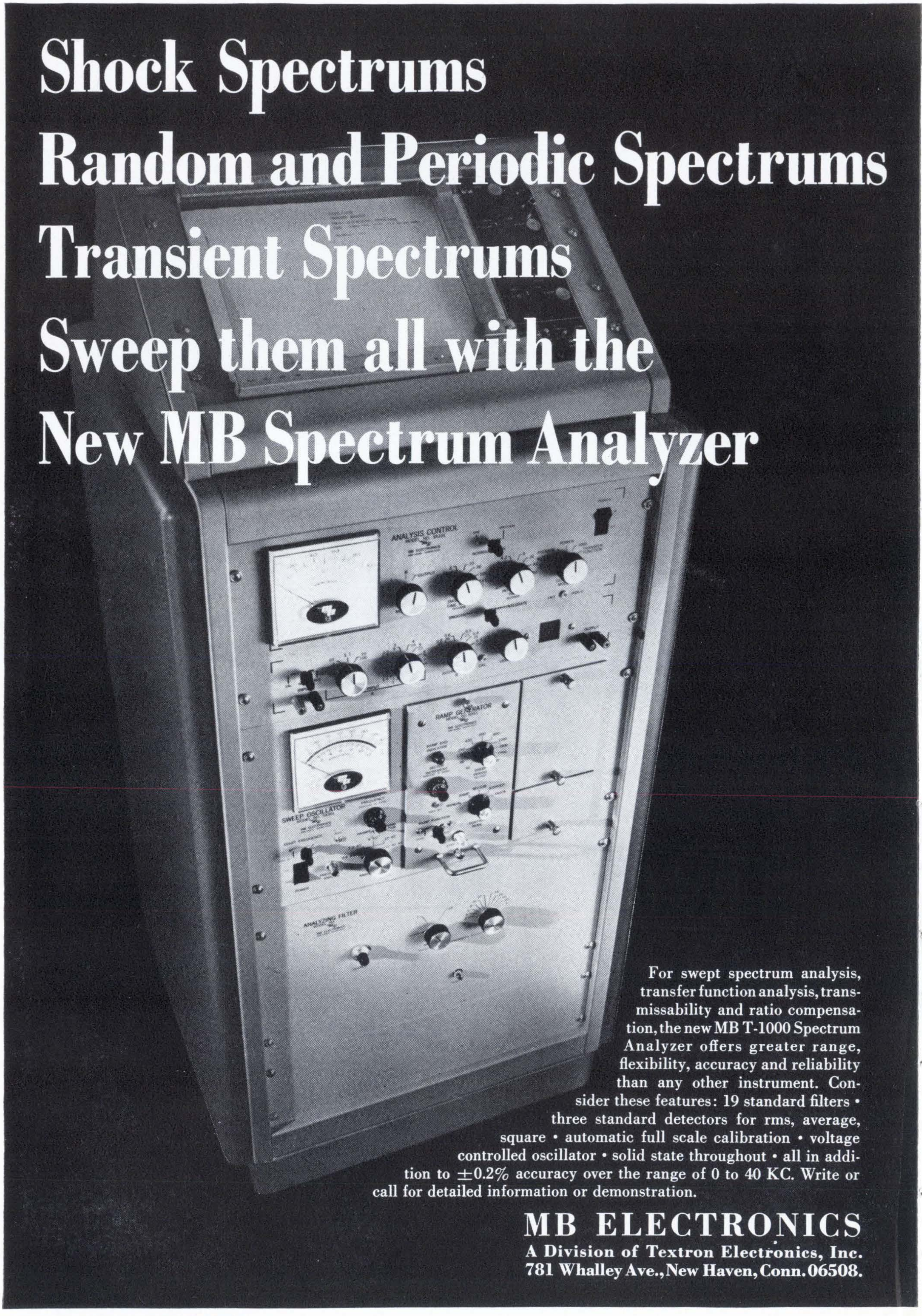
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New MB Spectrum Analyzer
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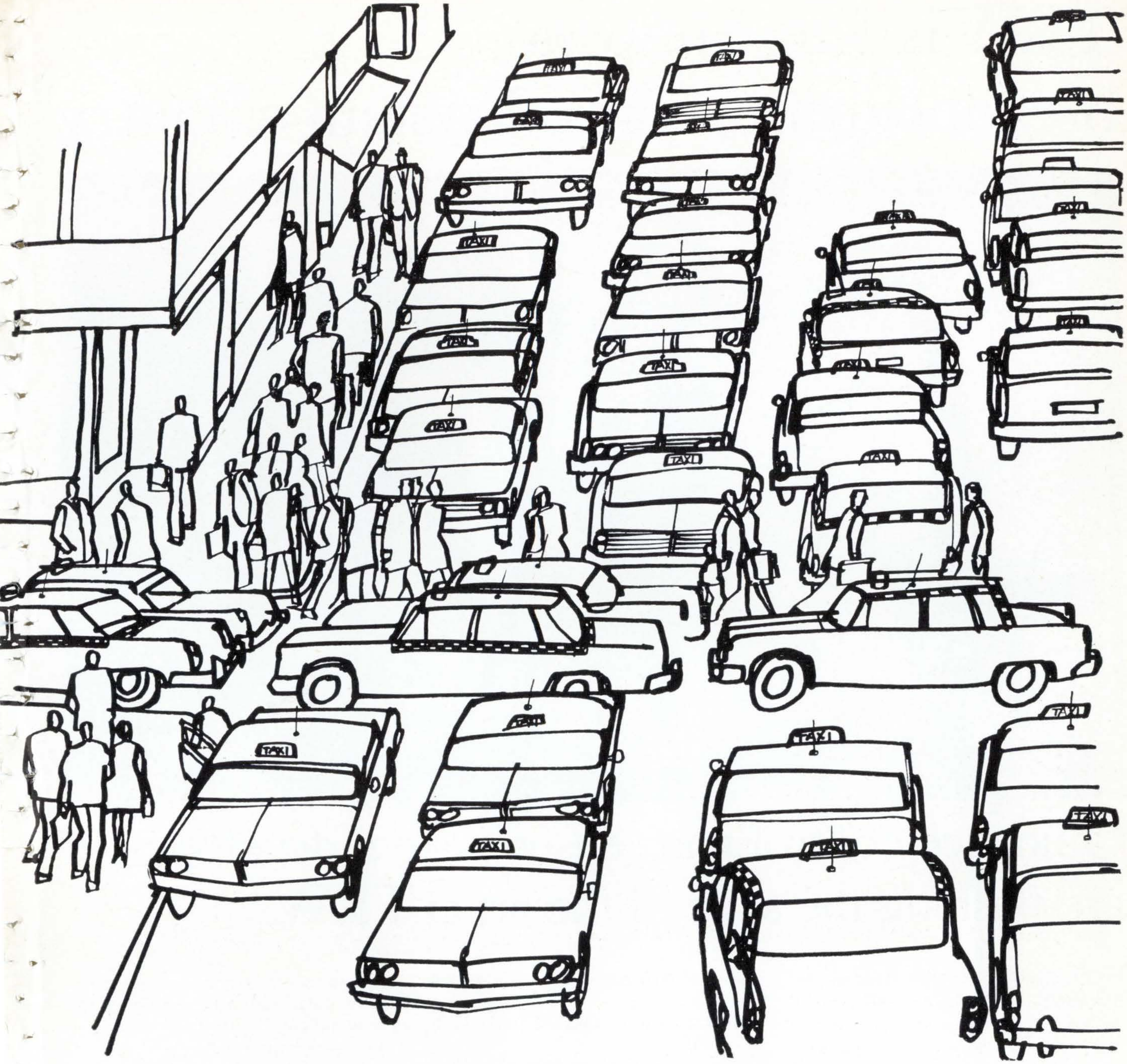

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ONE 8637—PUSH-PULL
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50 MHz	PLATE	OUTPUT	DRIVE
CCS	375v.	25w.	0.67w.
ICAS	450v.	34w.	0.82w.
PTTS	**600v.**	**84w.**	**0.86w.**
175 MHz			
CCS	300v.	18w.	1.4w.
ICAS	350v.	26w.	1.6w.
PTTS	**560v.**	**63w.**	**2.2w.**

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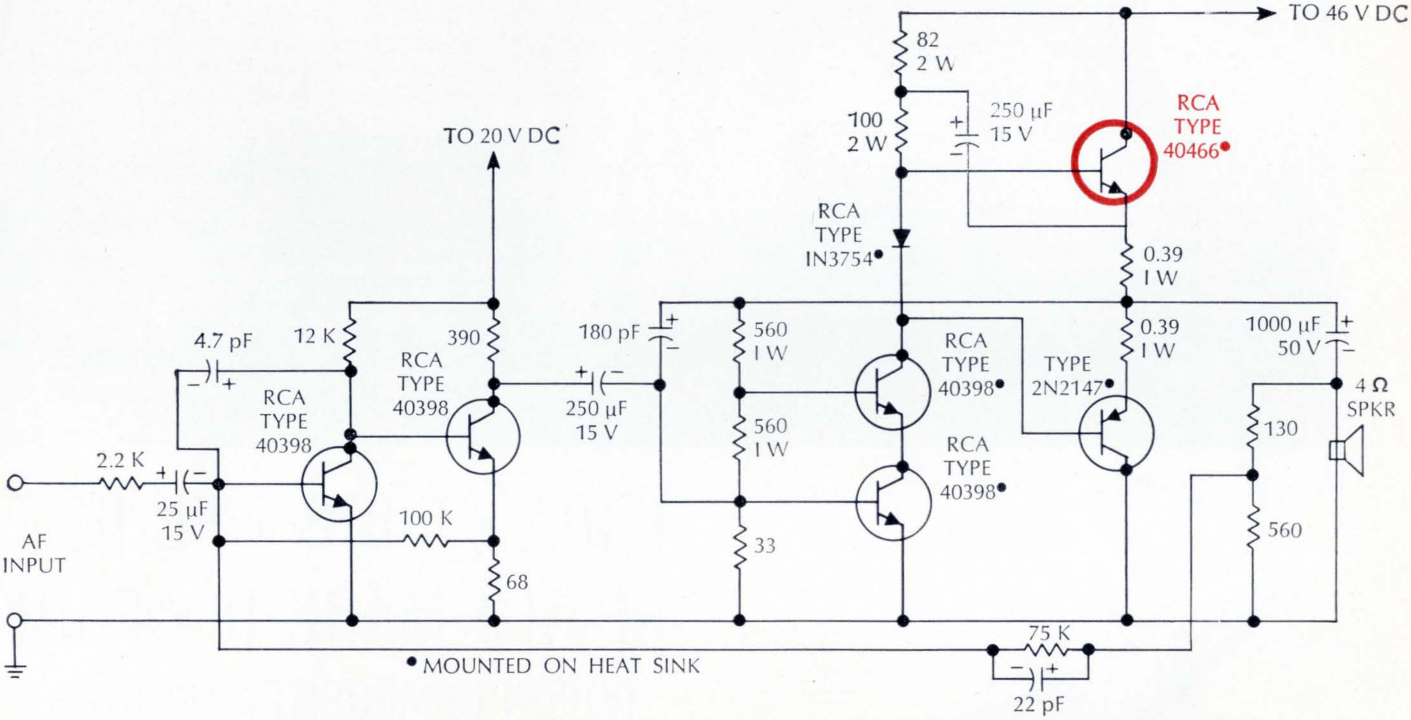
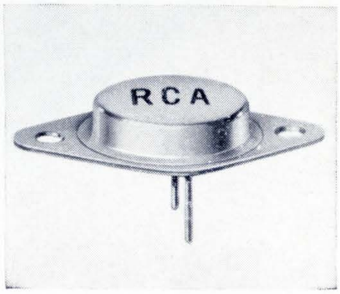


you can now design economical complementary-symmetry audio power amplifiers with extended high frequency response...simple driver requirements...and low distortion!



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RCA's new 40466 silicon n-p-n power output transistor lets you combine real high fidelity performance with superior electrical ruggedness and the economy of *transformerless design*.

You can get 50 watts music power per channel in the circuit shown when the 40466 is complemented with the high-performing RCA 2N2147 germanium drift-field power transistor. Together they make a low cost output pair.

Response is flat from 10 Hz to 80 KHz . . total harmonic distortion at 20 watts with a 1 KHz signal is 0.13% . . . 0.05% at 1 watt.

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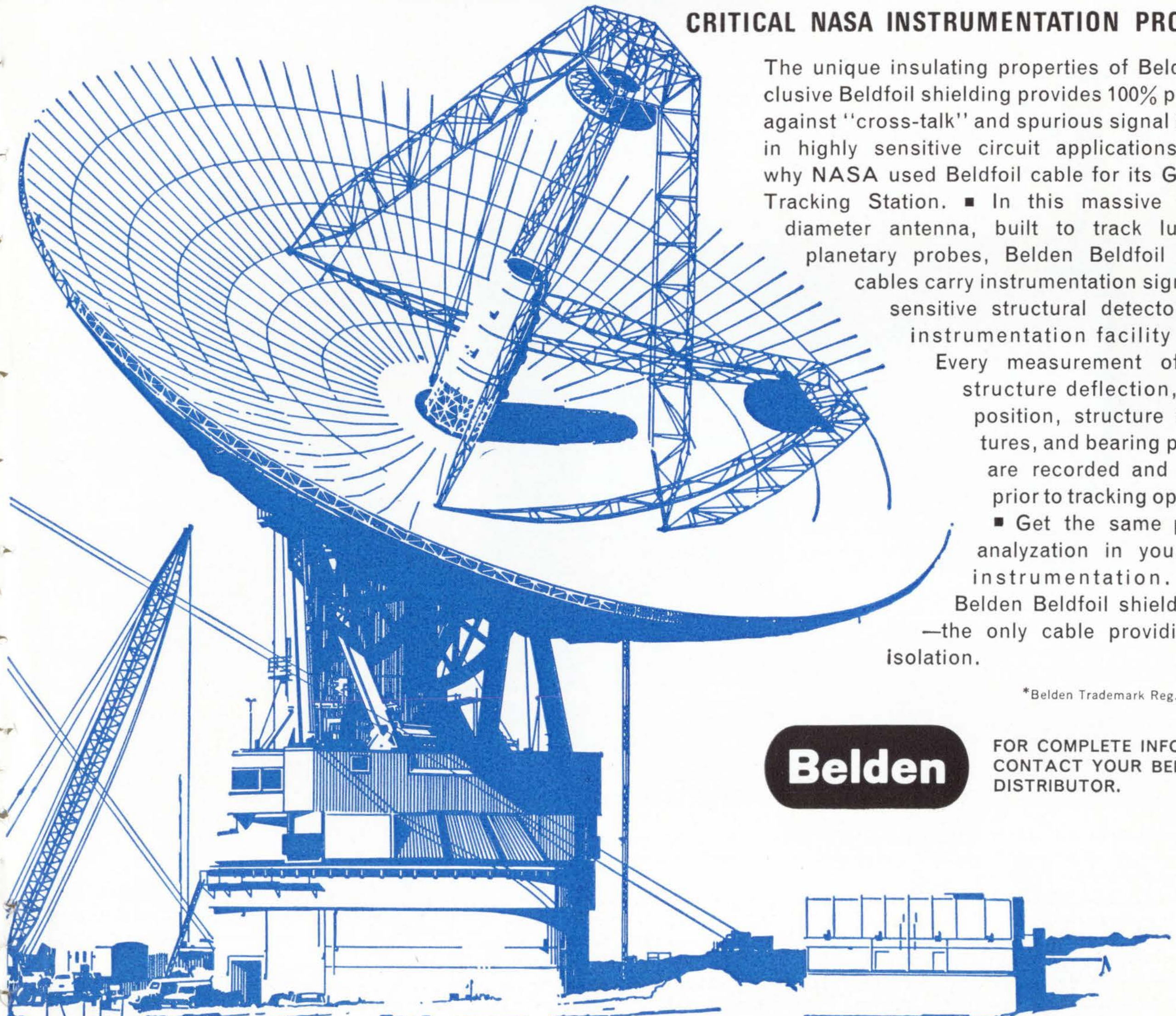

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Probing the News

Manpower

Electronics engineers are fair game

With graduates becoming choosier and experienced specialists warier, the scramble for talent is becoming more intense and wide ranging

"If 300 of the right electronics engineers walked in this door right now, I could find a job for them." The open door is at Lockheed Missiles & Space Co. in Sunnyvale, Calif., and the speaker is Lloyd Leoma, supervisor of employment. Over-all, the division of Lockheed Aircraft Corp. is beating the bushes for 1,000 electronics engineers.

Up the coast in San Francisco, an employment agency manager, John M. Harris, says: "We're down 40% in the number of qualified applicants from a year ago, and up 25% or more in job requests from electronics firms. There just aren't as many men available."

In Boston, the Raytheon Co. is urgently seeking 935 engineers for four New England divisions.

In New York City, Careers Inc., a recruiting organization, has booked 200 hotel rooms for interviews during the four-day International convention of the Institute of Electrical and Electronics Engineers, which opens March 20. Last year the firm represented 40 companies at the convention and attracted over 1,300 job-seeking engineers. This year it is back representing even more firms.

Paradox. This contest for electronics engineers, however, is being staged against a strange backdrop. While recruiters point despairingly to the problem of finding enough warm bodies, the threat of layoffs hangs over the semiconductor and consumer-oriented sectors of the industry. At some companies, one division will be hiring while another is laying off engineers.

Companies that have had to furlough engineers recently include the National Video Corp., Motorola Inc., and the appliance division of

Where the jobs are

	types of engineers	openings
East		
General Precision, Aerospace Group	circuit, systems	150
Lockheed Electronics	radar, antenna, circuit	175-200
Grumman Aircraft Engineering	systems	200
General Electric Missile and Space division	design	200
Sperry Gyroscope	design, systems, inertial	200
Westinghouse Electric Defense and Space Center	radar	300
Southeast		
Lockheed-Georgia	design, systems	100
Pan American World Airways	radar, communications	100
Radiation	systems, computer	150
Douglas Aircraft, Missile and Space division	computer	75-100
Southwest		
Collins Radio, Dallas	systems	200
Texas Instruments	circuit design, semiconductor	600
General Dynamics, Ft. Worth	systems, electromagnetics	200
Ling-Temco-Vought	digital, electro-optics	200
Midwest		
Control Data (nationwide)	circuit design, logic	200-250
Automatic Electric	solid state, packaging	175
Conductron	computer, radar	200
AC Electronics	circuit design, systems	50
New England		
Raytheon	circuit design	935
Microwave Associates	microwave, solid state	50
Mitre	communications, data processing	70-80
Honeywell, Electronic Data Processing division	computer development	100
West Coast		
Ampex	circuit design, audio	100
Lockheed Missiles and Space	communications, circuit	1,700
Fairchild Semiconductor	circuit, product	150
Varian Associates	instrumentation, circuit design	150
Litton Industries, Guidance and Controls Systems division	computer design, control systems	50-100
Hughes Aircraft	circuit design, radar	525
Autonetics	systems, circuit	800
TRW Systems	guidance and control, communications	1,450

the General Electric Co. Pending solution of a production problem in a project for the National Security Agency, a layoff of engineers at the Santa Clara, Calif., plant of Philco-Ford's Microelectronics unit is a distinct possibility.

Yet from coast to coast, the documented demand for engineers is awesome. The war in Vietnam, generally booming business conditions, and a high over-all employment rate have combined to make the good, specialized engineer a prize. The stress, however, is still on the specialty. Highly paid engineers in such comparatively narrow areas as the Gemini program, which is being phased out, are looking for jobs, while companies in the Southwest are searching for hundreds of people. In particularly strong demand are circuit engineers, communication experts, and systems and computer men.

I. Elusive prey

Recruiters are out in greater numbers than ever before. And they are finding their quarry harder to bag. He's demanding a higher salary. He's less anxious to move. He's harder to find.

Most personnel men see the problem as a continuing one. "There are fewer engineers around than a year ago," says Robert Condon, personnel manager at Microwave Associates, Burlington, Mass. "The supply has dwindled, if anything, and the demand is growing at an increasing rate."

To snare their game, the recruiters are sticking with tried-and-true methods. They're offering higher salaries to lure engineers away from competitors, putting greater emphasis on college recruiting, offering more money than ever for referrals—up to $250 in some cases—and looking overseas.

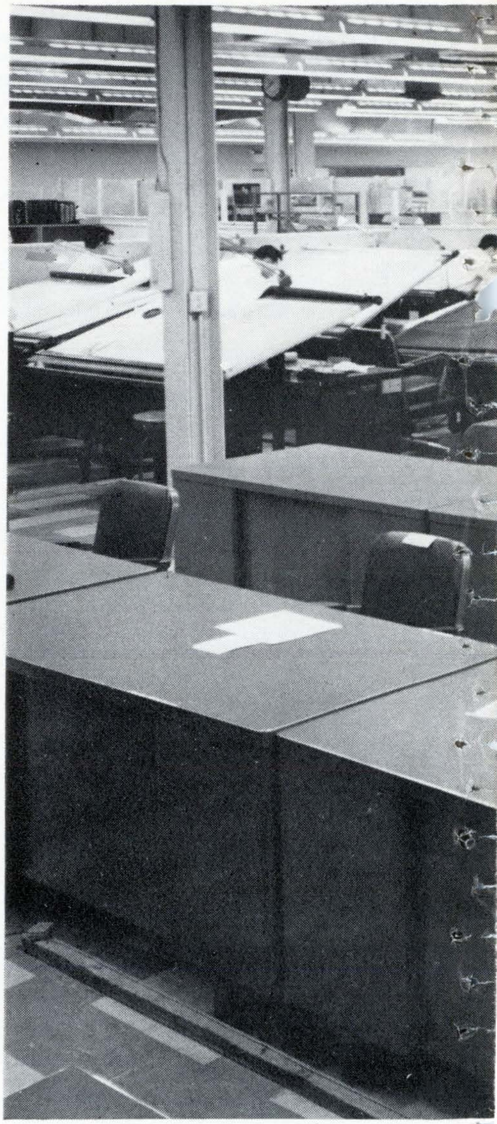
Far afield. The latter method is catching the attention of more and more companies. One reason, explains William A. Douglass, president of Careers Inc., is that the quality overseas is better. He says that four or five out of a dozen British applicants get to the interview stage; the proportion in the U.S. is nearer one in 10. Douglass estimates that about 50 U.S. firms are recruiting overseas right now, particularly in Britain.

Personnel men report good results from abroad. The Ampex Corp., Redwood City, Calif., makes two trips a year to England, and has hired 15 product and circuit engineers there. Lenkurt Electric Co., a subsidiary of the General Telephone & Electronics Corp., has an urgent need for 25 circuit designers and is recruiting in Europe for the first time in six years. Fairchild Semiconductor, a division of the Fairchild Camera & Instrument Corp., made a successful trip to Europe last fall and plans to go again in two or three months.

II. Back to school

Another favorite recruiting ground is the college campus, but here, too, competition is stiffer.

At Case Institute of Technology in Cleveland, 442 companies, 30% more than last year, have scheduled interviews this spring with graduating seniors and graduate students. Last year some 740 companies courted the 725 engineering graduates at the University of Illinois. The February 1967 graduating class numbered 260 graduates, the recruiting companies 500. Efforts to hire the approximately 500 engineers graduating this June have already started, with 40 companies on the Illinois campus now.



Empty desks at General Precision Inc. are scrambling for available manpower

Thomas W. Harrington, director of placement at the Massachusetts Institute of Technology, observes that concerns are now more willing to interview for summer employment. "It's a long-range gamble for the company," he says, "but it seems to pay off."

Harrington describes the current situation as "the most hectic" in 10 years. About 2,000 degrees of all kinds will be awarded at MIT this year, some 800 being bachelors' diplomas. But Harrington notes that, on the average, 79% of those receiving bachelors' degrees continue their education, and he expects this to hold true this year.

Babysitters. Responding to the challenge, corporate recruiters are beginning to rival professional football scouts in their resourcefulness

Screen tests

Some theatrical ability may help an engineer undergoing a 20-minute, video-taped interview at a certain Los Angeles studio. He won't get into the movies, but he may get his Big Break in the electronics industry.

His performance will be watched by prospective employers all over the country. The system, developed by H.H. Harberts of Harberts Associates, a Beverly Hills, Calif. firm that specializes in placing scientists, engineers, and professional managers, is designed to replace the cross-country trips made each year by recruiters and job hunters.

Harberts says the taped interviews provide an "extremely high order of preselection." A refinement of the screening process, they are used mainly to eliminate marginal candidates for jobs. Harberts Associates plans to open other interview studios in 10 more cities by April.

indicate the shortage of professional electronics engineers; recruiters to staff design facilities and research laboratories.

and aggressiveness. They get out to the campus early to secure the names of the students so they can send letters of invitation. Many send telegrams to remind students of scheduled interviews. Some even phone the students' homes or give prospects a dollar just to fill out a questionnaire.

Despite these efforts, many interviews are cancelled. The reason, says Dale Barbee, director of student placement at Case, is that the number of companies in search of employees is increasing while the number of students is holding fairly steady.

Jerry Hall, employment manager at Sylvania Electric Products Inc., a General Telephone subsidiary in Mountain View, Calif., agrees. He says his company is attracting fewer graduates than usual because the number of companies recruiting on campuses has more than doubled since last year. And Frank McCarter, employment manager at Litton Industries Inc.'s Guidance and Controls group, says: "We would like to fill about 25% of our engineering needs from college, but we only talk to the top one-third and they're hard to get." Litton usually ends up filling 15% of its new job openings with recent college graduates, according to McCarter.

III. Playing hard-to-get

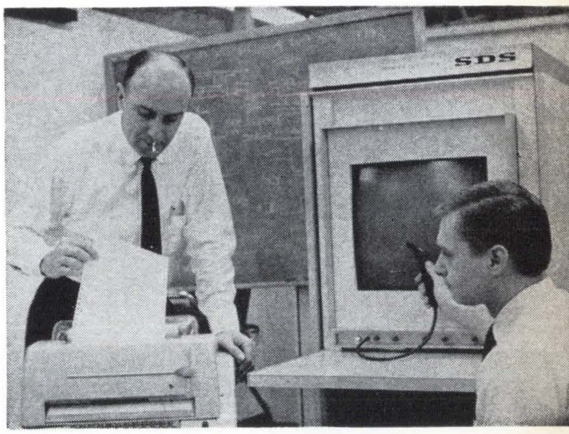
With an increasing number of graduates, many of them concerned about the draft, going on to work on advanced degrees, the available talent is getting choosier about the sort of job offers it will consider. Many students, taking the big pay packet for granted, are more interested in the level at which they would enter a company and their prospects for promotion, possible graduate work, and membership in prestigious professional societies.

With all of the attention being paid to the student, however, it isn't surprising to find that he's also asking for more money. "It's not unusual for the college student to be offered $9,450 a year," says Barbee of Case. Hall of Sylvania finds that new graduates with masters' degrees are asking $10,000 and up right off the bat. What's more, they're getting it. Larry Dooley, manager of personnel for the Bendix Corp.'s Launch Support division at Merritt Island, Fla., says a brand-new electrical engineer can expect $7,500 and up, depending on his background, his class standing, and the reputation of his college.

Like his younger colleague, the experienced engineer making a move is asking for, and getting, more money, but there is some disagreement as to how much the increase comes to.

For instance, most recruiters in the Southeast report a leveling off in the rate of salary rises at about 5%. But on the West Coast, the home of so many aerospace concerns, recruiters see no such leveling off. John Doolittle, personnel manager at Ampex, says engineers moving to new jobs can expect a 10% to 15% pay increase. James Pietrowsky, at the Autonetics division of North American Aviation, Inc., Anaheim, Calif., concurs. "Engineers won't move for less than a 10% salary hike, and they'll often ask for 15% without batting an eye," he says.

However, a fellow Californian



Brand new Case graduate learns the ropes at Goodyear Aerospace.

disagrees. Philip M. Oliver, director of industrial relations for Philco-Ford's Western Development Laboratory, estimates that engineers contemplating moves are being offered wage boosts of around 5% to 6% and he sees no acceleration in this rate.

Overpricing. In some sections of the country, recruiters report that companies aren't hiring specialists because of the high salary demands. Bernard A. Watts, manager of salaried personnel at Goodyear Tire & Rubber Co.'s Aerospace division, Akron, Ohio, declares that there aren't as many outfits looking for engineering specialists because the companies' budgets just can't afford them.

Salaries for experienced engineers range all over the lot. Daniel Hahn, employment manager at the Cocoa Florida State Employment Service, says starting wages for holders of bachelors' degrees range from $8,000 a year to $14,000 or $15,000, and from $18,000 to $20,000 where supervision of a fairly large group is required.

Information Sciences Inc., a recruiting firm that uses a computer to match engineers to job openings, says that on the basis of 1,600 resumes from electrical engineers all over the country, the average annual income is $13,620 for those with bachelors' degrees, $15,288 for masters, and $17,484 for Ph.D.'s.

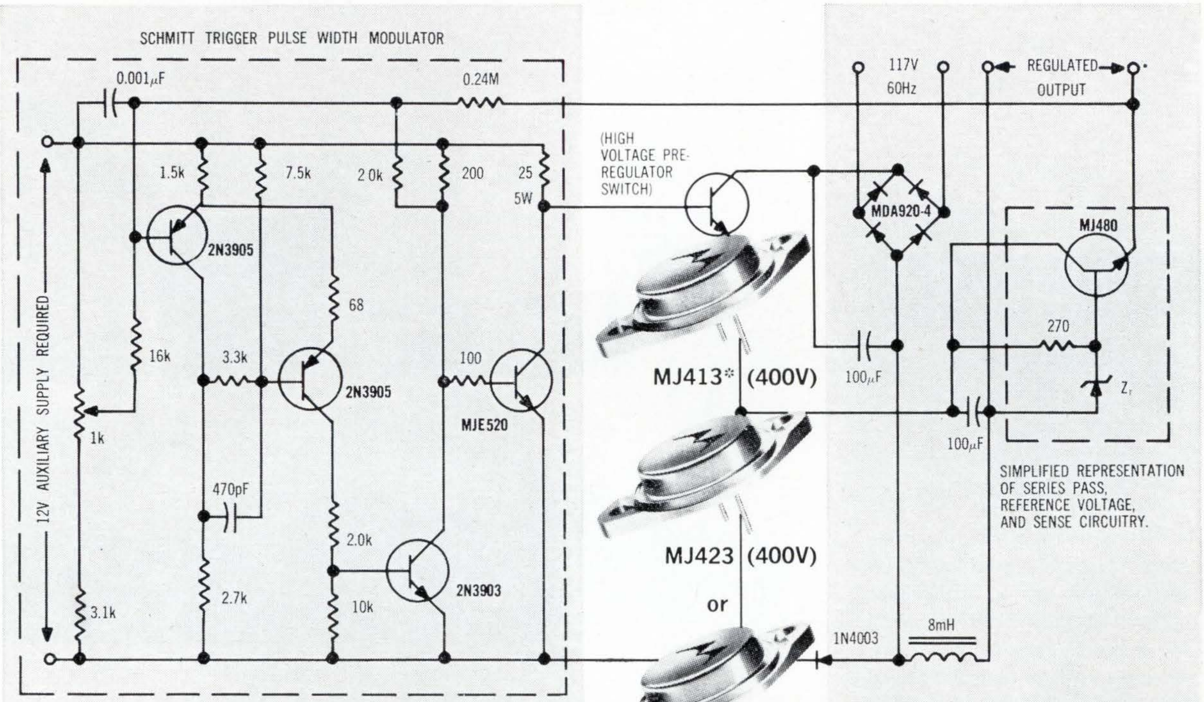
IV. Reluctance to move

Despite the higher salaries being offered, the electronics engineer is growing less inclined to move. The reasons vary, but companies across the country report that it's getting tougher to induce the engineer to move from one area to another.

A credibility gap of sorts is one of the reasons. Engineers have made moves only to learn a few months later that their new employer has lost a contract and that they must find another job. Herbert Krampner of the Banner Personnel Agency in New York City says some engineers are asking guarantees that the jobs they accept won't disappear.

Another reason for the tendency to stay put is noted by Charles A. Naramore of the Western Union Telegraph Co. "Men aren't moving because they have trouble selling their old homes and securing

Q: What are 400-Volt Silicon Power Transistors like you doing in a place like this?



Economical in size and weight, this all-silicon, regulated dc power supply — 0-100 V, 0-1 A — utilizes a HV silicon power switch in the pulse-width modulated switching preregulator. P-W modulation is accomplished by a Schmitt trigger controlled by sensing the voltage across the series pass transistor. Transformerless (with possible exception of Schmitt trigger) circuit operation is possible if line isolation is not required.

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TYPE	V_{CEO}	V_{CEO} (Sus)	I_C (Max)	h_{FE}	f_T	CASE
MJ400	325	325	200 mA	30 min (@ 50 mA, 10V)	15 MHz min	TO-66
MJ420 MJ421	250 325	250 325	100 mA	25 min (@ 30 mA, 20 V)	30 MHz min	TO-5
MJ3201 MJ3202	225 300	225 300	100 mA	30 min (@ 50 mA, 10 V)	15 MHz min	TO-66
MJ2251 MJ2252	225 300	225 300	500 mA	25 min (@ 50 mA, 10 V)	10 MHz min	TO-66
2N3738 2N3739	225 300	225 300	3 A	40 min (@ 100 mA, 10 V)	10 MHz min	TO-66
MJ3010 MJ3011	200 325	200 325	3.5 A	20 min (@ 0.5 A, 5 V) 10 min (@ 2 A, 5 V)	4 MHz min	TO-3
MJ413 MJ423 MJ431	**400 400 400**	**325 325 325**	**5 A**	**15 min (@ 1 A, 5 V) 10 min (@ 2.5 A, 5 V) 10 min (@ 3.5 A, 5 V)**	**6 MHz min 5 MHz min 4 MHz min**	**TO-3**

*For output currents to 300 mA.

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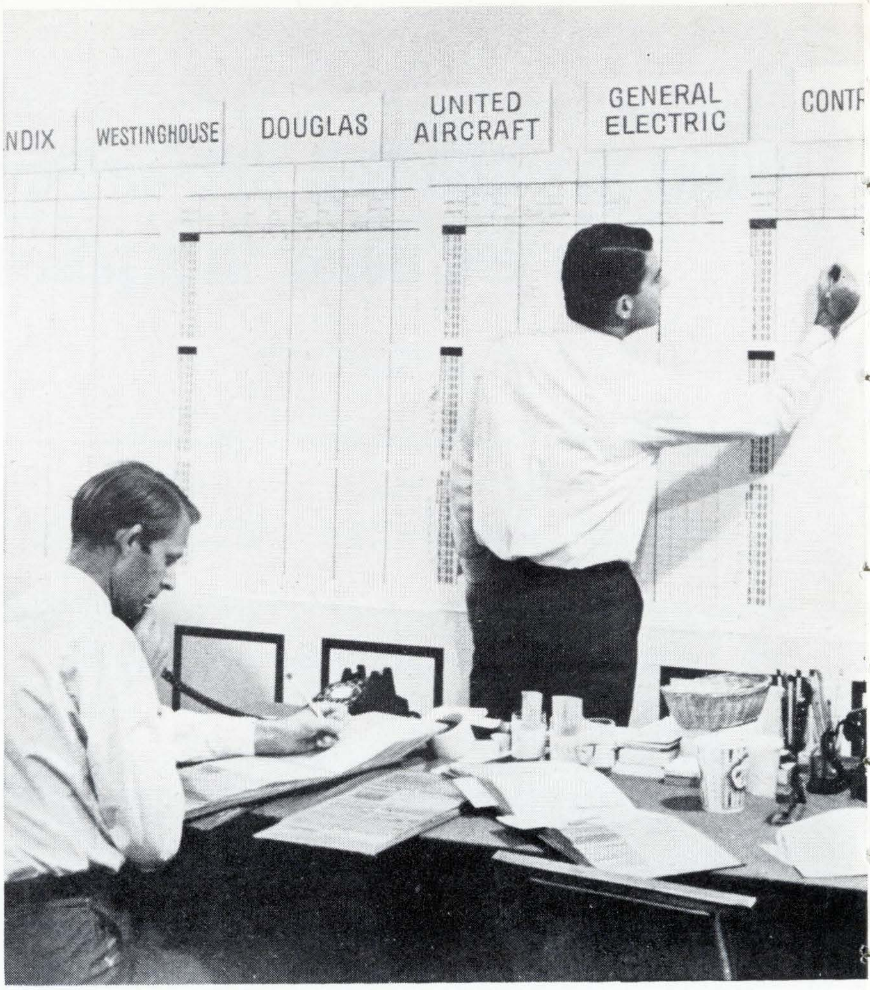


Appointments center, staffed by Careers Inc. personnel at 1966 IEEE convention attracted over 1,300 job hunters.

mortgages on new houses," he says. Joseph Dwyer, employment manager at Sperry Gyroscope Co., a Sperry Rand Corp. division, offers a third reason: "Opportunity is great in every region of the country right now. Unless a man works in an isolated area, he doesn't have to move to get a new job." Adds Charles Storm, personnel director for Lockheed-Georgia Co., a division of the Lockheed Aircraft Corp.: "Some engineers have had to refuse offers because they couldn't get their wives to move. When it comes to the home, the wife has a lot to say."

Retraining. Along with intensifying efforts to capture the engineer, many companies are increasingly turning their attention to keeping him once they've got him. A program at the Aerospace division of the Hughes Aircraft Co., Culver City, Calif., aims to upgrade the skills and education of electronics engineers to keep pace with the technology boom. The division has 2,000 engineers engaged in after-hours studies, according to Bob Martin, employment chief. A spokesmen for General Precision Equipment Corp., in New York City, cites the company's training program as a factor in keeping people with the firm.

And some companies are hiring engineers with the intention of training them for the job they're to fill—a practice that just about sums up the industry's supply situation. "In the past, we looked for the experienced electronics engineer who had been exposed to the realm of small-signal and digital systems," says Warren Christiansen, director of male personnel at Automatic Electric Co., a General Telephone subsidiary in Northlake, Ill. "Now we're willing to place personnel with little compatible experience and orient them to our telecommunications type of electronics. True it's more expensive, but what else can we do? We just aren't getting sufficient quantity or quality."

Friden looks for pot of gold at end of electronics rainbow

Five-year program to put electronics in its business machines is set to pay off as company introduces a billing and accounting unit with integrated circuits

By William Arnold

San Francisco Bureau

When the Friden Co. realized that electronics would eventually obsolete its entire product line of electromechanical business machines, it turned to advanced technology in general and integrated circuits in particular. Friden's effort to break into advanced electronics took almost five years to pay off. But late last month the company introduced its first homegrown product with IC's—a desk-sized billing and accounting machine, called the model 5610 Computyper, that employs transistor-transistor-logic circuits for all logic functions. These devices were supplied by Texas Instruments Incorporated and 85% were made to Friden's specifications.

"We are a big company now and we're beginning to think and act like one," says Martin H. Dubilier, 40, who wears two hats as executive vice president and executive vice president for operations. "Five years ago, we had two product lines in a stable business. Today, we have five product lines in a rapidly changing business," he asserts. Dubilier estimates that this year Friden will buy more commercial integrated circuits than any company outside of the computer business. Its demand will rise to over three million circuits this year and more than six million in 1968.

Winds of change. Since the Computyper represents Friden's IC debut, the huge increase in IC purchases suggests that the company is ready to make extensive changes in its products. "We can't rely on anything in the sales line being there five years from now," Dubilier says.

Electronic products, with life expectancies of five years or less, clearly require development times faster than those of Friden's conventional products, which once lasted from 10 to 15 years. "You can't waste six months on a product with a life cycle of four years," Dubilier reports.

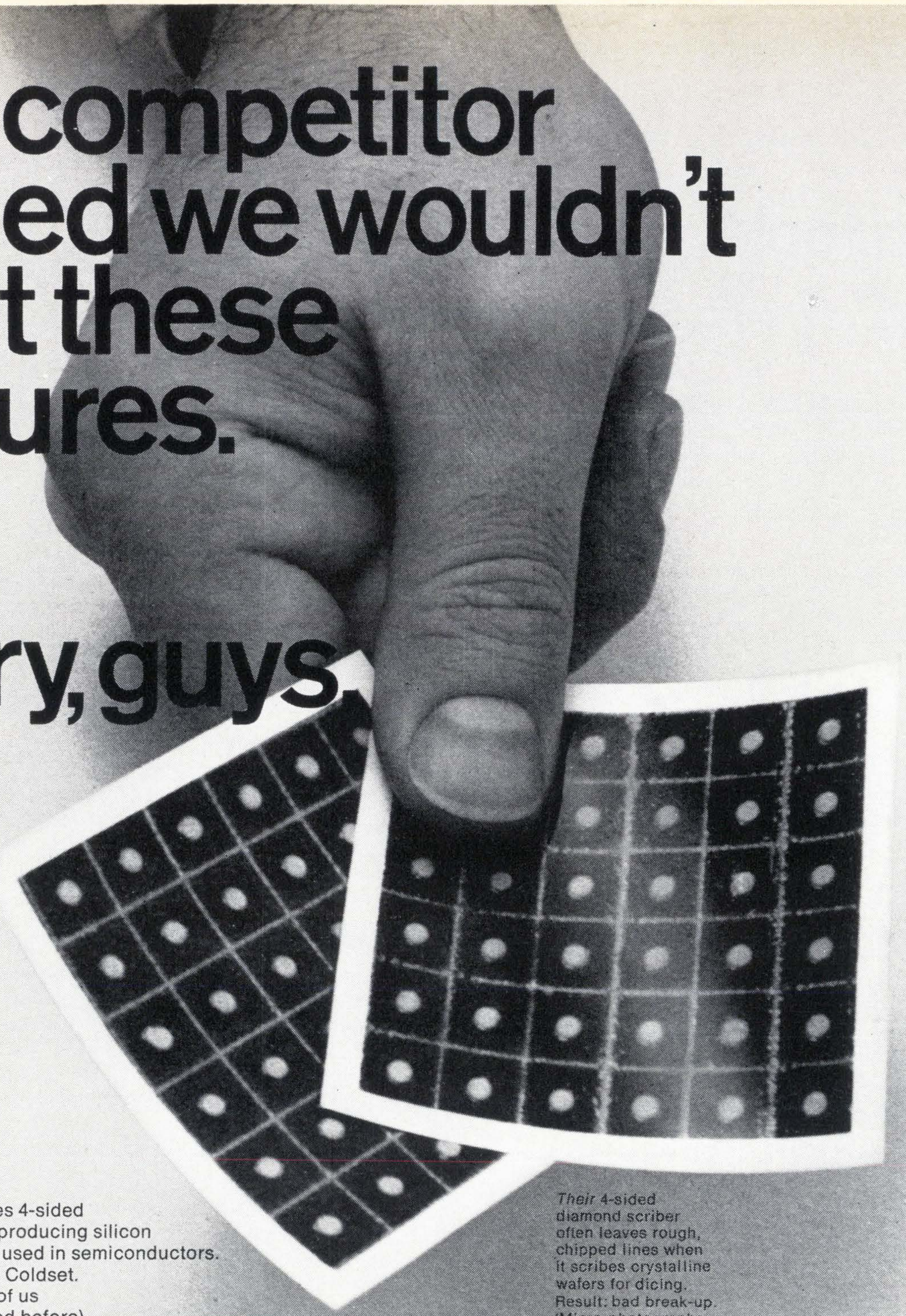
Friden, which was acquired by the Singer Co. in 1963, took its first tentative step into electronics that year by bringing out the model 6010 computer—essentially a sophisticated billing machine. A year later the company introduced its solid-state model 130 calculator, a desk-top unit for those with big desks. It followed up with the model 132—a 130 dressed up with a square-root key.

In 1966, Alan W. Drew took over as president and started action programs, increasing the number of employees in market research, and converting some field sales personnel to product management. He also redefined the product manager's role by making him a busi-

Custom-built IC's are mounted on board for Computyper—Friden's first advanced electronics business machine.

Our competitor hoped we wouldn't print these pictures.

Sorry, guys.



Our 4-sided diamond scriber (CT-904) scribes wafers with clean, true, straight lines. Result: high yield of perfect dice, rejections reduced by 90 per cent.

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If you've never heard of us (we've never advertised before), you probably buy a competitor's scriber. The pictures above may open your eyes to a better scriber: ours.
Our tool and theirs both fit standard scribing machines. Both draw scribe lines 0.020 to 0.040 inches square for dicing semiconductor materials. Both are mounted 20° to 30° from vertical. Both have 4 locating flats, the scriber being rotated 90° to expose a new sharp point as each previous point is dulled.
But the American Coldset 904 will consistently out-perform its rival. The Coldset scriber offers greater economy: instead of being scrapped, it can be reconstructed 3 to 4 times for a lower net cost per cutting edge. The Coldset scriber produces a significantly better break-up and remarkably higher yield of perfect dice.
If the photographs above don't convince you American Coldset makes a better scriber than the one you're using now, let one of our salesmen prove our points.
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AMERICAN COLDSET CORPORATION

ness manager for his line. To speed the planning process he tightened liaison between product planning, the product line manager, and the engineers.

During this period, Friden expanded its small stakes in graphic arts, mailing-room devices, and such original equipment as the photoelectric keyboard into full product lines to match its original lines of adding machines, calculators, and data processing wares. Concurrently, it began pumping more money into research and development. Friden had created the base for this diversification program during the 1950's when it acquired plants in Rochester, N.Y., Lewiston, Pa., Nijmegen, the Netherlands, and Mechelen, Belgium. In 1963 it acquired the Physical Sciences Corp. of Arcadia, Calif.

I. Double Time

In 1964, the company invested 2% of its sales dollar in research and development. Now it allocates 3%—a level that Dubilier expects to maintain. On an estimated $170 million in sales last year, that amounts to over $5 million. With sales growing at an annual rate of 20%, the company will spend another $1 million on R&D in 1967.

Two groups share research funds. One, the Friden Research division, is an autonomous entity set up to do Singer-wide research, though 99% of its work is now done for Friden. Its chief, Leland P. Robinson, stresses that his bailiwick is mainly a computer lab for applied research.

"Part of our mission for the next few years is to help in every way to accelerate the industrial design of integrated circuit technology," he says. By improving wiring, minimizing interconnections, and reducing the number of components, Robinson's group hopes to lower production costs on Friden's equipment. The group has two main approaches: incorporating IC's in Friden products, and introducing computer-aided design to the engineering process.

Friden's other R&D operation is headquartered in a $1.25-million, 40,000-square-foot building that houses 180 employees. Three years ago, it had only 80. This facility is set up to compress research time, according to George E. Comstock, vice president for research and development. Essentially, he explains, Friden wants to use engineering as "a working tool for the marketing man to evaluate new products from a marketing point of view." Thus Friden can be in a better position to consider the economic tradeoffs in its custom-designed circuits.

Pathway. So far, and for some time to come, Comstock indicates, Friden sees those tradeoffs favoring double-diffused integrated circuits. "In today's technology," he says, "double-diffused technology is economical. It's basic, the art is well understood, and the yields are agreed upon." Comstock calls metal-oxide semiconductor technology "glamorous but impractical," and does not expect it to be really useful for five years.

II. Hardware and soft

First fruit of Friden's fling with advanced technology is the 5610, which makes use of about 220 custom-built circuits containing six inverters, acting as three flip-flops per chip. The chip has been dubbed the Hex (Greek for six) and costs about $2 per unit. Friden chose the transistor-transistor-logic chip some 18 months ago on the advice of Texas Instruments which said that it would be cheaper for custom design.

Friden claims it achieves flexibility by using the same chip throughout the machine. With external diodes the chip functions as a diode-transistor-logic input, since TTL devices can't operate with diodes. As a TTL output, the circuits afford speed and high fan-out. The 5610 contains 3,000 diodes in high-voltage delay lines and in the interface with Friden's model 2205 Flexowriter, one of the 5610's input-output paths.

The machine stores 60 programs on punched tape and comes with a simple software package called Swift—for software implemented Friden translation. With Swift, an operator can type out simple commands in English or any other language, and not worry about adhering strictly to computerese.

One program gives the 5610 troubleshooting capability, which Friden says is unique in a small-scale data processor. If the machine malfunctions, a diagnostic program can be fed in and the fault will be isolated and typed out.

III. Taking it easy

The glamor of IC's has not blinded Friden to its bread-and-butter business. The company now produces four times as many conventional calculators as electronic machines, and expects the changeover to all-electronic units to be gradual. It will be some time, Dubilier believes, before electronic calculators can match rotary machines in price. One conventional machine costs $1,195, while its speedier electronic counterpart has a price tag of $1,950.

But the company is now in the third year of an ambitious sales drive which it hopes will more than double volume and profits by 1970. At the same time Friden wants to keep its production force at the 13,000 level that now prevails around the world. "We're right on target, so far," Dubilier says. The business-machine industry, with a growth rate more than five times that of the economy as a whole, provides a nice foundation for Friden's ambitions.

A possible check on those ambitions is the need for trained personnel. Comstock admits to some difficulties in recruiting because "we're cloistered and not well-known in electronics." He feels, however, these drawbacks are offset by Friden's aggressiveness, growth, potential, and high salary scales. Still, San Leandro is across San Francisco Bay and removed from the electronics enclave in Santa Clara County. Robinson's research division, now located near Oakland International Airport, is currently negotiating for land in the Stanford University Industrial Park in Palo Alto in an attempt to bridge that distance. Friden is also trying to set up with the University of California at Berkeley the same kind of working agreements that many Peninsula companies enjoy with Stanford.

Change is not easy. Friden, which considers itself number one in calculators and adding machines, was once in danger of being leapfrogged by the electronics industry. But with electronics capability, says Dubilier, ". . . you keep up the momentum, and competitors can't catch up."

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Time-sharing inquiry shakes industry

The FCC probe into computers' impact on communications will bring to a boil the controversies now simmering among common carriers, computer makers, users, service bureaus, and specialty companies

When the FCC decided to probe the impact of computers on communications last November, the language of its notice startled a lot of attorneys used to working with regulatory agencies. Instead of requesting comments on carefully defined issues, the Federal Communications Commission asked business firms to suggest areas for the inquiry. Said one attorney, "From reading this notice, I'd say the commission doesn't even know where to begin."

Now the commission has filed a supplementary notice of inquiry and everybody can see where the probe is going. It will delve into every aspect of time-sharing from the pricing of computers to the policing of compupter connections. Its scope could reshape the computer industry. At the International Business Machines Corp., an excited executive who studied the announcement exclaimed, "There's a large chunk of our future in here."

Nearly 35 companies responded to the FCC's November call for suggestions and the replies fell into two broad camps: one wants the commission to regulate time-sharing of computers completely, the other wants as little regulation as possible. In general, the common carriers familiar with the FCC and its procedures want regulation; industrial companies want regulations restricted to tariffs for communication lines.

The current investigation started when the FCC found difficulty untangling cases involving time-shared computers, machines in which many users have simultaneous access to a single computer from a distant site. Ostensibly the commission's interests were threefold:

- Are communications utilities providing adequate services to computer users?
- Are there any aspects of data processing that the commission should regulate?
- Is the privacy of subscribers to time-shared computers being adequately safeguarded?

Now industrial companies, to whom any regulation is anathema, believe the probe is going much deeper. What is at stake, they feel, is who will profit from the exploding market for data transmission. In fact, almost every company that has a computer may have something to gain or lose from the outcome of the inquiry. Soon there will be hardly a single computer that is not connected by telephone lines to a data bank, other computers, branch offices, or departments within a company.

I. Behind the probe

At the FCC over the past 18 months, the men assigned to watch communication common carrier companies, facilities, and services have become preoccupied with computer matters. The first major impasse, which most people claim prompted the FCC's inquiry, cropped up in 1965 when the Bunker-Ramo Corp. complained unofficially that the American Telephone and Telegraph Co. would not make telephone lines available for a specialized computer service to connect brokerage houses around the country with stock exchanges. The telephone company claimed that 5% of the traffic the new service would carry was the kind that ought to go over ordinary telephone or telegraph lines.

In the new service, which was to be called Telequote IV, a broker in any branch office anywhere in the United States could send a buy or sell order for a stock or commodity to any security or commodity exchange through a central computer which would assign the order to the firm's floor man at the proper security exchange, and send an acknowledgment of the completed transaction back to the proper office as well as do all the necessary computation and paperwork. Using the system, the branch office could also send and receive such ordinary messages as requests for hotel reservations, inquiries about the weather, or personal communications. Bunker-Ramo saw the system as an extension of the stock market pricing service it now offers brokerage firms. But the telephone company considered the move a definite encroachment upon its common carrier business.

Basics. Since both the service company and the telephone company recognized that a fundamental principle was involved, they agreed to go to the FCC unofficially. Since the experts at the commission did not have enough background information to make a precedent-setting ruling they persuaded the two companies to compromise. Bunker-Ramo would eliminate the features the telephone company found objectionable and the utility would supply lines for the remaining service. The company's modified service, now called Telecenter omniprocessing system will begin in about two months.

Then, Western Union International, a carrier regulated by the commission, disclosed plans for leasing data processing time on the same computers it was installing to switch Telex lines [Electronics, Nov. 28, 1966, p. 128], thereby adding an activity the commission could not regulate.

To cap the commission's worries, a professor at the Massachusetts Institute of Technology warned that computers were generating so much data for transmission over telephone lines the lines were in danger of being clogged, and the tele-

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. . . common carriers want to diversify into data processing services . . .

phone system faced ruin.

In the replies to the commission's first notice of inquiry, storm signals were apparent from the number of companies that responded and their conflicting interests. Among them were: common carriers, including the two biggest, AT&T and Western Union; computer companies like IBM, Honeywell Inc., and the General Electric Co.; service bureaus operations like CEIR and McDonnell Computer Service; leasing companies such as Randolph Computer Co.; trade associations, the National Association of Manufacturers, the National Association of Broadcasters, the Business Equipment Manufacturers Association, and the American Petroleum Institute; manufacturing companies with an interest in electronics, for example, the Xerox Corp. and the Collins Radio Co.; and companies that want to sell specialized computer services like Bunker-Ramo.

Specific battle lines have been clearly drawn:

- The common carriers will fight to keep any computer-oriented company from performing a service which could be done by conventional telephone or telegraph lines. At the same time, the carriers want to diversify into data processing.
- Service bureaus and computer users want lower charges for the use of telephone and telegraph lines carrying data. They claim that the lines in use today are not as efficient as they should be because they were designed to carry voice communication primarily, not data.
- Computer manufacturers want a relaxation of restrictions that ban their hardware from being connected directly to telephone and telegraph lines. They fear that carriers could set arbitrary rules that would make some forms of data transmission uneconomic. AT&T has enjoyed a marketing advantage with its Dataphone equipment because it is the only data input gear a Bell System company will allow on a dial telephone line. Late last year, Bunker-Ramo Corp. went to the FCC and forced a reduction in rental of Dataphone sets, charging that AT&T's prices were far too high. The commission agreed and cut rentals from $40 per month to $30.
- Specialty companies want the common communication carriers to provide all the lines they need even if some ordinary message traffic is carried by the specialized service. For example, Bunker-Ramo expected to use the same telephone lines that already supplied buy and sell prices for its proposed Telequote IV brokerage service and its stock market quotation service. So far AT&T has forced the company to use separate lines—a procedure which runs up a customer's cost considerably.

II. The computer utility

In addition, Western Union, which is diversifying into a data processing service bureau operation, would like the commission to regulate prices of computers, a proposal that makes computer manufacturers furious.

Western Union's plans to build a so-called computer utility that will provide all kinds of data processing services has given the FCC still another kind of problem. The telegraph company has already installed big computers to switch Telex lines automatically, a function clearly under the FCC's jurisdiction. Later this year, the company will start leasing time for data processing to outside customers on these same machines, an activity the commission currently does not regulate. The big dilemma is how Western Union should divide the cost of the computers between regulated and nonregulated services when they are operating at the same time.

Which route? A question that worries nearly everybody is what the giant AT&T will do about data processing. So far, the telephone company has shown no inclination to follow Western Union down the computer utility route. But computer manufacturers and service bureaus are nervous because Bell System companies are installing electronic switching systems that are really special-purpose computers. Although AT&T engineers say considerable hardware and software modifications would be

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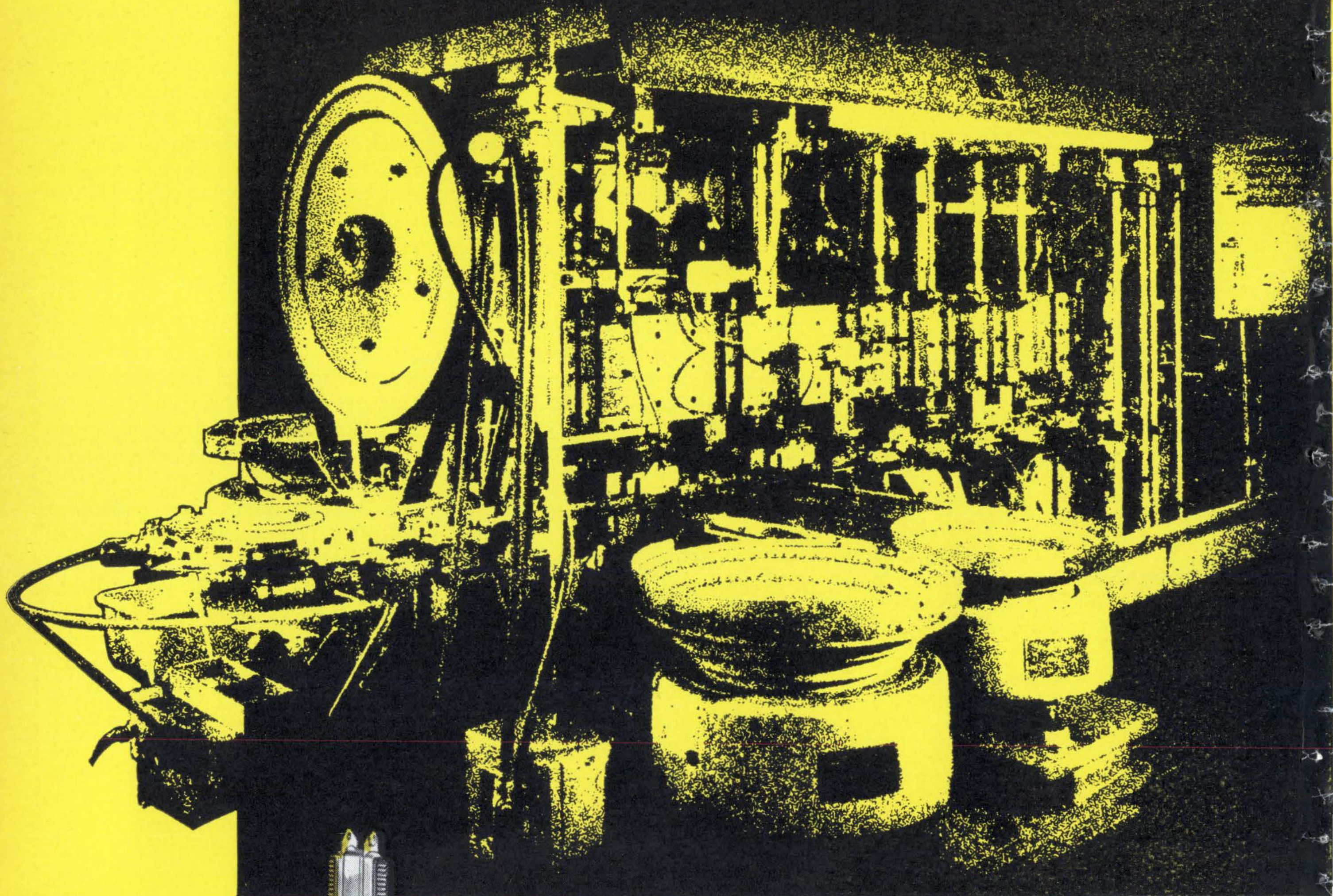

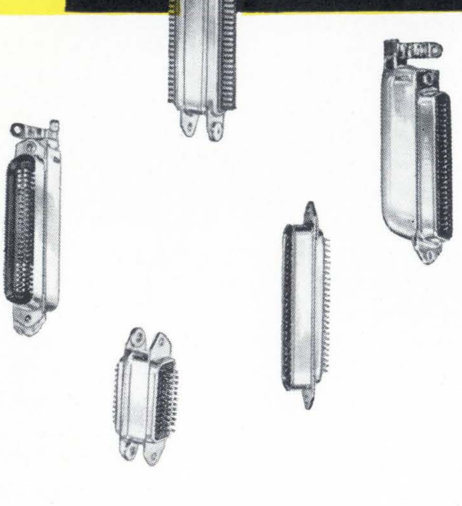

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required to enable these machines to perform ordinary data processing, they admit it is technically feasible.

Some people have felt that a consent decree in which AT&T entered with the Justice Department in 1956 would bar the company's diversification into the data processing business or service bureau operation. But some experts say no and the company agrees with that view. In the consent decree, the phone company agreed to engage only in activities regulated by the FCC. Testifying before a Congressional committee last year, AT&T executives offered the opinion that if the company filed and the FCC accepted a tariff for a computer service, the strictures of the consent decree would not apply.

Thus if, as a result of the current probe, the FCC should ask for and receive legislation to control data processing activities that cross state lines, AT&T might well launch a large-scale invasion of the data processing service bureau business.

Government's role. The great concern over, and interest in, computer utilities is shown by the calling of two major meetings later this month. The American Management Association has scheduled a three-day session from March 8 to 10 entitled "The computer utility—management's stake in shared-time and shared-information systems." Later in the month, March 20 to 22, the College of Engineering at the University of California at Los Angeles will host a meeting called: "Computers and communications; toward a computer utility." At both meetings a discussion of the role of Government in the computer utility occupies an important place on the program.

Nobody expects the FCC to reach a fast conclusion from its probe into computers and communications. Most experts are predicting the inquiry will take three or four years. But the betting is that the commission will decide to ask Congress for additional legislation so it can regulate time-sharing. Explained one attorney who has specialized in presenting cases before Government agencies, "I never heard of a regulatory agency that didn't try to expand its operations. The main question is where the FCC will stop with time-sharing."

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Easing of tube shortage in Japan opens color tv markets for set makers

With prices coming down and outlets available both at home and in the U.S., the industry gears for volume production

By the Lunar calendar, this is the year of the sheep in Japan. But for the country's color television manufacturers, 1967 could be more aptly named.

For the color tv industry in Japan has moved into a phase where none can afford docility. The color tube shortage that long held the pack at bay ended last summer. Unleashed, the dozen or so Japanese receiver makers scurried to get into big-volume production. Now that the production lines are pouring out sets, the scramble to sell them has started.

Geared up to turn out upwards of a million color tv sets this year, the Japanese will toil like beavers to keep their prodigious output from piling up in warehouses. Color tv makers figure to be tigerish in their marketing techniques. Indeed, any set maker who outwardly appears attuned to the celestial conjunction of the ancient calendar most likely is a wolf masquerading in sheep's clothing.

Poised to climb. Luckily, the two major outlets for Japanese color tv makers should expand sharply this year. An early-year flurry of new models priced at below $500 shows signs of triggering a color boom in the domestic market. And in the United States, where the outlook is for total sales of some 6 million sets, Japanese producers expect to sell at least 500,000 units, double their 1966 business.

Export prospects, in fact, may become even brighter before year's end. So far, Japanese producers have made the 19-inch set their bread-and-butter model. Most, though, will add 15-inch sets to their lines before the year is out. Traditionally, Japanese consumer electronics producers have fared best in the U.S. market with small, low-cost receivers.

For the long term, Japanese producers seem to be in a good position to snare a substantial share of the U.S. small-screen color tv market. Both the Sony Corp. and the General Corp. (formerly the Yaoun Electric Co.) have in the works post-deflection focus tubes—without shadow masks—that are admirably suited for the forthcoming generation of small solid-state sets.

I. Full swing

More than anything else, what makes 1967 anything but the year of the sheep for Japanese color tv makers is a burgeoning shadow-mask tube output in the country. In mid-1966, the Asahi Glass Co. boosted its bulb capacity substantially. The company, which exports heavily but at the same time supplies more than half of the bulbs used in Japanese color sets, will probably turn out two million this year, as against 800,000 last year.

Smaller tube makers have followed suit. Tokyo Shibaura Electric Co. (Toshiba), for example, recently doubled its monthly capacity to 60,000 bulbs. Hitachi Ltd. is going from 13,000 to 30,000 units and the Matsushita Electrical Industrial Co. from 15,000 to 25,000. The New Nippon Electric Co. will soon begin its own tube production at a rate of 20,000 units a month.

Shadow-mask makers are keeping pace. By mid-1967, the three major Japanese producers will have doubled their output. By then, the industry leader, the Dai Nippon Micro Co., a subsidiary of the Dai Nippon Printing Co., will hit 100,000 monthly. The other two will put out 70,000 between them.

With tubes no longer a problem, Japanese color set production most likely will run about 1.3 million

Toshiba, one of a dozen Japanese tv makers cashing in on the color boom, at home and overseas, will be producing at a rate of 30,000 sets in March.

sets this year. In 1966, the total was just under 511,000.

All of the major manufacturers have invested heavily during recent months in readying new production lines. Toshiba, for example, in March will be turning out 30,000 sets monthly, double its year-end level. Matsushita, too, soon will be at the 30,000 figure. The Victor Co. of Japan, a Matsushita subsidiary, will shortly have on-stream a new plant with a monthly capacity of 15,000 sets. Hitachi is jacking up its monthly production to 15,000.

II. Domestication

With color sets flowing fast to Japan's 45,000 retailers, the domestic market started to perk up early this year. Last year, some 220,000 receivers—barely enough to fill the pipeline—were shipped to dealers. Potential customers could see sets in showrooms, but it was sign up and wait for most who wanted one for the living room. This year, the industry should pump at least 500,000 sets into the domestic market and perhaps as many as 700,000.

Slim margin. What's more, with every one tooled up for volume production, prices have started to come down. Sanyo Electric Co. was the first to break through the "$500 barrier" in January with a 19-inch table model listed at $453. Sanyo executives say they shaved the price to near the break-even point, counting on stepped-up volume to make the move profitable. The strategy has apparently worked. The set has been selling so well that Sanyo has boosted its output to 6,000 receivers a month when originally it had planned to make 3,000.

Sanyo, though, had the low price" market to itself for only a month. In February, the Hayakawa Electric Corp., the Mitsubishi Electric Corp., the Nippon Columbia Co., Toshiba, Matsushita, and Victor all announced 19-inch table models at list prices around $460. Matsushita, in fact, rocked the competition with a console ticketed to sell at a retail price of $497. Up through last year, the list price for consoles was $550.

The spate of low-cost sets, to be sure, will prove a tonic for the domestic market. And at the level of $460 list price—most retailers give discounts of at least 10%—color tv seems to be in much the same situation as black-and-white when it started to take off 10 years ago. Then, set prices ran about $280 but the average of consumers' disposable income was half what it is now. Moreover, starting in April there'll be plenty of color programs on the air. In the Tokyo area six key stations will be colorcasting a total of 17 hours daily.

Defense. Although the trend toward lower color set prices has trimmed profit margins to the point where manufacturers must keep volume up at all costs, it may well cure at least one industry headache: an antitrust suit brought by the government against six major producers [Electronics, Jan. 9, p. 241]. Crucial to the government's case is the contention that the manufacturers set a minimum retail price of $500 for 19-inch color sets. Now that floor no longer exists, backing up the companies' claim that while they discussed prices no binding pacts were made.

No matter how good a year they have at home, Japanese producers must channel 500,000 to 600,000 sets into the U.S. market to keep volume at a profitable level. But exporters will be under heavy price pressure on their 19-inch sets as U.S. manufacturers step up production of small-screen color units. Free-on-board prices of Japanese sets range from $170 to $190 but many U.S. importers have been pushing to trim prices 7% or 8%.

In addition, estimates of U.S. sales volume for 1967 slid 25% in the past month to about 6.3 million sets. Since U.S. component and receiver producers geared up for an 8 million-unit sales year, the December estimate, overcapacity has developed. The Japanese will be selling into a somewhat softer market than they expected, but they have long since proved their ability to survive, and thrive, in price wars.

Most Japanese imports are sold under American brand names. Toshiba, for example, produces for Sears, Roebuck and Co. Montgomery Ward and Co. merchandises Hayakawa's color sets. Sanyo sells to both Sears and the Magnavox Co. Nippon Siegler Inc., Matsushita, Hitachi, Toshiba, and Sanyo, though, have tackled U.S. markets with their own brands.

Shrinking. Although the short-

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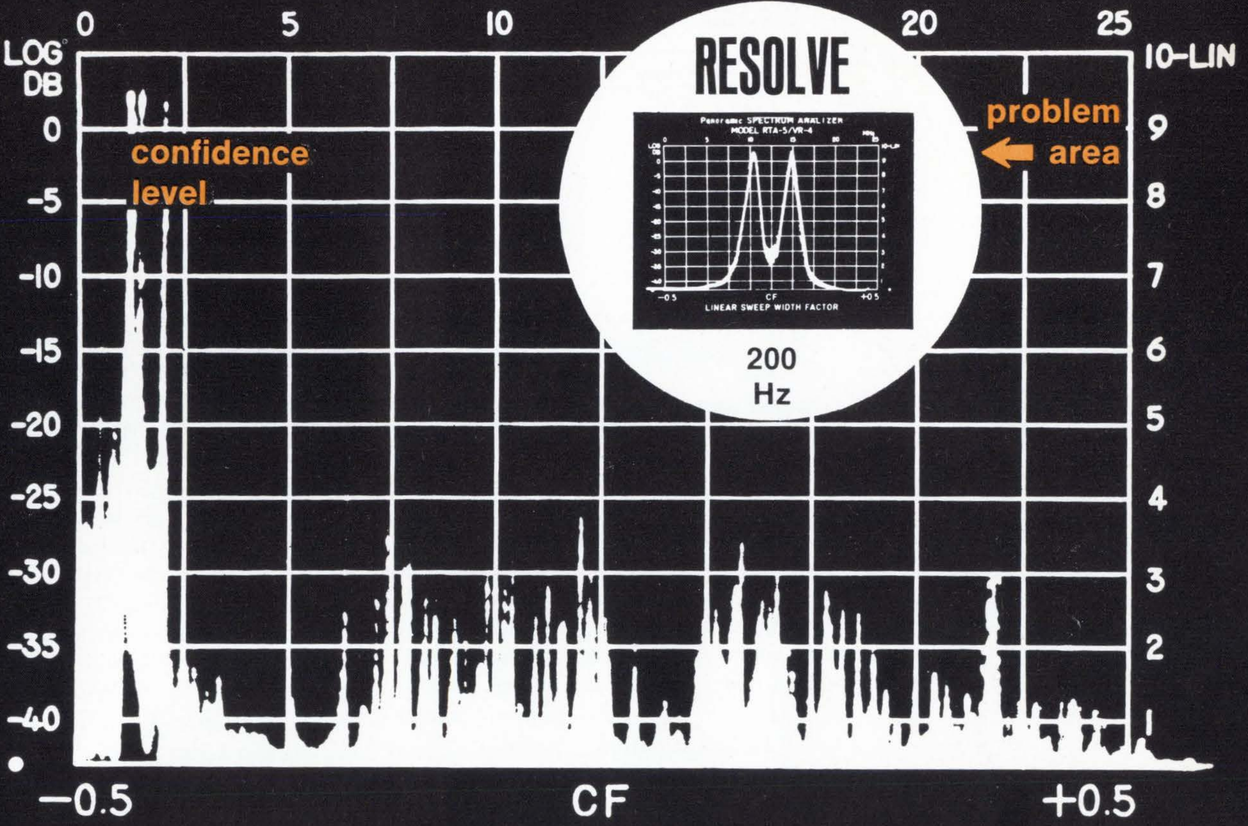

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THE SINGER COMPANY, METRICS DIVISION • 915 Pembroke St., Bridgeport, Conn. 06608, U. S. A. • PHONE (203) 366-3201 term prospects look all right for 19-inch Japanese sets, most manufacturers feel their best seller in the American market over the long run will be something smaller. Says one Japanese marketing man: "The smaller sizes are more salable and as far as our present estimates go, the smaller the better. Perhaps not as small as 12 [inches], but certainly in the 12 to 16 [inch] range."

The Radio Corp. of America just last week started selling its long-awaited 15-inch color set which lists for $330 and on RCA's heels will come Sears with a 16-inch portable produced by Toshiba. To hit the market with a small set ahead of other Japanese companies, Toshiba established a 16-inch tube line. Except for the tube size, Toshiba's set is the forerunner of a generation of Japanese hybrid sets. The model it is producing for Sears has all-transistor circuitry in its radio-frequency and intermediate-frequency stages up to the second detector in the video channel and up to the ratio detector in the sound channel.

Most of the major Japanese set makers have readied hybrid prototypes and presumably will go into production on them as soon as Asahi Glass starts turning out 15-inch color picture tubes this summer. The wave of 15-inch sets should start to lap at the American shores late this year and then build up to a flood tide in 1968. The FOB price for the 15-incher most likely will run around $150.

Even smaller. And the Japanese have 12-inch color sets in mind. Asahi should have the tubes available by early 1968 and a crop of all-transistor portables could come late that year.

Still to be heard from in the U.S. color tv market is the Sony Corp., which has developed a pair of post-deflection-focus color tubes, the three-gun Chromatron and the single-gun Chromagnetron. Sony, which has experienced some cost woes, has been selling small quantities of 19-inch Chromatron sets in Japan. The company says it has no plans to enter the U.S. color market this year and won't come in until it has something "sensationally different" to sell. Sony's sensation most likely will be a transistorized 12-inch or even 9-inch set with a post-deflection-focus tube.

Uncalculated risks keep calculator on the shelf

Trying to take too big a step from the lab to production of an IC-equipped calculator, General Micro-electronics stumbled over a number of technical obstacles

By Lewis H. Young
Editor-in-chief

Sixteen months ago, at the annual show of the Business Equipment Manufacturers Association, the Victor Comptometer Corp. introduced a radically new electronic calculator that set some startling precedents. For one thing, 29 metal oxide semiconductor chips were to replace nearly 21,000 conventional discrete components. For another, the entire calculator, the Victor 3900, was to be fabricated and assembled by a semiconductor company, General Micro-electronics Inc. of Santa Clara, Calif. After the show, however, the Victor 3900 disappeared.

Last month, executives at Victor and the Philco-Ford Corp., which purchased General Micro-electronics last summer, shamefacedly explained the disappearance. The semiconductor company hasn't been able to manufacture the Victor 3900.

Philip Ferguson, president of Philco-Ford Micro-electronics, conceded that serious production problems have delayed the calculator's debut.

Items:

- Nearly half of the 29 integrated circuits had to be redesigned.
- Cost reduction efforts were too stringent and resulted in the use of components that couldn't perform satisfactorily.
- Engineers who designed the IC's underestimated the difficulty of shifting from hand manufacture in a research laboratory to commercial production.

But Ferguson had some good news, too. Redesign of the calculator has now been completed and mass production will start this summer. The new circuits are currently being evaluated and a few calculators are being assembled for testing.

Prototype on schedule. The initial design and construction of a prototype moved right on schedule after the project was begun in September 1964. By October 1965, every circuit worked and the assembled machine performed well. An over-confident Victor signed a fixed price contract with General Micro-electronics for a large number of machines at this point, but big troubles cropped up when the design went into production.

Because General Micro-electronics was running a pilot-line operation in 1965, the switch to mass production became a nightmare. Employment was more than tripled, and floor space was increased from 30,000 square feet to 100,000. The company, which was to deliver the calculators at a price low enough to make them competitive with conventional machines, found itself anteing up money at a rate it couldn't sustain. On some circuits, the yield was, in Ferguson's words, "substantially less than 1%." On one or two, yields were zero; they simply couldn't be mass produced.

Problems. "Most large steps forward take longer than you think," says Philco-Ford's J. Philip Ferguson.

Pound foolish. To keep costs down, the company cut corners and suffered the consequences. For example, it bought a cheaper transformer for the power supply only to find that the component couldn't perform satisfactorily. By the spring of 1966, Ferguson realized the worst; a major redesign was necessary if the calculator was ever to be mass produced.

The chief difficulty, according to Ferguson, was that the engineers who designed the circuits were overoptimistic about what they could do. "Mos was in research and development when the project started," he said, "so both systems designers and circuit people were going to school on the calculator, learning the technology."

I. A matter of microns

Probably the most important thing the engineers learned was that while design rules produced theoretically satisfactory integrated circuits when the devices were carefully made in the laboratory, the same rules weren't practical for commercial production. The big problem turned out to be a matter of microns.

One big advantage of MOS technology is that a transistor takes up an area only 5% the size of that required by a similar device made by bipolar diffusion techniques. Cramming as many as 600 components on a single chip for a memory circuit, engineers left only microns for masking tolerances for the width of a line and the spacing between two p areas. This turned out to be far too tight. In addition, production men found that the viscosity of the Kodak Photoresist used to mask areas would change, and that these variations caused changes in dimension that were disastrous when tight tolerances were imposed.

Since the technology was so new, the engineers at General Microelectronics had no computer-aided design program to help lay out interconnection patterns. They did them by hand in a trial-and-error fashion, and, because of this, some chips required metalization areas so large that metal homogeneity couldn't be maintained. As an additional nuisance, draftsmen had to draw every part of every circuit by hand. Errors in drawings caused a couple of circuits to malfunction.

Comeback. The first thing Ferguson's engineers had to do was rewrite design rules to loosen the geometry. Instead of 6 microns, the new rules allow 10. Ferguson expects the loosened geometry alone to improve yields by at least 100 times. Then too, the company learned a lot during the past year about using Photoresist to obtain better resolution.

Another necessary design alteration involves the ratio between load resistors and inverters. A typical switching function in the calculator uses an inverter, or gate, device and a load resistor. Since both are MOS transistors, the design of the switching function depends on the transconductance ratio between the two. The resistance of the transistor depends on the width of the p material. Initially, the designers chose a 7:1 transconductance ratio so that a 14-volt supply would put 2 volts across the output of one transistor. But production methods added at least another micron to the width of each transistor, cutting the ratio to 8:2 or 4:1. The 3.5 volts this put across the transistor—instead of 2—was too high and the gate wouldn't shift. To counter this, the theoretical transconductance ratio has been raised to 10:1 so that the width

No hard feelings. Victor's A.C. Bueler Jr. says relations between his company and Philco-Ford are as good as ever.

added during production made the real ratio 11:2. About 2½ volts are put across the device and the gate works.

A computer program now lays out interconnection paths to minimize metalizing. And a system of standard building blocks simplifies mask-making and reduces the dependency on the correctness of draftsmen.

Of the chips that had to be redesigned, about half needed new design rules and the rest required improved layouts.

Testing turned out to be another area in which General Micro-electronic's engineers grossly underestimated complexity. The big questions were what and how to test to prove a chip's performance. The analysis indicated that 2^9 inputs were required to prove a chip was good. The answer turned out to be a compromise. Philco now tests for functions instead of putting each chip through exhaustive electrical trials.

II. Rumor mill

While Victor and Philco-Ford have kept silent about the Victor 3900 calculator for the past 16 months, executives in the semiconductor industry have been far from closemouthed. Rumors have flown thick and fast.

Rumor: The basic trouble was that General Micro-electronics tried to cram too many components on a chip.

The engineers who created both the early and later designs insist that the low cost targeted for the calculator dictated the high component density. Fewer components per chip would have meant more chips and raised costs sharply. As Ferguson explains it, "We think the true potential of MOS technology is in very complex circuits. The attractiveness of MOS drops rapidly as complexity falls." Even with revised design rules and loosened geometrical restrictions, Philco-Ford engineers have put 400 to 600 components on each of the machine's 23 different circuits (seven of the machine's total of 29 circuits are 96-bit shift registers). "We took exactly the right design route," Ferguson asserts.

Rumor: The electronic calculator was a poor product in which to try integrated circuits.

Experts at competitors debunk this charge. At Texas Instruments Incorporated, for example, Jack Kilby, often regarded as the father of IC's, agrees that the calculator is an excellent subject for MOS technology. His company is one of several conducting research aimed at producing MOS circuitry for a calculator.

Rumor: The work on MOS integrated circuits has gone so badly that Philco-Ford has built calculators with discrete transistors in MOS IC cans to replace IC's that didn't work.

"Ridiculous," scoffs Philco-Ford's Ferguson. Another executive declared that the high cost of such discrete devices would preclude their use in this design.

Rumor: Victor is so upset about missed deliveries it is ready to sue Philco-Ford.

At Victor, Albert C. Beuler Jr., executive vice president, admits he would like to have had the machines in time for the planned January 1966 marketing debut, but says he understands the delay caused by the pioneering nature of the development. Victor has kept close watch on the difficulties at Santa Clara, so the schedule slippage was no surprise. Beuler says the relationship between the two companies is as good as ever.

Rumor: Philco-Ford will never build the Victor 3900.

Ferguson says prototype production has started again and deliveries should begin by summer. Beuler, at Victor, expects to start receiving machines by mid-1967. Normally, the business-machines company would need at least 1,500 calculators just to fill its distribution pipelines, but it is so anxious to show the Victor 3900 that it will initially put only one or two machines in each of its sales regions instead of the larger number generally needed for an introductory campaign.

Rumor: Philco's purchase of General Micro-electronics set the project back sharply.

Although some people left General Micro-electronics after the purchase, including a few project engineers on the calculator task force, most key engineering personnel stayed. Resignations slowed only non-critical portions of the work. Executives at Philco-Ford figure, however, that uncertainty over the company's future probably slowed work a little for a month or two.

On the other hand, Beuler thinks there would have been more problems if Philco-Ford hadn't purchased the semiconductor producer. General Micro-electronics' biggest nontechnical problem was a lack of money, and Philco-Ford has remedied that by pouring in from $5 million to $10 million since it made the initial purchase. General Micro-electronics was also short of space in which to set up the production lines for the calculator. Since last summer, Philco-Ford has added 50,000 sq. ft. of floor space at Santa Clara.

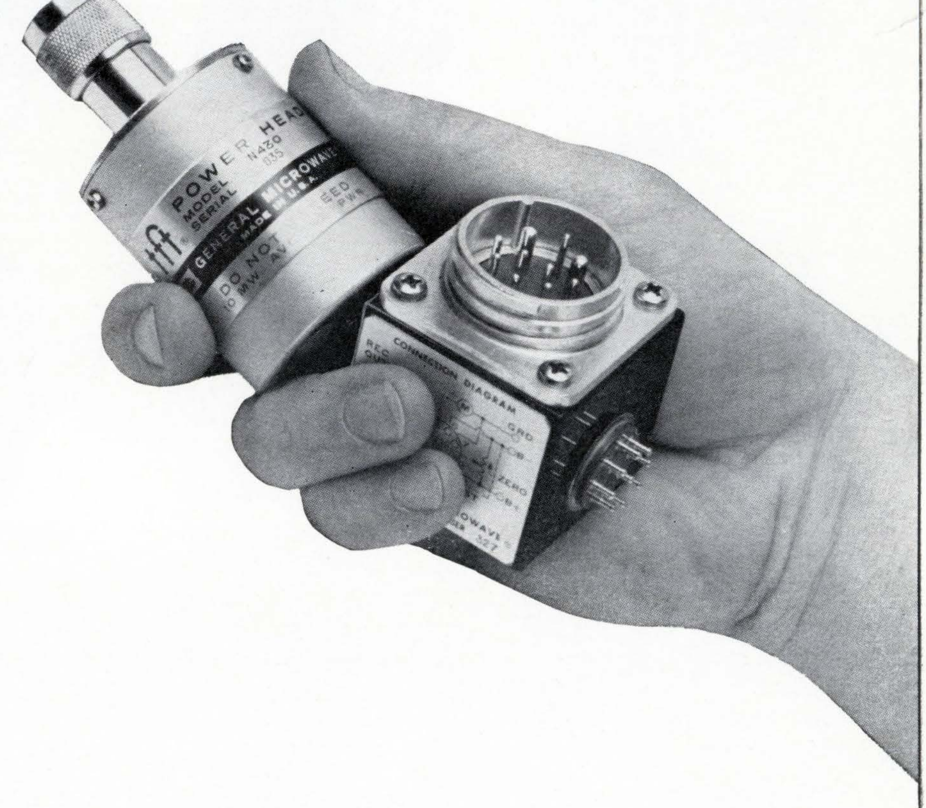
III. Threat of competition

If the initial production schedule had been met, Victor would have had a full year's lead on the industry with a calculator made with integrated circuits. But now Hayakawa, a Japanese firm, has an IC calculator, and several U.S. concerns are on the verge of making announcements in this field. Looking at it from Victor's standpoint, Beuler says he doesn't fear competition. He says philosophically: "If we were first so much the better. If there is competition, it won't affect us in the least."

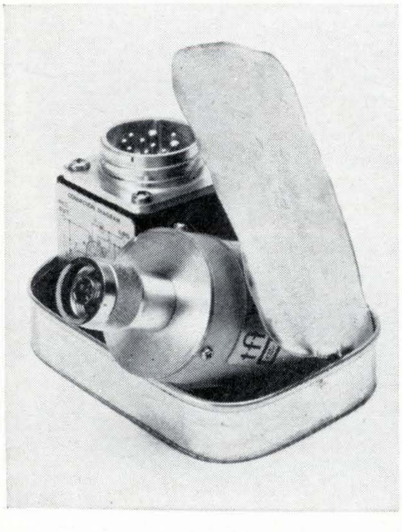
Ferguson sums up Philco-Ford's harrowing experience this way: "Most large steps forward take longer than you think. To make big gains you take big risks."

The question still unanswered, however, is whether Philco-Ford's gamble on the Victor 3900 will ever pay off.

Here's a miniature microwave power meter that will fit anywhere.



...well, almost anywhere. But who wants a microwave power meter packaged in a sardine can, anyway? On the other hand, we know of many people who need a truly miniaturized system for measuring and monitoring microwave power in a wide variety of applications, from airborne radar sets to undersea communication equipment. We hasten to add that small size and light weight are not the only virtues of our new system—it does a big job when it comes to performance, as witness below:



Accuracy—Model 462: ±2% on low range; ±1% on medium and high range. Model 463: ±3% on low range; ±2% on medium range; ±1% on high range.
Operating Temperature Range—Model 462: −55°C to +125°C. Model 463: 0°C to +70°C.
Power Range—Choice of three Power Heads, with overlapping ranges, provides a total of seven full-scale power ranges: 100μw, 300μw, 1 mw, 3 mw, 10 mw, 30 mw, and 100 mw. With each Power Head used, Amplifier offers three-range selection covering 20 db.
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Model	Power Range	Price
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N431	1mw to 100mw	$175
N432	10μw to 1mw	$200

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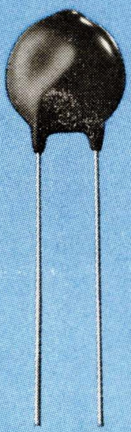

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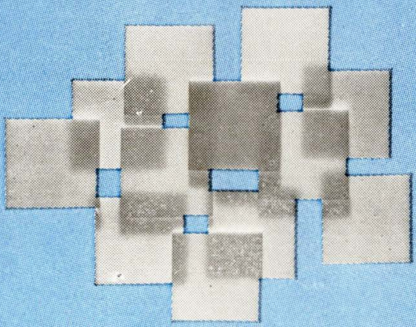

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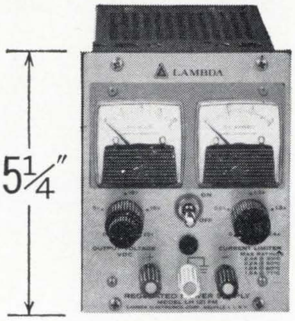

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3 full-rack LK models—Size 5¼" x 19" x 16½"

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

6 half-rack LK models—Size 5 3/16" x 8 3/8" x 16½"

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. For metered models add suffix (FM) to model number and add $30.00 to price.
[3] Overvoltage Protection: Add suffix (OV) to model number and add $70.00 to the price for half-rack models; $90.00 for full-rack models.
[4] Chassis Slides: Add suffix (CS) to model number and add $60.00 to the price.

5 quarter-rack LH models—Size 5 3/16" x 4 3/16" 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

5 half-rack LH models—Size 5 3/16" x 8 3/8" x 15 5/8"

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

[1] Current rating applies over entire voltage range.
[2] Prices are for non-metered models. For metered models add suffix (FM) to model number and add $25.00 to price. For non-metered chassis mounting models, add suffix (S) to model number and subtract $5.00 from non-metered price.
[3] Overvoltage Protection; Add suffix (OV) to model number and add $60.00 to the price.

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Their low saturation voltage (typical 0.4 V. @ 10 A.), and low thermal impedance (0.5° C. per W.), insure cool running. This, plus demonstrated freedom from second breakdown, makes them ideal for repetitive switching into inductive loads. Perfect for inverters and regulators as well as sonar amplifiers.

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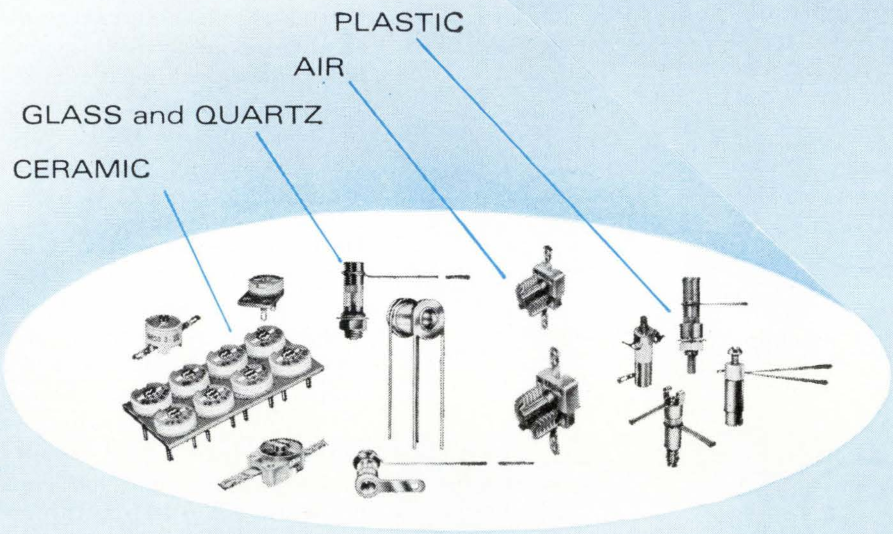

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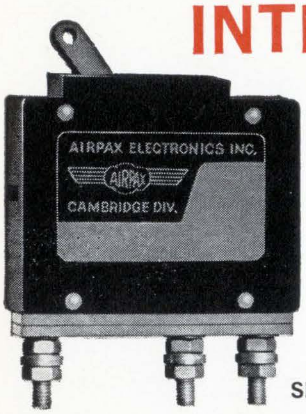
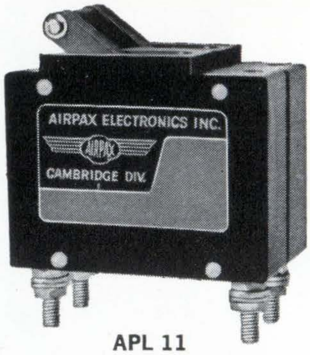


APL 3
SHUNT TYPE

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

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



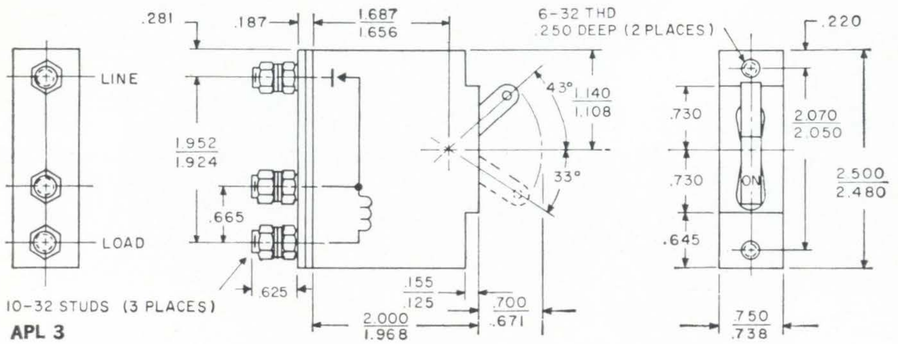
APL 11
TWO POLE PROTECTOR

APL 1-RE
SERIES WITH REMOTE

TYPICAL DATA

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

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



APL 3

MORE DATA

We've a lot more data: delay curves, coil impedances, and several typical protector applications. Ask for Bulletin 16E-5R.

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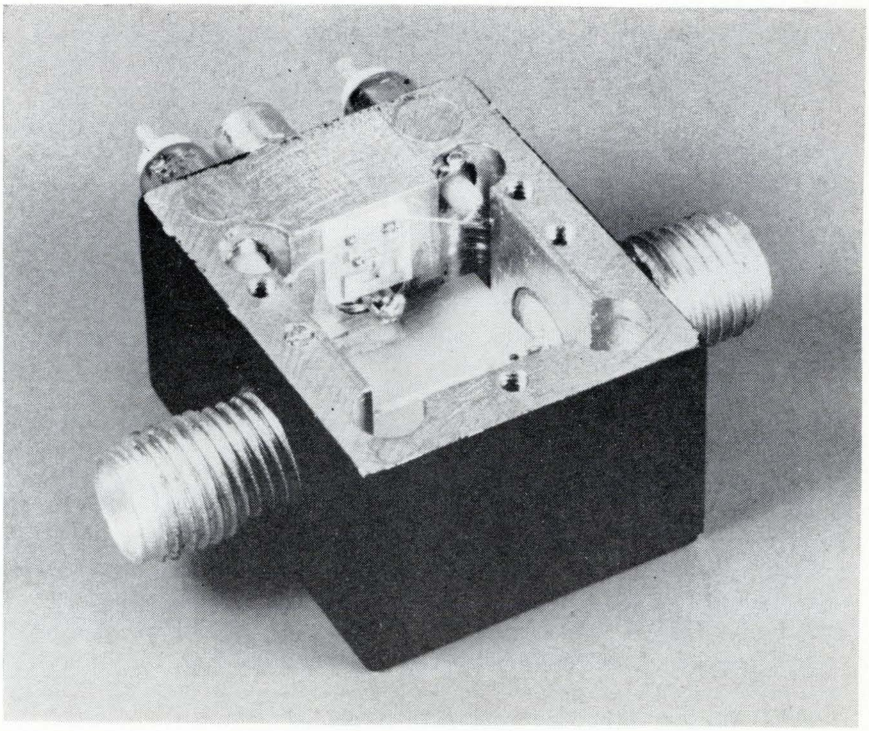
Microwave switch is integrated by microstrip

Interconnections printed on a ceramic base and elimination of diode packages improves isolation and raises speed of S-band device



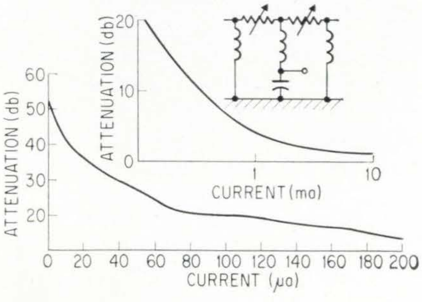
High isolation, fast switching speed and low insertion loss have been achieved by putting an S-band switch and its driver circuit onto ceramic substrates and interconnect components with a microstrip transmission line. Because the assembly is a hybrid integrated circuit, it's also small—about one-sixteenth the size of its predecessor, also made by Microwave Associates, Inc. The company claims it's the first commercially made IC that operates at microwave frequencies.

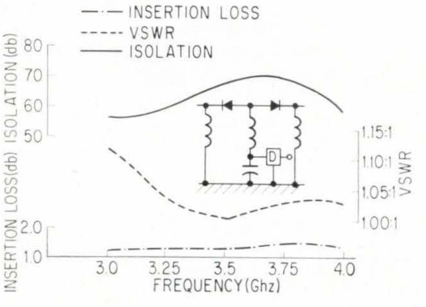
It has always been difficult to get high isolation and speed with low insertion loss in solid-state microwave switches. With discrete components, parasitic capacitance from the diodes' packages increased the over-all capacitance. The capacitance could be reduced by using several series-connected diodes. But the more numerous the diodes, the higher the insertion loss and the longer the time required to remove the injected charge.

The company solved this circular problem by getting rid of the diode packaging and by using only two diodes, specially made p-i-n chips, mounted directly onto the microstrip transmission line. The resulting circuit switches in 20 nanoseconds, with 50-decibel isolation and 1.75-db insertion loss.

The driver circuit's bipolar signal quickly removes the injected charge in the diodes during turn-off. The importance of the driver's closeness to the diodes is shown by comparison tests. Using the internal driver, the switching speed is nominally 20 nanoseconds (in experimental models, the time has been halved). When the same switch was actuated by an external driver connected by a 10-inch coaxial lead, the best speed possible was 30 to 35 nsec.

One major factor in reducing size stems from the high dielectric constant of the ceramic substrate. Alumina—which has a dielectric constant of close to 9—was chosen.





Specifications

Frequency	S band
Bandwidth	1 Ghz
VSWR	1.5 max.
Isolation	50 db
Insertion loss	1.75 db max.
Switching speed	20 nsec
Power handling	
continuous wave	0.5 watt
peak	25 watts
Size	0.875 x 0.675 x 0.55 in.
Weight	0.5 oz
Price	
with driver	$375
without driver	$295
Delivery	60 days

Since wavelength is proportional to the square root of the dielectric constant, the microstrip was trimmed to about one-third the size of one with a conventional dielectric.

The microstrip is formed on the alumina board by depositing a silver circuit pattern and ground plane. When the structure is fired at high temperatures, the resulting bond forms a strong base for soldering and welding the components and leads. Since the microstrip can be reproduced by photographic methods, there is potential for low-cost mass production.

The driver incorporates a current-limiting circuit which sets the pulse output current at the desired level and prevents current spikes or surges from damaging the switching diodes and the dielectric layer of the driver's capacitor. The switch can also be used without the driver as an electronically controlled attenuator. With an input current varying from 0 to 10 milliamps, the attenuation varies from about 53 db to about 2 db.

To be exhibited at the IEEE show.

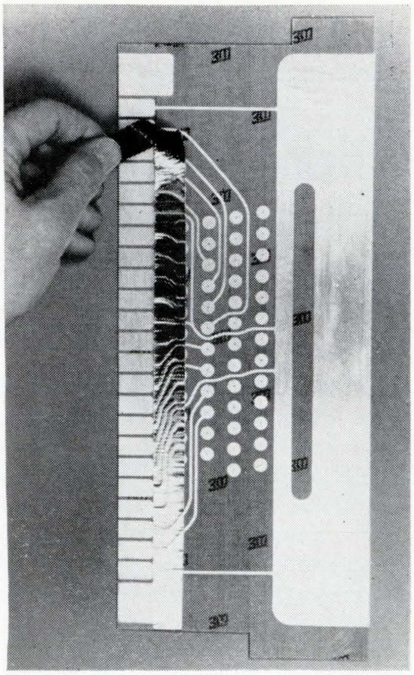
Microwave Associates, Inc., Burlington, Mass.
Circle **349** on reader service card

Plating tape foils corrosion

During the gold-plating process for printed-circuit-board edge contacts, the contacts must be connected to act as one plating electrode. But when the board is put into service, the contacts must be isolated. The most common method for achieving the connection and disconnection has led to difficulties with corrosion at the edge of the board and has sometimes caused the copper fingers to lift from the board. But now the 3M Co. has a new Scotch-brand tape that, it says, solves all this. The tape consists of copper foil backed by an electrically conductive pressure-sensitive acrylic adhesive.

In the standard method, the contact fingers are connected together by a thin conductor, etched with the contacts, running along the edge of the board. After the fingers are plated, this edge is sheared off and the fingers are isolated. However, when the edge is sheared, the edges of the fingers have copper exposed under the gold and there may be burrs which can cause the fingers to lift off the board when it is inserted in the edge connector. Most manufacturers bevel the edges to remove the burrs, but this results in still more copper exposed.

The 3M conductive tape, No. X-1226, eliminates the need for the thin conductor, so the broad edge need not be sheared off. The tape is placed behind the contacts (see photo) and thus makes them all electrically common for plating. Now, the ends of the contacts can also be plated so that no copper is exposed. The tape is easily removed after plating. The tape adhesive is resistant to common etching and plating solutions and will not corrode the copper circuitry, but should be applied with a rubber roller to prevent the plating solution from seeping underneath.



Plating tape is applied behind contacts to form one plating electrode.

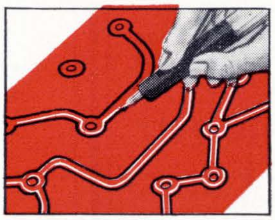
Specifications

Adhesion	40 oz/in.
Tensile strength	20 lb/in.
Resistance	0.085 ohm/in.
Thickness	2.5 mils
Width	¼ to 1 in., ⅛ in. increments
Price (36-yd. roll)	$3.69 (¼ in.) to $14.76 (1 in.)

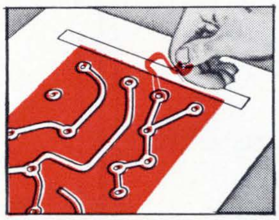
3M Company, Dept. Di7-1, 2501 Hudson Road, St. Paul, Minn. 55119 **[350]**

New products in this issue

In Making Masks for Electronic Components... ...there's no Margin for Error!

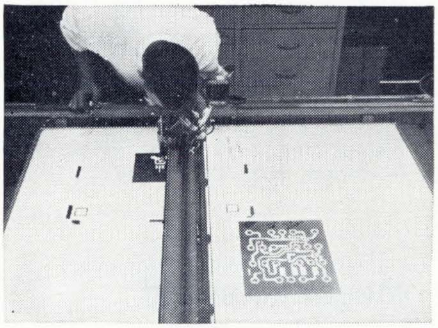


With sharp blade, outline the areas to be masked. **Do not cut through the backing sheet.** The Ulano Swivel Knife does the job quickly, easily.



Now carefully peel off the film as outlined leaving a completed photo mask, positive or negative, that corresponds exactly to the desired pattern.

THAT'S WHY EXPERIENCED DESIGNERS AND ENGINEERS ALWAYS INSIST ON...



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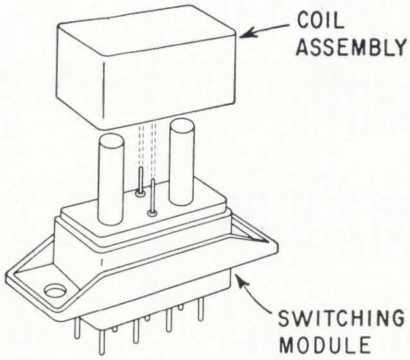
Two packages make one relay



The organic contaminants given off by conventional insulators for magnet wires can, if they form a film, interfere with the operation of an electromechanical relay's contacts.

To prevent these contaminants from getting near the contacts, Filtors, Inc., a division of the Deutsch Co., has physically separated the switching module (contacts plus armature) from the coils in its Super-J crystal relay. The switching module is hermetically sealed in a metal container which serves as a base. The package containing the coils is fitted onto poles sticking from the base, with small pins mechanically connecting the two sections of the relay.

To stay clean, the inside of the base component must start out clean. Filtors accomplishes this by manufacturing the units in a clean room and, prior to hermetically sealing them, baking out (degassing) the units at 250° C—about 100° greater than conventional bake-out temperatures. In addition, the all-metal structures can withstand more efficient cleansing solvents than can conventional relays which have organically insulated coils in the same package with the contacts.

The coils will discharge gas during operation, but into the atmosphere, not into the contacts. To minimize even this slight degree of air pollution, the coil package is seamed by an electron beam welder, bypassing the potential contamination the presence of flux brings. In addition, it welds at a low temperature, reducing heat distortion.

The double-pole, double-throw relay will be available off the shelf in a month or two, in standard coil sizes of 6, 13, and 26 volts. Custom assemblies, with voltages from 6 to 110 v, can also be ordered. The interior of the switching module is identical for all standard sizes and will be stockpiled. There are three mounting styles—the straight plug-in case shown, a flange case, and one with hooks on either side. Each style is less than 1 cubic inch and weighs a maximum of 1 ounce. Prices will be about $30 to $40, depending on coil voltage and quantity—about twice the price of the company's standard J configuration.

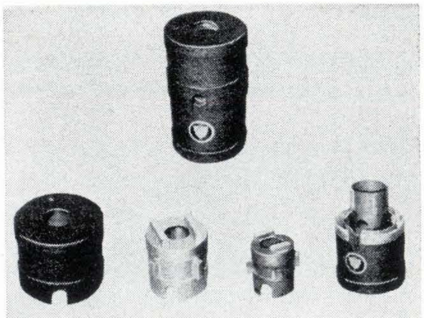
To be exhibited at the IEEE show.

Specifications

Contact rating	2 amps
Shock resistance	250 g's, 11 msec
Vibration resistance	50 g's at 3 khz
Temperature range	−65° to 125° C
D-c relay pull-in time	5 msec, max at 25° C
Release time	5 msec
Pull-in power	340 mv, max.

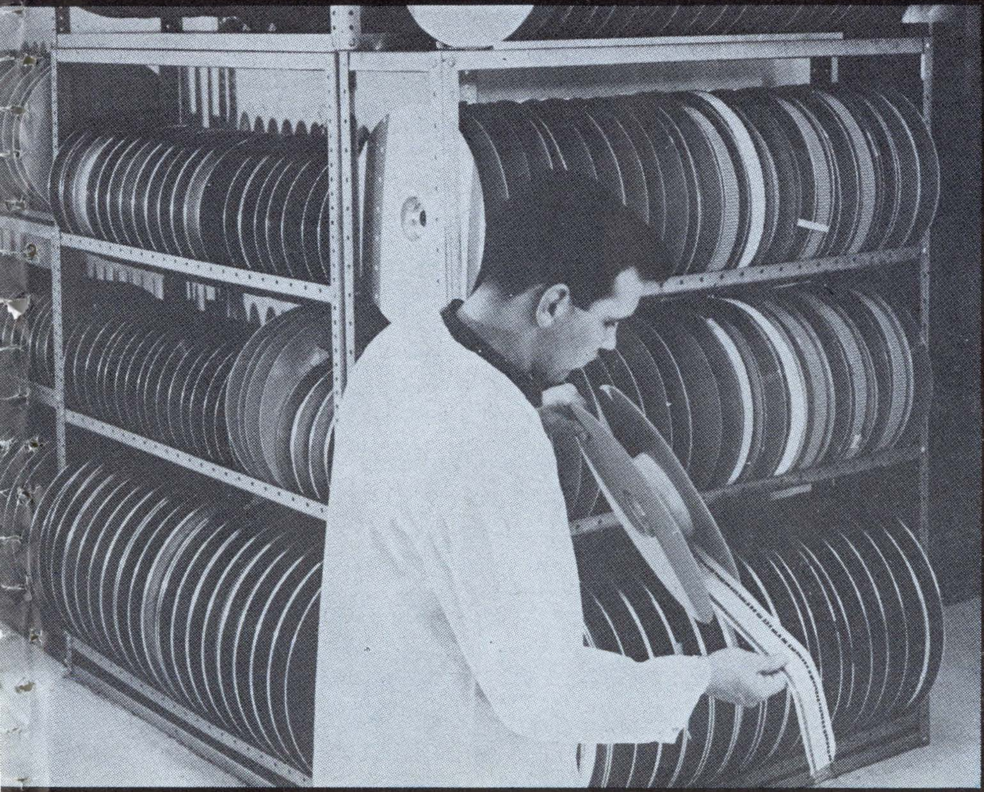
Filtors, Inc., 65 Daly Road, East Northport, N.Y. 11731 **[351]**

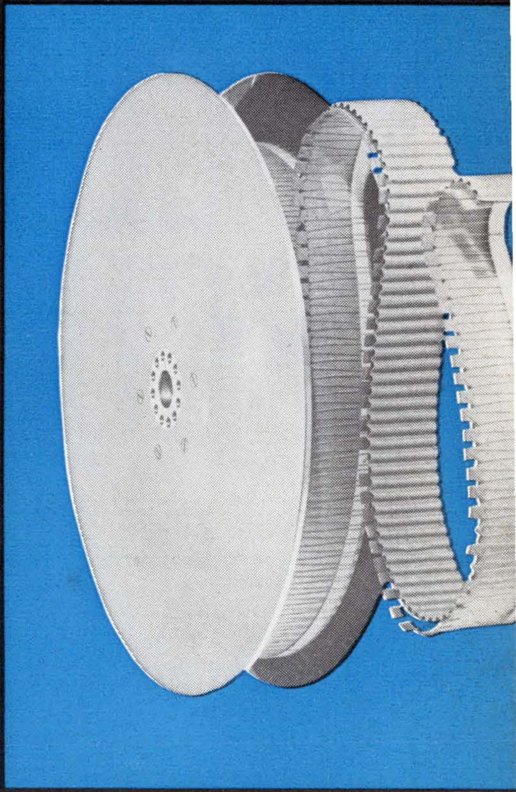
Magnetic shield protects sensors



Ionization gauges and other sensing devices can operate safely in magnetic field environments up to 1,000 oersteds with a magnetic shield. The shield structure is designed on a concentric assembly basis with each shielding system a complete magnetic shunt. Convection cooling is provided by open-

Reel fast delivery of ceramic capacitors . . . the result of Mepco's automated production techniques





Mepco's subminiature Ceramic Capacitors meet the standards of military specifications, yet are designed and priced for high-volume industrial-commercial programs.

- Conformal epoxy enclosure offers excellent environmental protection and unusually high body insulation.
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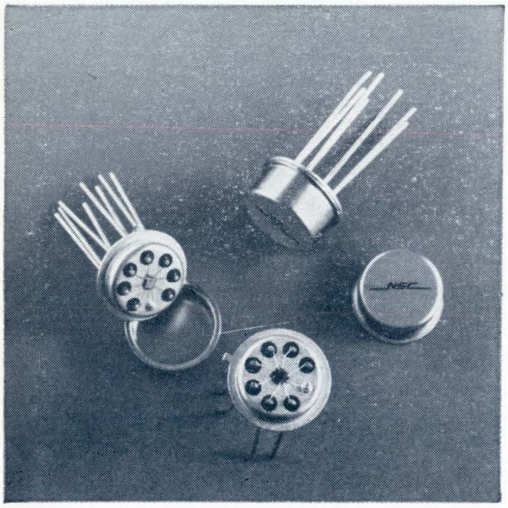

- Output adjustable from 2V to 30V.
- Output currents in excess of 5A using external power transistors.
- Can be used as either a linear or a high-efficiency switching regulator.

The first of a new line of monolithic linear integrated circuits

This versatile regulator features regulation better than 1 percent for widely varying load and line conditions. Temperature stability is better than 1 percent over the full military temperature range. As a linear regulator, the LM100 provides current limiting, excellent transient response and unconditional stability with any combination of resistive or reactive loads. As a switching regulator the circuit will operate at frequencies up to 100KHZ with efficiencies better than 85 percent.

The LM100 is immediately available from distributor stock.

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MICROCIRCUITS DIVISION
NATIONAL SEMICONDUCTOR CORPORATION
2950 SAN YSIDRO WAY, SANTA CLARA
CALIFORNIA 95051 (408) 245-4320

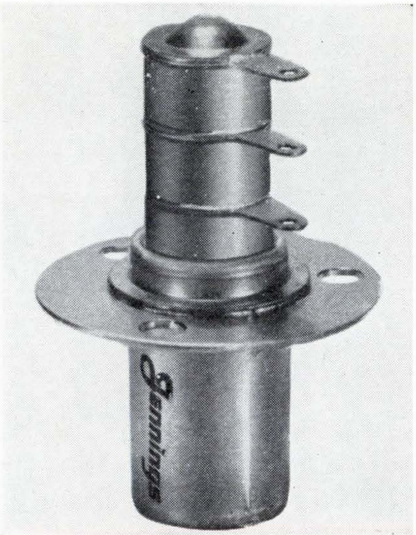
ings in both ends of the shield, and an aluminum bar stock attached to the outer wall perimeters provides the spacing between shields. To simplify tube installation, all lower shield cylinders are cemented in position with epoxies and remaining components are detachable. Shielding qualities are not affected by ordinary shock.

After proper heat treatment of magnetic components, the Netic shield sections are cadmium plated to minimize rusting with no periodic annealing required. The outer shield has a baked wrinkle enamel finish.

Prices, beginning at $350, depend on complexity and size. Delivery is four to six weeks depending on structural modifications required.

To be exhibited at the IEEE show.
Magnetic Shield Division, Perfection Mica Co., 1322 North Elston Ave., Chicago, Ill., 60622. [352]

Vacuum dielectric gives long life to relay



Interrupting resistive power, carrying high r-f currents and withstanding high voltage, are features of the RF1D vacuum relay.

The relay interrupts 1,000 watts of d-c power for over 100,000 operations at a maximum of 1 amp or 2 kv. It also withstands 4 kv peak test voltage and carries r-f currents of 4 amps rms at 16 Mhz. This is made possible with a vacuum dielectric and a new internal design.

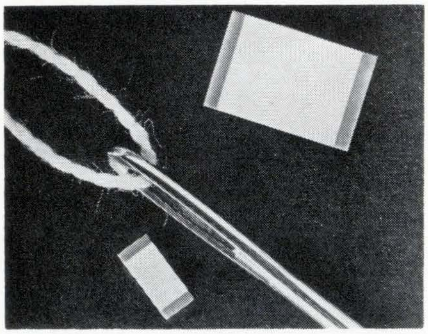
Contact arrangement is single-pole double-throw; contact resistance, 0.010 ohm maximum; switching time, 10 msec maximum; coil voltage, 26 v d-c.

The unit weighs ¾ oz and occupies less than ⅓ cu. in. of space.

To be exhibited at the IEEE show.

ITT Jennings division of International Telephone and Telegraph Corp., P.O. Box 1278, San Jose, Calif., 95108. [353]

Rugged chip capacitor provides high stability



Construction and materials designed to be impervious to environmental conditions have resulted in high stability for a miniaturized NYT-CHIP capacitor. Advantages include high capacitance-to-volume ratio; superior packaging flexibility; and mounting versatility, particularly for outboard mounting on integrated, thick-and thin-film circuitry.

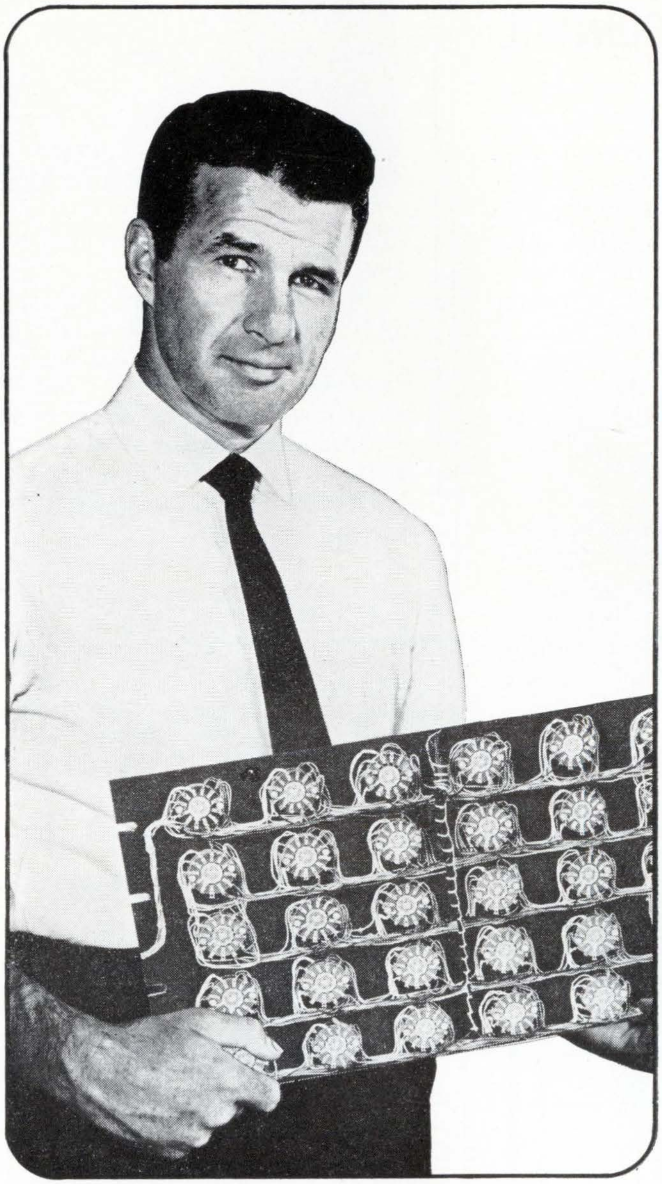
Dimensions with tinned terminals range from 0.170x0.065x0.070 in. with capacitance range of 4.7 to 82 pf, and 0.280x0.195x0.070 in. for 100 to 1,000 pf. Voltage rating is 200 v d-c.

Nytronics Inc., 550 Springfield Ave., Berkeley Heights, N.J., 07922. [354]

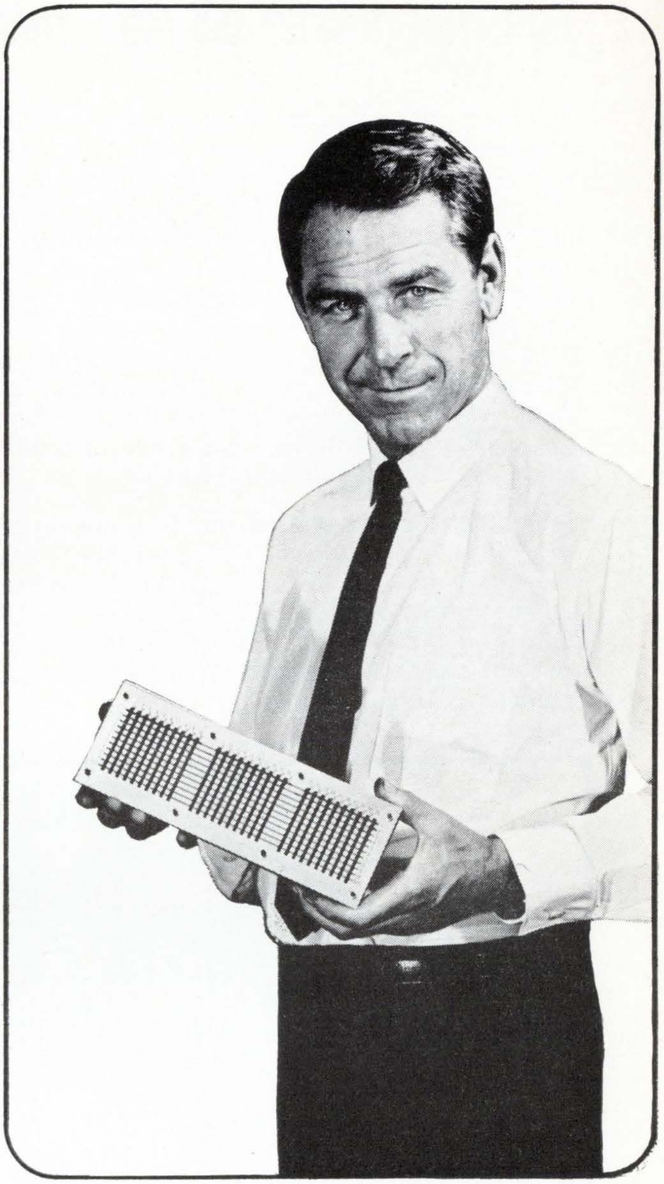
Quartz crystal offers peak stability

Designed for use in crystal oscillators where ultrastability is a prime requirement, a 1-Mhz quartz crystal fits in an HC-27/U glass assembly. The highly reliable unit

TWO ENGINEERS WITH THE SAME PROGRAMMING PROBLEM



USING ROTARY SWITCHES requires 330 soldered joints . . . over 8 hours of labor . . . occupies 293 square inches of panel space . . . costs $88.00 installed.
(That's $0.29 per switching point.)



USING CHERRY SELECTOR SWITCH requires no soldering . . . less than 5 minutes of labor . . . occupies 41 square inches of panel space . . . costs $32.95 installed.
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WRITE TODAY for full details on the totally new Cherry Selector Switch. It may change all your old ideas about programming devices.

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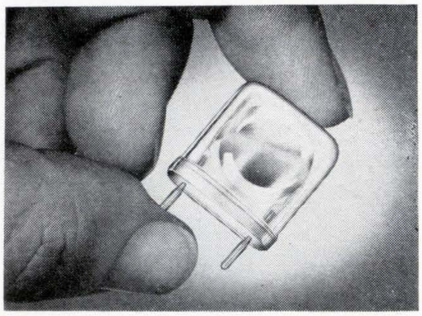
New Components



features aging stability equal to 2 parts in 10^8/week.

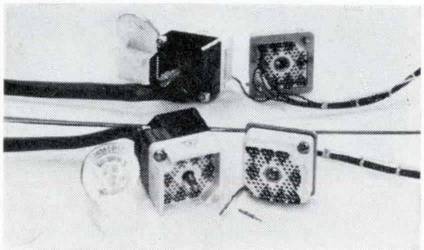
Absolute turnover characteristic of the crystal can be attained within $\pm 5°C$ of any given temperature between 50° and 85°C, and the ruggedized mounting enables it to withstand vibrations of 50 to 2,000 hertz at the rated level of 15 g's.

Crystal dimensions are 0.775 in. (excluding pins) x 0.757 in. x 0.352 in.

Price of the type MW-GT-1 ranges from $20 to $50 in production quantities, depending on specific requirements.

Midland Wright Corp., 3151 Fiberglas Road, Kansas City, Kansas, 66117. [355]

Connector promises high density mounting



In the same mounting area normally required by a size 18 MS shell, a new connector will provide 100 removable contacts and six polarization positions. Because of their square design, ten of these connectors can be mounted in a space required for six round ones.

The crimp type, removable contacts are the standard 0.030 pins and sockets used in the manufacturer's SREC subminiature rack and panel connectors. These contacts are rated at 5 amps and will ac-

Does AE make the world's prettiest dry-reed switches?

Some of our customers think so. They go for the chic look of our PC Correeds on a printed circuit board.

Our designers are flattered. But they point out that the beauty of a PC Correed is more than skin-deep.

Take the contact leads. We keep them separate from the terminals—to eliminate strain. The terminals themselves have "I-beam" strength. They are longitudinally ribbed for extra rigidity—for easy insertion in PC boards.

The contact terminals are *welded*, not soldered. This makes a better electrical connection.

We filled the plastic bobbins with glass, to prevent moisture absorption. And to boost structural strength. You can pack these smart-looking switches as densely as you like. Because of their low profiles, magnetic shielding, and standard PC terminal spacing (multiples of 0.200″).

PC Correeds are available with 1, 2, 3 and 5 reedcapsules, in contact forms A, B, C and magnetic latching. You can get many of these modules right from stock. So it's easy to put a little beauty in your life.

Want some helpful new design information? Ask your nearest AE representative for Circular 1070-B. Or drop a line to the Director, Electronic Control Equipment Sales, Automatic Electric Company, Northlake, Illinois 60164.

AUTOMATIC ELECTRIC

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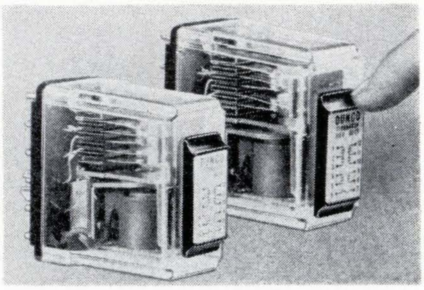
commodate No. 20 through No. 32 Awg wire.

The new connector features an integral, polarized shell of a tough thermoplastic and has a center jack screw. It also has a protective hood with cable clamp. The connector will be called the SQC100P (plug) and the SQC100S (receptacle).

To be exhibited at the IEEE show. Winchester Electronics, division of Litton Industries, Main St. and Hillside Ave., Oakville, Conn., 06779. [356]

Control relays for industrial use



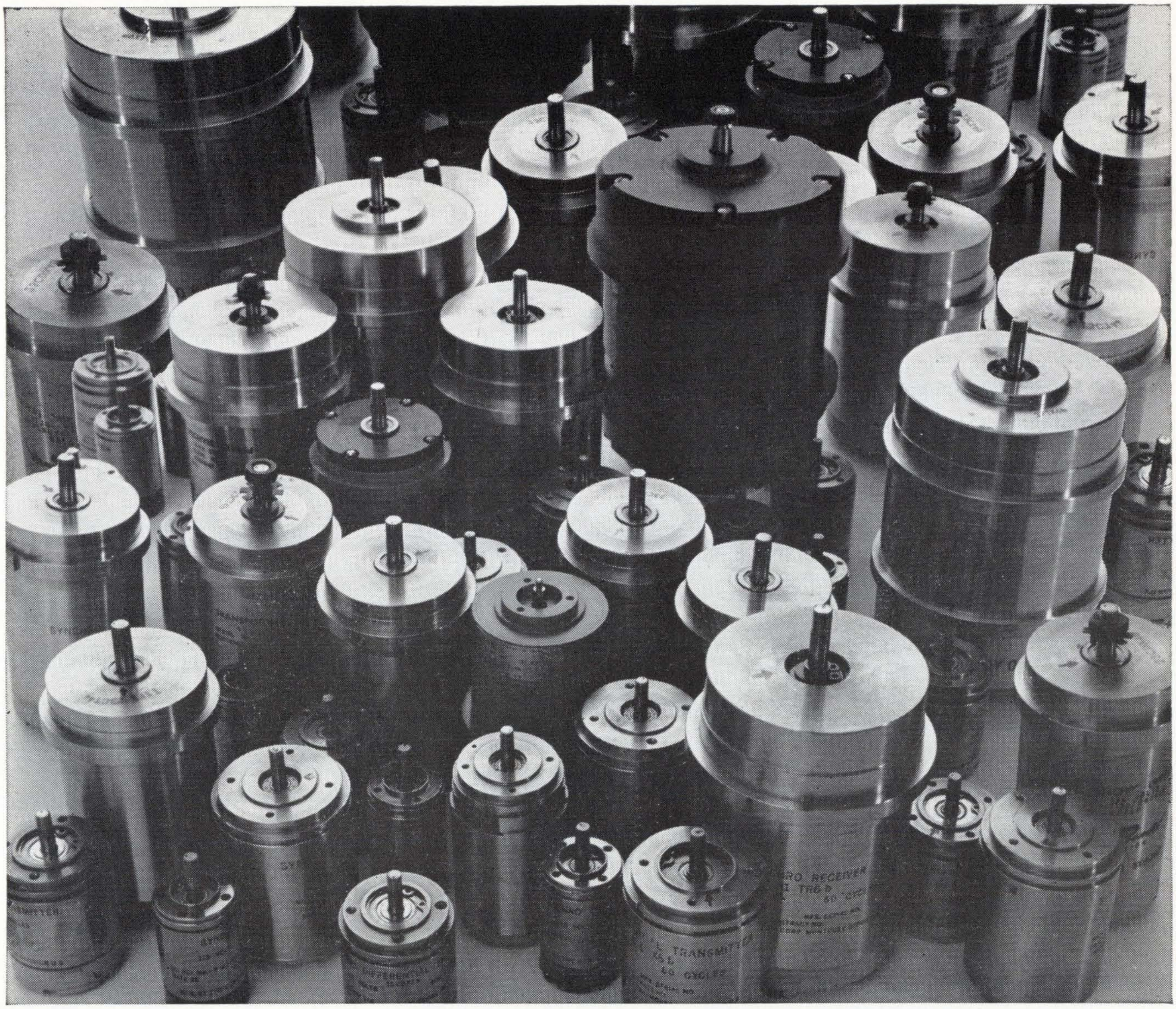
A manual actuating lever that enables the contacts of a relay to be actuated without removing the case cover is a feature of one of three plug-in control relays. A second model contains a neon indicating lamp visible through the clear plastic cover whenever the coil circuit is energized. The third model combines both the lever and the clear case. All three relays are for 150-v industrial service. The special features have been incorporated to simplify and speed circuit checkout and troubleshooting.

Each of the relays is available in three different contact arrangements and ratings of 10 amps. Coils are available from 6 to 230 v a-c, 6 to 125 v d-c.

To be exhibited at the IEEE show. Struthers-Dunn Inc., Pitman, N.J., 08071. [357]

Stand off mounting for pulse transformers

Molded pulse transformers that operate in nanoseconds are designed to stand off when applied



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Bendix® Mil-Spec synchros total 107 different synchro models—cover 11 major military specifications—and include nine primary sizes, ranging from the dwarf Size 08 (our most recent addition) to Size 37 (see chart for both).

What the numbers mean to you is simple: you now have a single source of supply for virtually every Mil-Spec synchro you'll ever need—and nearly all the others, just in case.

What the numbers mean to us is simple, too: Bendix Mil-S-20708 synchros are consistently chosen for use on ground support equipment and navy ships. That's a record we intend to keep.

There's more: a valuable asset called experience. Ours began in the 1920's with the original synchro concept. Since then we've helped develop nearly every major military spec in use. Today, we'll provide everything from Mil-Spec to our famous Autosyn® line to special, custom-made synchros for the unique problem.

What it all boils down to is this: when you need a Mil-Spec synchro (or any other kind), call the leader in synchros at (717) 278-1161. Or write for our 42-pg. catalog. Flight & Engine Instruments Division, Montrose, Pa.

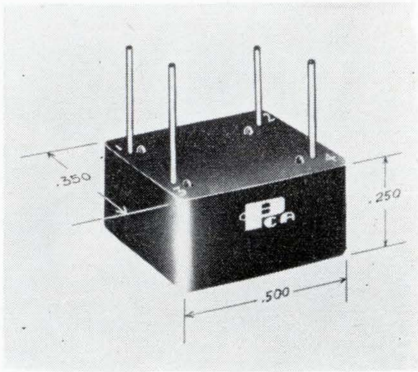
Size	Max. Diameter (In.)	Typical Weight (Oz.)	No. of Models
BuWeps 08	0.750	1.6	3
BuWeps 11	1.062	4.4	10
BuWeps 15	1.437	9	19
BuWeps 18	1.750	17	16
Ordnance 23*	2.250	21	20
BuWeps 23	2.250	31	20
BuWeps 30	2.962	99	2
BuWeps 31	3.100	65	10
BuWeps 37	3.625	124	7

*MIL-S-12472, 16892, 20708, 2335; MS-51080, 51081, 51082, 51083.

Bendix Aerospace Products

Circle 263 on reader service card

New Components



to printed-circuit boards. The units are available in two or three windings and come in a variety of miniature epoxy cases.

Featuring low leakage inductance and distributed capacity, which make possible a wide operating bandwidth, these SN series transformers are said to give best performance in pulse coupling applications.

When employed in blocking oscillators, the transformer's materials greatly improve the efficiency of such circuits.

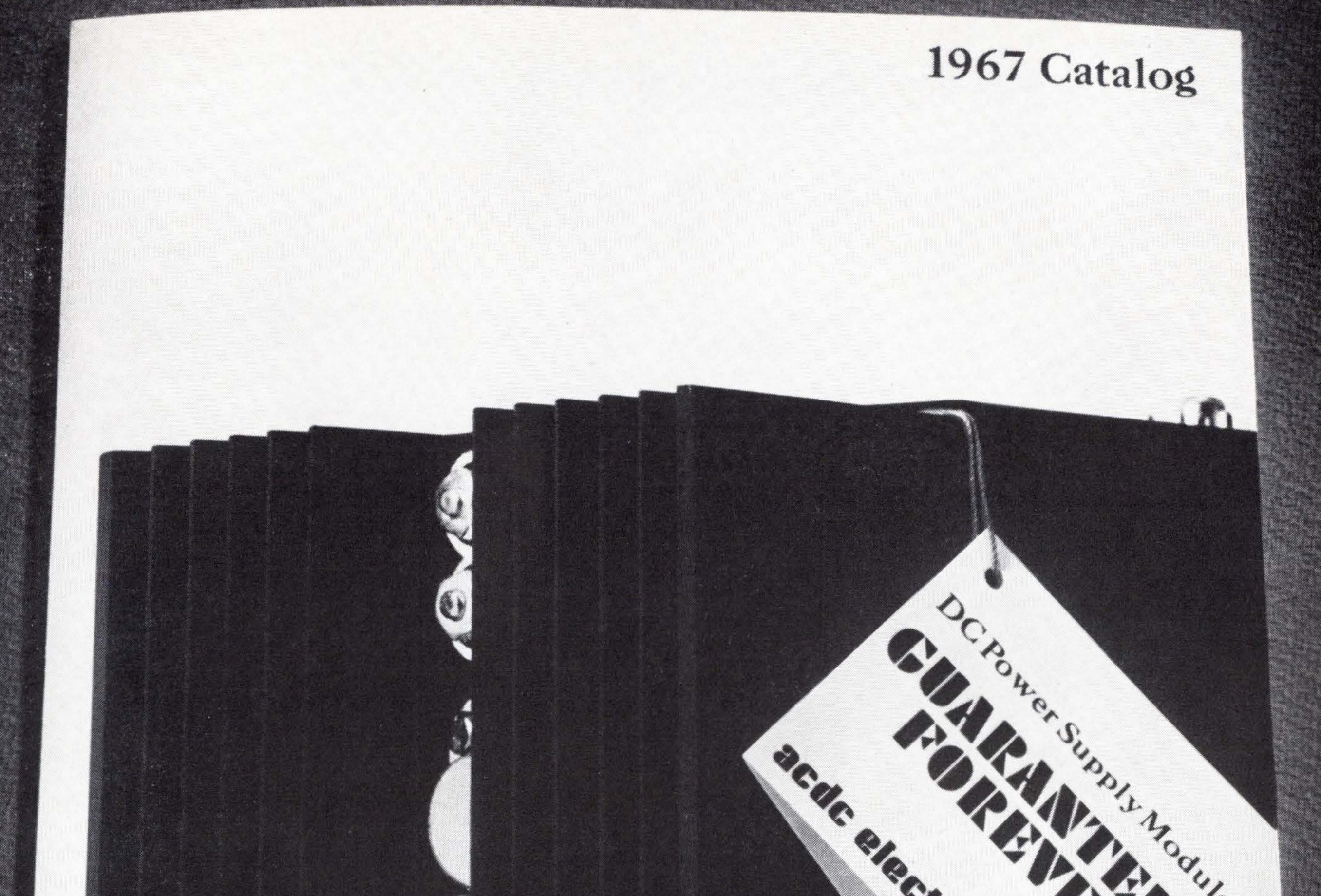
Units are designed to operate in an environmental range of from −55° to +125°C. Measuring only 0.250 in. high, they are 0.250 in. wide, 0.500 in. long and meet all MIL-T-27 Grade V, Class S specifications.

Price is approximately $15; delivery, about eight weeks.

PCA Electronics Inc., 16799 Schoenborn St., Sepulveda, Calif. 91343. [358]

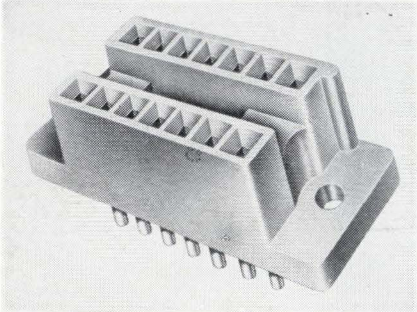
Sockets accommodate dual in-line IC's

Dual in-line integrated circuit packages can be aged, production tested, breadboarded, and life or sample tested in a new IC socket series. The sockets accommodate all commonly used dual in-line packages with 14 or 16 leads on 0.100-in. centers as well as round, rectangular and octagonal leads, trimmed as short as 0.100 in. Large chamfered entrances permit fast, easy insertion of devices. A quick-removal slot facilitates rapid withdrawal, and an ejection slot is avail-



If you'll circle Reader Service #25, we'll send you one by return mail.

New Components



able for semiautomatic device removal.

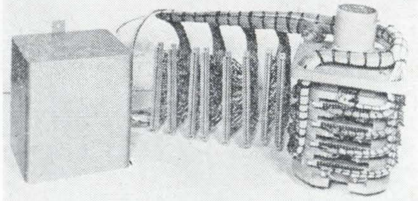
Designed for chassis mounting or dip-soldering to p-c boards, the series is available with or without mounting flanges and with tubular or tab terminals. For maximum packing density, over-all socket dimensions have been held to ¼ in. above board and ½ in. wide by ¾ in. long. With mounting flanges, length is $1\frac{1}{16}$ in.

For greatest reliability, contacts are one-piece, precision-formed of beryllium copper, full spring tempered, hard gold over nickel plated. Body dielectric is Polysulfone for continuous operation from −65° to 150°C. Socket life is typically 20,000 insertions.

Price is 41 cents to $1.50, depending on type and quantity. Availability is from stock to two weeks.

Barnes Development Co., Lansdowne, Pa., 19050. **[359]**

Rotary scanner switch samples sequentially



Data sampling and data logging in process control are two applications for a new rotary scanner switch. The high reliability switch is basically a sequential sampling device for feeding a large number of signal inputs into one channel,

We've got a chip on our shoulder!

Not enough of you know that we are one of the industry's leading manufacturers of high-quality 930 DTL digital integrated circuits. Well, we are.

Who has a larger more modern facility devoted exclusively to the manufacture of these kinds of microcircuits? (We don't dilute our efforts with the manufacture of a thousand other semiconductor components.)

Who has better yields in this DTL line? (Our manufacturing capability is unsurpassed, and we invite you to inspect it for yourself.)

Who can give you better delivery on these products? (It's pretty hard to beat our *immediate* delivery!)

Who can offer you better prices? (Try us on a quantity bid.)

Who has a more substantial name behind them than the "Stewart-Warner" name—a name associated with the manufacture of quality products for more than 85 years? (We'll be around to keep you supplied with microcircuits for years to come.)

Why have we got a chip on our shoulder? Not enough of you have tried our 930 DTL monolithic circuits, and that's too bad. We know you'd like our product, available in all the standard packages. So why not help us take the "chip" off our shoulder and put it in your equipment. Send for our 20-page "Composite Data Book" for the industry's best coverage of the 930 DTL series.

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2856 Size #20. . .Alpha Distributors
2857 Size #18. . .Alpha Distributors
2858 Size #16. . .Alpha Distributors
2859 Size #14. . .Alpha Distributors
2859/12 Size #12. . .Alpha Distributors
2859/10 Size #10. . .Alpha Distributors

MIL-W-16878D TEFLON WIRE
TYPE EE—EXTRUDED (1000 VOLTS)

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2878 Size #16. . .Alpha Distributors
2879 Size #14. . .Alpha Distributors
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2812/3 3 cond., size 22. . .Alpha Distributors
2812/4 4 cond., size 22. . .Alpha Distributors
2815 1 cond., size 20. . .Alpha Distributors
2815/2 2 cond., size 20. . .Alpha Distributors
2815/3 3 cond., size 20. . .Alpha Distributors
2815/4 4 cond., size 20. . .Alpha Distributors
2818 1 cond., size 18. . .Alpha Distributors
2818/2 2 cond., size 18. . .Alpha Distributors
2818/3 3 cond., size 18. . .Alpha Distributors
2818/4 4 cond., size 18. . .Alpha Distributors
2807 1 cond., size 16. . .Alpha Distributors
2807/2 2 cond., size 16. . .Alpha Distributors

MIL-W-16878D SHIELDED TEFLON CABLE; TEFLON IMPREGNATED BRAID OVER SHIELD:

2811 1 cond., size 24. . .Alpha Distributors
2811/2 2 cond., size 24. . .Alpha Distributors
2811/3 3 cond., size 24. . .Alpha Distributors
2811/4 4 cond., size 24. . .Alpha Distributors
2814 1 cond., size 22. . .Alpha Distributors
2814/2 2 cond., size 22. . .Alpha Distributors
2814/3 3 cond., size 22. . .Alpha Distributors
2814/4 4 cond., size 22. . .Alpha Distributors
2817 1 cond., size 20. . .Alpha Distributors
2817/2 2 cond., size 20. . .Alpha Distributors
2817/3 3 cond., size 20. . .Alpha Distributors
2817/4 4 cond., size 20. . .Alpha Distributors
2819 1 cond., size 18. . .Alpha Distributors
2819/2 2 cond., size 18. . .Alpha Distributors
2819/3 3 cond., size 18. . .Alpha Distributors
2819/4 4 cond., size 18. . .Alpha Distributors
2820 1 cond., size 16. . .Alpha Distributors
2820/2 2 cond., size 16. . .Alpha Distributors

MIL-W-16878D SHIELDED TEFLON CABLE; TEFLON TAPE WRAP JACKET OVER SHIELD:

2821 1 cond., size 24. . .Alpha Distributors
2821/2 2 cond., size 24. . .Alpha Distributors
2821/3 3 cond., size 24. . .Alpha Distributors
2821/4 4 cond., size 24. . .Alpha Distributors
2824 1 cond., size 22. . .Alpha Distributors
2824/2 2 cond., size 22. . .Alpha Distributors
2824/3 3 cond., size 22. . .Alpha Distributors
2824/4 4 cond., size 22. . .Alpha Distributors
2827 1 cond., size 20. . .Alpha Distributors
2827/2 2 cond., size 20. . .Alpha Distributors
2827/3 3 cond., size 20. . .Alpha Distributors
2827/4 4 cond., size 20. . .Alpha Distributors
2829 1 cond., size 18. . .Alpha Distributors
2829/2 2 cond., size 18. . .Alpha Distributors
2829/3 3 cond., size 18. . .Alpha Distributors
2829/4 4 cond., size 18. . .Alpha Distributors
2826 1 cond., size 16. . .Alpha Distributors
2826/2 2 cond., size 16. . .Alpha Distributors

MIL-W-16878D SHIELDED TEFLON CABLE; TEFLON FEP EXTRUDED JACKET OVER SHIELD:

2831 1 cond., size 24. . .Alpha Distributors
2831/2 2 cond., size 24. . .Alpha Distributors
2831/3 3 cond., size 24. . .Alpha Distributors
2834 1 cond., size 22. . .Alpha Distributors
2834/2 2 cond., size 22. . .Alpha Distributors
2834/3 3 cond., size 22. . .Alpha Distributors
2837 1 cond., size 20. . .Alpha Distributors
2837/2 2 cond., size 20. . .Alpha Distributors
2837/3 3 cond., size 20. . .Alpha Distributors
2839 1 cond., size 18. . .Alpha Distributors
2839/2 2 cond., size 18. . .Alpha Distributors
2839/3 3 cond., size 18. . .Alpha Distributors
2836 1 cond., size 16. . .Alpha Distributors
2836/2 2 cond., size 16. . .Alpha Distributors

MIL-W-7139B CLASS 1
TEFLON* AIRFRAME LEAD WIRE

6494 Size #22. . .Alpha Distributors
6495 Size #20. . .Alpha Distributors
6496 Size #18. . .Alpha Distributors
6497 Size #16. . .Alpha Distributors
6498 Size #14. . .Alpha Distributors
6499 Size #12. . .Alpha Distributors

*T.M. Dupont

ALPHA WIRE
A Division of Loral Corporation
Elizabeth, New Jersey 07207

or conversely, feeding one signal channel to a large number of outputs.

The switch consists of from one to ten 2-pole wafers with 64 ways per wafer. Information can be accurately fed to computers and data logging instruments, display oscilloscopes or trip level controls at 640 points per second, per wafer. Action is break before make. Scanning speed is 30 to 120 rpm at 50 hz.

Switching contacts and brushes are 0.015 in. 24-K electrodeposited gold to reduce self-generated noise to less than 3 μv. Disk flatness is controlled to a 4-microinch finish and the insulating medium has no effect on contact performance. Each switch wafer is fitted with four printed-circuit edge connectors for input cables. Solder terminals are provided for output cables.

Normal method of connection is by printed socket, but the unit can be modified to meet customer requirements. Synchronization of any number of scanners and random access can be achieved by incorporating a 64-bit binary coded disk and logic module. A mounted 45 v single-phase synchronous motor drive is also available.

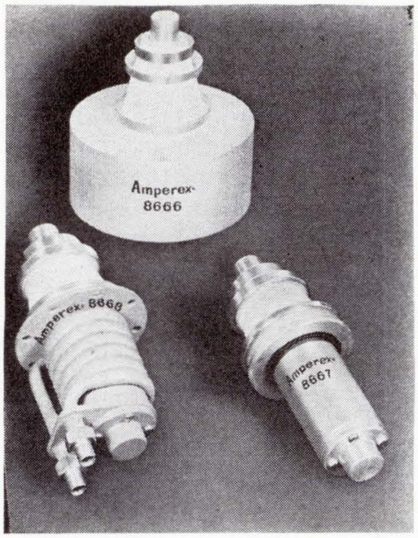
Suggested applications include scanning, multiplexing, distributing, sampling, programing, testing, process control, data logging, transducers, thermocouples, strain gauges and telemetering.
Electro-Tec Corp., Box 667, Ormond Beach, Fla., 32704. **[360]**

Metal-ceramic triodes operate at 250 Mhz

The demand for high frequencies and high power in today's dielectric and induction heating equipment has led to the development of a line of metal-ceramic industrial triodes. These units extend the equipment capability to frequencies greater than 160 Mhz without derating; 250 Mhz with derated operation.

Two families of tubes are available: the series 8731, 8732 and 8733 with 5-kw dissipation and the se-

Circle 269 on reader service card



ries 8666, 8667 and 8668 with 10-kw dissipation. Each series is either air-cooled or water-cooled. Water cooling is accomplished with a conventional water jacket or with an integral helical coil attached directly to the tube anode. The helical cooled version offers a substantial reduction in water consumption.

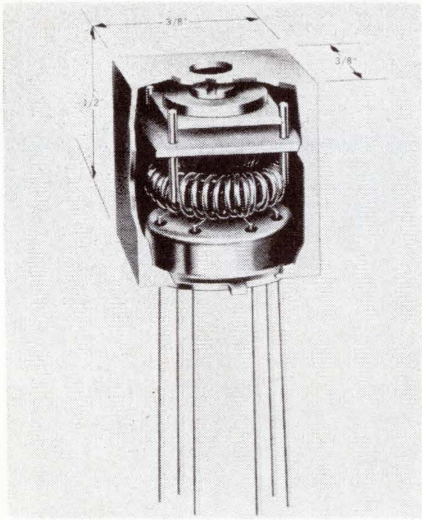
The 8700 series operates at a maximum frequency of 150 Mhz with a power output of 7.5 kw and at an anode voltage of 7.2 kv. The 8600 series operates at 120 Mhz with a power output of 15.5 kw at an anode voltage of 7.2 kv. Either series provides performance and efficiency that produce the lowest cost per kw available at these high frequencies.

New concepts in material design and interior construction have been built into these industrial tubes. A singular development is the use of K material for the grid. A multimetal alloy makes possible anode power that is independent of load factor, so that wide variations of load do not cause a drop-off in power. It also enables the grid to withstand high short-duration overloads which would normally cause grid emission and eventual tube deterioration.

Of special importance is the mesh construction of the grid and filament. It provides for more emission per unit area of cathode surface and thereby permits the construction of smaller tubes. Another advantage of the mesh design is the increase in contact area from the grid to its external connection which results in excellent heat transfer and insures high thermal conductivity. This construction technique limits the possibility of deformation of the grid or cathode during life, thus minimizing the possibility of grid-to-cathode shorts.

Electrode connections with large contact area achieve low thermal resistance between connectors and the tube. This reduces r-f losses and heat at the connection.
Amperex Electronic Corp., Hicksville, L.I., N.Y., 11802. **[361]**

Phase detector in a square can



Typical of a line of miniature LC circuits is this phase detector packaged in a square can—⅜ in. square and ½ in. high—mounted on a standard 6-pin, TO-5 glass-to-metal-sealed header. A recent application has been in a monopulse radar system for weapons control, in which it detects the output phase difference between two 60-Mhz input signals emitted from an i-f amplifier.

Model MTLCJ013 includes a trifilar wound toroidal inductor and a MT320 Modutrim ceramic variable capacitor which is adjustable from the top. The capacitor uses a proprietary ceramic and patented monolithic rotor for extremely high stability (capacitance drift is 0.75% of nominal maximum capacitance).

Operating frequency of the

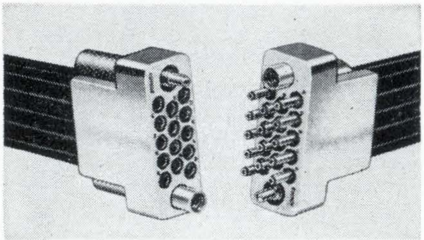
Circle 271 on reader service card

New Components

MTLCJ013 is 60 Mhz. Primary Q is a minimum of 90; secondary Q, a minimum of 75. The network is encapsulated in a multilayer epoxy silicone rubber system. This, together with the square configuration, minimizes shock and vibration effects. Operating temperature range is from —55° to +85° C. Operating altitude is 70,000 ft maximum.

The case of the unit is made from cold-rolled steel, electrotinned and gold plated and is also available in a round configuration. JFD Electronics Co., 15th Ave. at 62nd St., Brooklyn, N.Y., 11219. **[362]**

Spring-back connector effective against rfi



Designed for grounding radio-frequency interference, a line of molded plastic connectors assures good electrical contact with a double-finger construction. The contact is made possible by designing the locking springs as part of the subminiature coaxial connector. Thus, additional commoning springs and retaining plates are eliminated.

The assembly consists of contacts crimped to an inner conductor and assembled within outer contacts crimped to the braid. The springs that lock the contact in the connector body and tie it electrically to the conductive surface of the connector are of simple design.

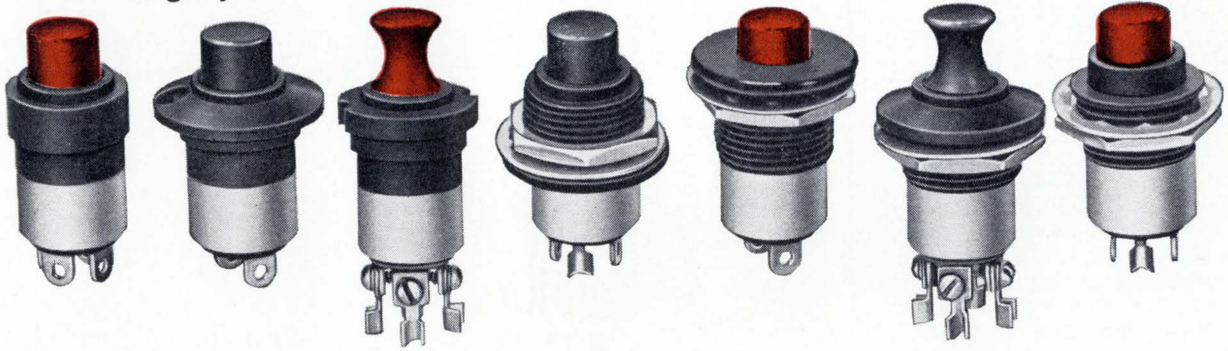
Lower cost and reduced weight are distinct advantages of these connectors over conventional pigtailing or metal connector blocks. The connector block is shielded throughout and has removable contacts that allow for quick circuit changes and repairs.
Burndy Corp., Norwalk, Conn., 06852. **[363]**

Control Switch announces

First and only pushbutton switches certifiable to MIL-S-8805

All 110 Versions of MIL-S-8805/3 – MS25089

- **7 mounting styles**



- **5 circuit arrangements**

SP-NO	SP-NC	SP-NO 3 Terminal	SP-NC 3 Terminal	2-CIRCUIT
Single pole, normally open	Single pole, normally closed	Single pole, normally open, three terminal	Single pole, normally closed, three terminal	(may be jumpered for SPDT)

- **2 button colors.**
- **2 button styles.**
- **Momentary or push-pull actions.**
- **Temperature range: —55°C to 85°C.**
- **Life: 25,000 operations minimum at rated load.**
- **Shock: High Impact, momentary types. 50G, all types.**
- **Vibration: 10 to 500 cps.**

This new Series may include the pushbutton switch you need right now for extreme dependability in military or other equipment. Or the switch that breaks a design block, or sparks a new design idea. The specifications speak for themselves!

Series W190 pushbutton switches are another in a spectacular series of firsts from Control Switch . . . source of the widest selection of high-reliability switches and indicator lights available anywhere. More firsts are coming. Soon! Order Series W190 from your Control Switch distributor, or direct from us.

CONTROLS COMPANY OF AMERICA®

CONTROL SWITCH DIVISION

1420 Delmar Drive, Folcroft, Pennsylvania 19032

A Subsidiary of

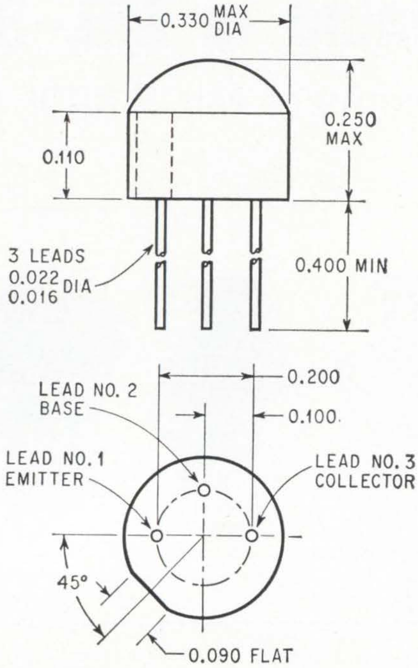
GP General Precision Equipment Corp.

DETAILED BULLETIN!

Check Number on Reader Service Card corresponding to number at left below for our Bulletin on new Series W190 pushbutton switches. While you're at it, get all the items listed below:

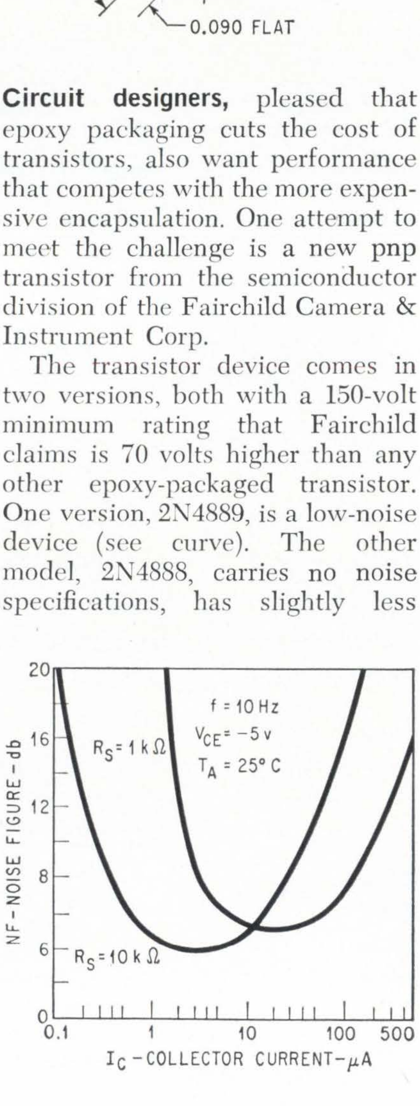
#483 **MIL-S-8805 Bulletin 64**
#484 **Condensed Switch Catalog 100**
#485 **Basic Snap-Action Switch Catalog 110**
#486 **Toggle Catalog 180**
#487 **Indicator Light Catalog 120**
#488 **Hermetic Switch Catalog 130**
#489 **Switchlite Catalog 220**
#490 **Pushbutton Catalog 190**

High voltage comes in epoxy packages



Circuit designers, pleased that epoxy packaging cuts the cost of transistors, also want performance that competes with the more expensive encapsulation. One attempt to meet the challenge is a new pnp transistor from the semiconductor division of the Fairchild Camera & Instrument Corp.

The transistor device comes in two versions, both with a 150-volt minimum rating that Fairchild claims is 70 volts higher than any other epoxy-packaged transistor. One version, 2N4889, is a low-noise device (see curve). The other model, 2N4888, carries no noise specifications, has slightly less gain, and sells for about two-thirds the price of the first.



The manufacturer does not make clear whether the latter version is a noise-test dropout or is merely not noise tested. In any event, it is the version recommended for high-voltage switching applications where a guaranteed low noise is not vital.

The 2N4889 is designated for use in intermediate-frequency, radio-frequency, and linear amplifiers for audio and video applications. It has a maximum noise figure of 3.0 decibels at 1 kilohertz with a current of 30 microamps, a collector-emitter voltage of −5 volts, and a resistance of 10 kilohms. The wideband (10 hz to 10 khz) noise figure is typically 2 db, a maximum of 4 db, at 250 μa, −5 v, and 1 kilohm. At −10 volts, the 2N4889 exhibits a typical d-c pulse current gain of 135 at 100 μamps, and 150 at both 1 milliamp and 10 milliamps; for the 2N4888 the figures are 30, 40, and 45.

Both units are encased in a three-lead package that fits inside the standard TO-5 outline. The 2N4888 sells for $1.20 in small quantities, and 48 cents in lots of 10,000. The 2N4889 is $1.80 each for a few, 72 cents for quantities.

To be exhibited at the IEEE show.

Specifications

Model number	2N4888	2N4889
Collector-to-emitter voltage	−150 v, max	
Collector-to-base voltage	−150 v, max	
Emitter-to-base voltage	6.0 v, max	
Collector-to-emitter sustaining voltage	−150 v, min	
Maximum power dissipation	1.0 w	
Narrow band noise figure at 1 khz	3.0 db, max	
D-c pulse beta at 1 ma, typ	40	150
Collector cutoff current, max	50 na	10 na
Pulsed collector saturation voltage, max	−0.5 v	
Emitter-to-base breakdown voltage, min	−6.0 v	
Beta at 20 Mhz, typ	1.8	3.3

Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, Calif. **[364]**

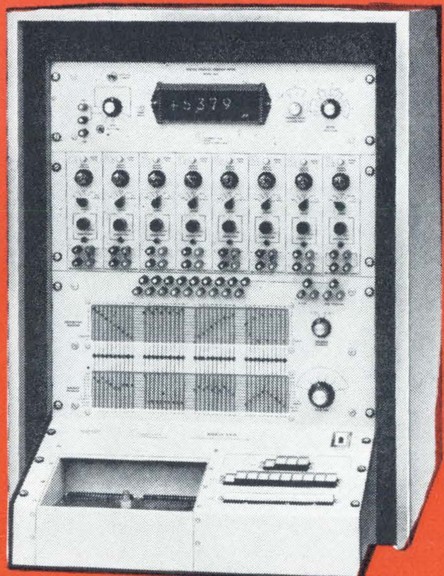
Full power operation for tiny rectifiers

Recovery times as low as 250 nsec permit full power operation at

NEW

semi-automatic integrated circuit analyzer

MICA-150



IEEE DEMONSTRATION

During the IEEE Show, you are cordially invited to a demonstration of the MICA-150 IC Analyzer

St. Moritz Hotel
50 Central Park South
Mar. 20-23 From 12 Noon

COMPUTER TEST CORPORATION

Now the integrated circuit user can get all the flexibility and performance of an expensive, large scale IC test system in an accurate and reliable DC bench top analyzer.

The new MICA-150 Modular Integrated Circuit Analyzer tests all IC configurations of up to 40 pins with unique programming, fast pushbutton sequencing and built-in DVM readout.

Fast, Versatile Programming Two independent 10x40 crossbar switches and rapid pushbutton sequencing provide up to 40 tests on a single device without re-programming. For example, it's now quick and easy to check a 10 pin device using four completely different test programs without resetting any switches to advance the test from pin-to-pin or program-to-program. Additional flexibility allows the built-in DVM to measure current on one pin of the device and voltage on another—all pre-programmed.

Universal Test Adapters Through use of universal test adapters, the MICA-150 is designed to check ICs according to the number of pins of a particular package, not device or circuit type. Adapters are available for diode, transistor, TO-5, flat-pack, dual in-line and other package configurations, and can also be provided for Kelvin connections.

Accurate Digital Readout Specifically designed for the MICA-150 analyzer, the built-in Digital Volt/Ammeter has a conservatively rated readout accuracy of 0.1% with a four digit display. Other features include automatic ranging and polarity selection, self-calibration, automatic voltage or current readout selection. Measures currents as low as 1 nanoamp, voltages to 1 mv.

Modular Design Modular construction allows users to select an economical, customized tester without obsolescence problems. Maximum capacity of eight function generators permits later expansion, including modules for AC and pulse testing, without additional modifications.

Variable Soak Time Marginal device operation can be easily detected through use of an adjustable test time control which provides a period for thermal stabilization prior to measurement. A continuous position on the control allows parameters to be varied while observing results.

Precision, Wide Range Power Supplies Highly precise supplies utilize multi-turn calibrated potentiometer controls with high resolution and repeatability. Constant current supplies are continuously variable from 0-100 ma with voltage compliance adjustable to 100v. Constant voltage supplies are variable from 0-100v with automatic current limiting to 100 ma to provide device protection.

QUICK ACTION REPLY

Detailed technical literature on the MICA-150 will be mailed immediately upon receipt of this request.

Attn.: A. Norman Into, Marketing Manager
Computer Test Corporation, Three Computer Drive
Cherry Hill, N.J. 08034 • Phone: (609) 424-2400

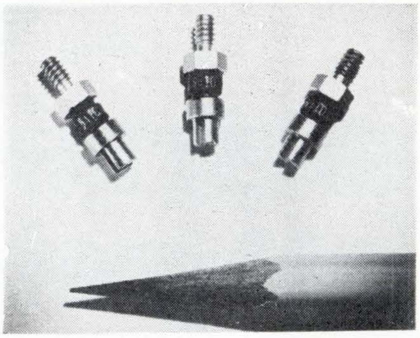
Name____________________

Company____________________

Address____________________

City__________ State______ Zip______

Circle 275 on reader service card



square wave frequencies as high as 40 khz, or even higher sine wave frequencies for new miniature rectifiers. They offer a 9-amp current rating and peak inverse voltage up to 400 v with all models having controlled avalanche characteristics. Surge ratings are as high as 150 amps for one cycle.

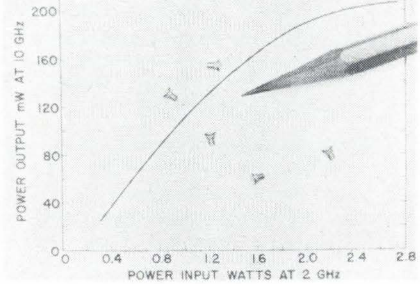
Dimensions are 0.187 in. in diameter and 0.46 in. long with a 4-40 stud 0.19 in. long for attachment to a heat sink. Unit weight is less than 1.5 grams.

The rectifiers feature the manufacturer's monolithic, voidless, whisker-free construction. The silicon is metallurgically bonded to two terminal pins and hard glass is fused directly to the silicon and pins. Then a stud is brazed to one pin and a turret terminal to the other.

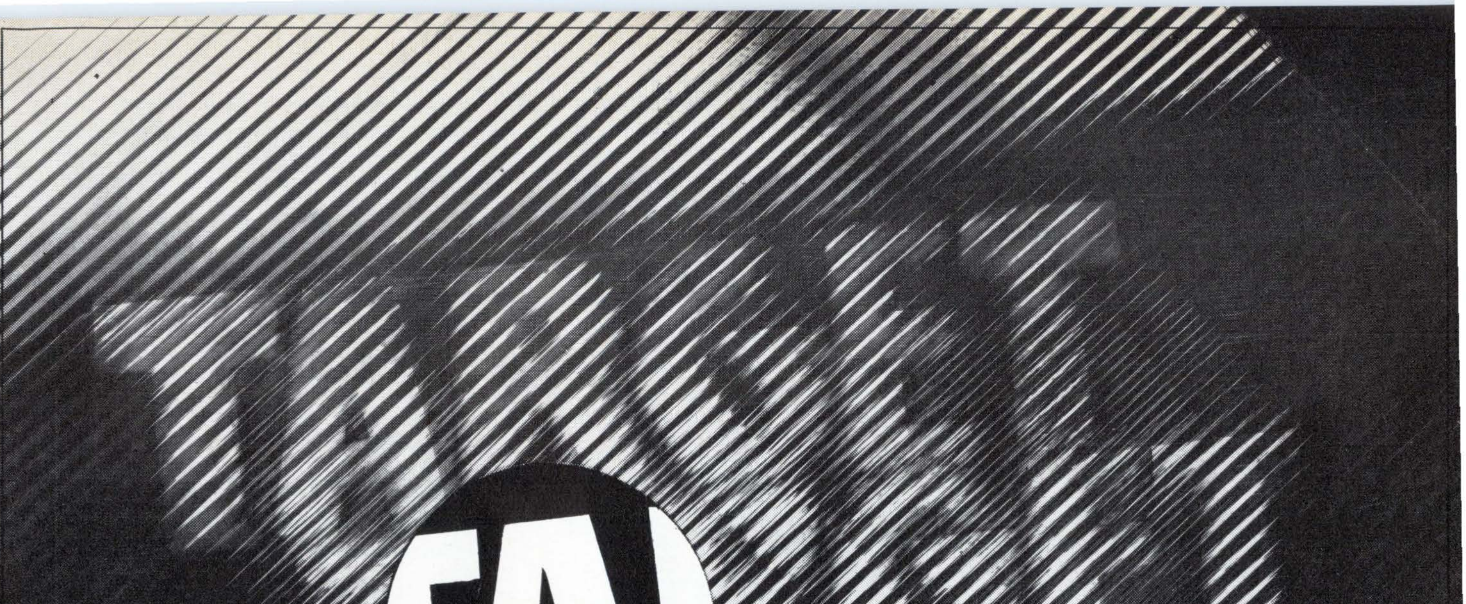
Delivery is from stock. Prices range from $8.50 to $22.

To be exhibited at the IEEE show. Unitrode Corp., 580 Pleasant St., Watertown, Mass. **[365]**

Step-recovery diode boasts high power



When used as a high-order multiplier at microwave frequencies—X-band and above—a new step-



People who counteract countermeasures count on us.

A traveling wave tube for a missile to enable it to home on a target despite the most sophisticated countermeasures. That's what the OEM design engineer on the phone needed. His frequency, power output, and gain requirements were way out. Like nothing we had, or anyone else had. And his time schedule was tight.

In two days we'd visited his plant. Reviewed the performance criteria. Committed ourselves. Another seven days and we'd submitted complete tube specifications. And ninety days later we delivered the first tube. On time and bug-free.

That's how we do business with everyone. We react fast and we know you can't afford false starts. We'll review your technical requirements and if we can't meet them, we'll say so—on the spot. Or we'll take on your job, and stick with it until our tube is working in your system.

If that's how you like to do business, call us. Or write for complete data on our standard TWT's and other types of high-performance tubes: Dept. EL, ITT Electron Tube Division, International Telephone and Telegraph Corporation, P.O. Box 100, Easton, Pennsylvania.

electron tube division ITT

Circle 277 on reader service card

New Semiconductors

recovery diode achieves greater power output than previous diodes, the manufacturer says. For example, when driven at 2 Ghz with 2 watts of power in a single-stage × 5 multiplier, the diode provides a minimum of 150 mw of power at 10 Ghz.

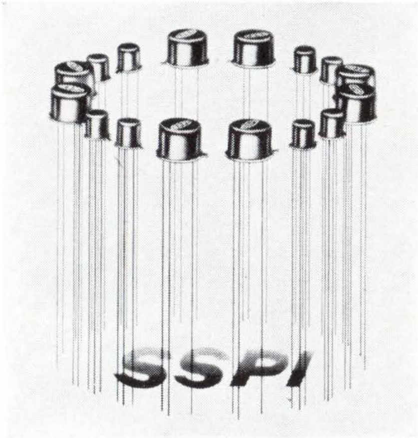
Model 0320 is an epitaxial, surface-passivated silicon device with an abrupt junction gradient. Minimum minority carrier lifetime is 10 nsec, assuring sufficient charge storage for high power output. The single-stud ceramic package has low inductance which, with a reverse-bias capacitance of only 0.7 to 1.3 pf, allows operation at the higher microwave frequencies.

The thermal resistance of the junction-to-mounting-stud path is 50°C/watt and maximum permissible junction temperature, either operating or in storage, is 200°C. Breakdown voltage of the device is 20 v.

Price in quantities of 1 to 9 is $92.50 each; in quantities of 10 to 99, $75 each. Delivery is from stock.

To be exhibited at the IEEE show. HP Associates, 1501 Page Mill Road., Palo Alto, Calif., 94304. **[366]**

Industrial scr's come in 3 sizes



Low cost, low-level triggering, high pulse power and fast switching are offered in a line of silicon controlled rectifiers intended for control and switching in computers and industrial systems. These scr's

Semiconductors

NEW IDEAS IN APPLICATION AND DESIGN

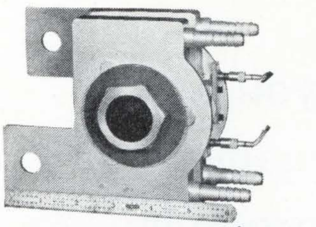
PROVEN PERFORMER FOR HIGH POWER SWITCHING: GE C500X1 WATER-COOLED SWITCH

Even welding locomotives doesn't tax the high power capability of these SCR's.

For seven months one GE C500X1 water-cooled switch has been in use at a large locomotive plant. It operates at 900 amperes RMS and 480 volts, with an on-time of 1.5 seconds and a 25% duty cycle for resistance welding.

The same plant has been using a second C500X1 for five months and expects to install more of them in the future.

C500X1's are also now in use for automotive welding. Other possible applications include particle accelerator power supplies, primary transformer control, static switching, and control of large lighting loads. (Three C500X1's could theoretically control all the lighting in a 60,000-seat stadium.) The C500X1 is rated at 1200 amps



You'll get 1800 volt peak blocking capability from this 1200 amp GE C500X1 water-cooled switch.

RMS with peak blocking capability to 1800 volts in both directions. Surge ratings are 4000 amperes peak for ten cycles and 7000 amperes for one cycle. The device can be used directly in 440 or 550 volt a-c service. Circle number 811.

These are just a few examples of General Electric's total electronic capability. For more information on all GE semiconductor products, call your GE engineer/salesman or distributor. Or write to Section 220-53, General Electric Company, Schenectady, New York. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: Electronic Components Sales, IGE Export Division, 159 Madison Ave., New York, N.Y., USA.

Lots of new application ideas at GE's IEEE seminars

New application ideas for both standard and exotic semiconductors —ideas that can enhance your solid-state circuitry—will be presented at GE's Semiconductor Products Department IEEE seminars on March 21 at the Barbizon-Plaza Hotel Theater, New York City.

The morning session, titled "Innovations for Industrial Semiconductor Circuits," starts at 9 a.m. and features these subjects and speakers:

The complementary unijunction . . .

Bob Muth discusses new IC fabrication techniques and characteristics of this ultra-stable threshold for timers and oscillators.

Tunnel Diodes revisited . . .

Rick Spofford introduces the first truly low-cost planar tunnel diode.

Opto-electronics . . .

Dick Stasior examines the principles and applications of lasers, light emitting diodes, detectors, light-activated SCR's, and SCS's.

Sophisticated functions using GE's newest plastic semiconductors . . .

Joe Byerly presents some of the new, low-cost circuit approaches now possible with advanced plastic encapsulated semiconductors.

The afternoon seminar (1:30), "Semiconductor Control and Power Conversion Applications," features:

The widening world of the fast recovery rectifier diode . . .

John Hey discusses the unique advantages of fast recovery diodes for both low and high frequency power conversion equipment.

Design/application assistance case histories . . .

Tom Penkalski uses actual cases to illustrate symptoms, analysis, and solutions of semiconductor application problems.

Increased current ratings from PRESS PAK semiconductors . . .

Bernie Jalbert shows how new mounting methods increase power handling capability without increasing pellet size.

Primary phase control of transformer coupled loads . . .

Forest Golden examines trigger circuit and transformer requirements in three phase applications.

Economy control circuits and modules for light industrial and consumer applications . . .

Andy Adem discusses a variety of low-cost reliable motor and temperature controls, and power switching circuit modules.

Low-cost precision power control module using zero-voltage switching . . .

Jim Galloway presents a compact control with 3600 watt capability for a variety of open and closed loop control systems.

You'll also be interested in GE's computer time sharing demonstration. Just feed simple design or specification problems into one of the four consoles at the exhibit and the pre-programmed computer will recommend a solution.

All this and more is waiting for you from GE's Semiconductor Products Department at the IEEE show.

GENERAL ELECTRIC

Circle 279 on reader service card

The Predictables.

Some computer manufacturers stockpile diodes.

The others order from ITT.

ITT ships any size order, any day you say. Any part number, silicon or germanium, double plug or DO-7. Make us prove it. RFQ: The Predictables.

diodes ITT

ITT SEMICONDUCTORS IS A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

FACTORIES IN WEST PALM BEACH, FLORIDA; PALO ALTO, CALIFORNIA; LAWRENCE, MASSACHUSETTS; HARLOW AND FOOTSCRAY, ENGLAND; FREIBURG AND NURENBERG, GERMANY

New Semiconductors

are packaged in hermetically sealed metal cases and come in three sizes: TO-46, TO-18 and TO-5. Specifications are essentially identical, except as package size increases, so do average current and power ratings.

The silicon planar passivated construction employed provides long-term parameter stability and inherent reliability. The units are available in anode voltage ratings from 30 to 200 v and feature peak forward currents to 40 amps, maximum trigger currents of 200 μa, 8-μsec recovery times, and 0.2-μsec turn-on times.

The scr's are suited for solenoid or lamp driving, sensing, timing, programing, motor control, and other related high-gain, high-output functions.

All are available from stock and are designated as follows: B150 series—TO-46, BA150 series—TO-18, and CD1040 series—TO-5. They are priced at under $1 in 100-lot quantities.

To be exhibited at the IEEE show.
Solid State Products Inc., One Pingree St., Salem, Mass. [367]

High voltage rectifier stacks

Avalanche silicon rectifier stacks can supply 350 ma at voltage ratings varying from 3,000 to 30,000 volts. Type 35-ST stacks have built-in reverse avalanche voltage characteristic at a minimum of 20% or 2,000 v above the rated peak inverse voltage. All rectifier stacks have a built-in short circuit surge capacity of 15 amps for a maximum of 8 msec.

These high-current stacks are made up of hermetically sealed glass diodes encased in Hysol epoxy which has a dielectric strength of 900 v/mil and electrical insulation resistance of 4.3×10^{14} ohms at 30°C.

Prices start at $2 each for the 3,000-v units in quantities of 100 and run up to $12.50 each for the 30,000-v units.
Atlantic Semiconductor Inc., a division of Aerological Research Inc., 905 Mattison Ave., Asbury Park, N.J. [368]

Reaching a new low with analog meter

An analog meter capable of measuring a-c voltages from 2 hertz to 6 megahertz will be introduced at the IEEE show by Ballantine Laboratories Inc. The company's president, A.W. Parkes Jr. reports it is the first transistorized analog instrument capable of operating at such a low frequency.

Spanning the voltage range from 300 μvolts to 350 volts, the meter has an accuracy within 2% of the indicated value. A 20-decibel probe, available as an optional accessory, extends the voltage range to 1,000 volts. The meter plus 10-db mode permits measurements as low as 100 microvolts but over the narrower frequency range of 10 hertz to 1 megahertz. The instrument is an average responding type, calibrated in the root-mean-square value of the sine wave.

Exceptional resolution is promised for the instrument as a result of a 5-inch logarithmic scale which is mirror-backed and restricted to a 10-db range rather than the more common 4-inch scale which covers a 20-db span. With the logarithmic scale, the accuracy of the indicated value is as specified whether the reading is at the high or low end of the instrument's scale.

Model 303 is designed with signal ground isolated from case ground, an important feature when measuring high-frequency, low-level signals since it is simple to eliminate ground loops.

The mode selector on the front panel includes a "battery" position that enables checking the condition of the battery without removing it or connecting jumpers. When the meter reads less than 13 volts, recharging is needed; a reading of 16.8 volts indicates the battery is fully charged. To recharge, a switch is set at the charge position. Although a full recharge takes 15 hours, the meter may be operated from the a-c line.

The input signal is connected through a BNC connector to give complete shielding of the input and low-impedance ground paths with coaxial input cables.

The instrument is available in two models; 303 contains rechargeable batteries and operates from line or battery power and 303-01 runs on line power only.

Specifications

Voltage (without probe)	300 μv to 350 v in 12 ranges
Frequency 3 db bandwidth	2 hz to 6 Mhz 1 hz to 10 Mhz
Accuracy (% of indication)	1%, 30 hz to 1 Mhz 2%, 20 hz to 2 Mhz 3%, 10 hz to 3 Mhz 5%, 2 hz to 10 hz 5%, 3 Mhz to 6 Mhz 10%, 3 Mhz to 6 Mhz
Input impedance	10 megohms in parallel with 20 ±5 pf
Price	$320 battery/line operation, $290 line only

Ballantine Laboratories Inc., Boonton, N.J. 07005 **[369]**

Relay lets recorder return to the fold

The smudge is gone from Z-fold paper. The problem of ink spreading on folded recording paper whenever the pen crosses a crease has been licked in a new eight-channel pressurized ink recording system offered by the Hewlett-Packard Co.'s Sanborn division.

"Z-fold paper in recorders is not new," says Robert Sanderson, the Sanborn project leader, "but it has been restricted to thermal recorders or capillary ink systems. . . ." In pressurized ink systems, when the pen slowed down at lower frequencies the ink spread heavily at the paper's crease. To avoid this,

Circle 283 on reader service card→

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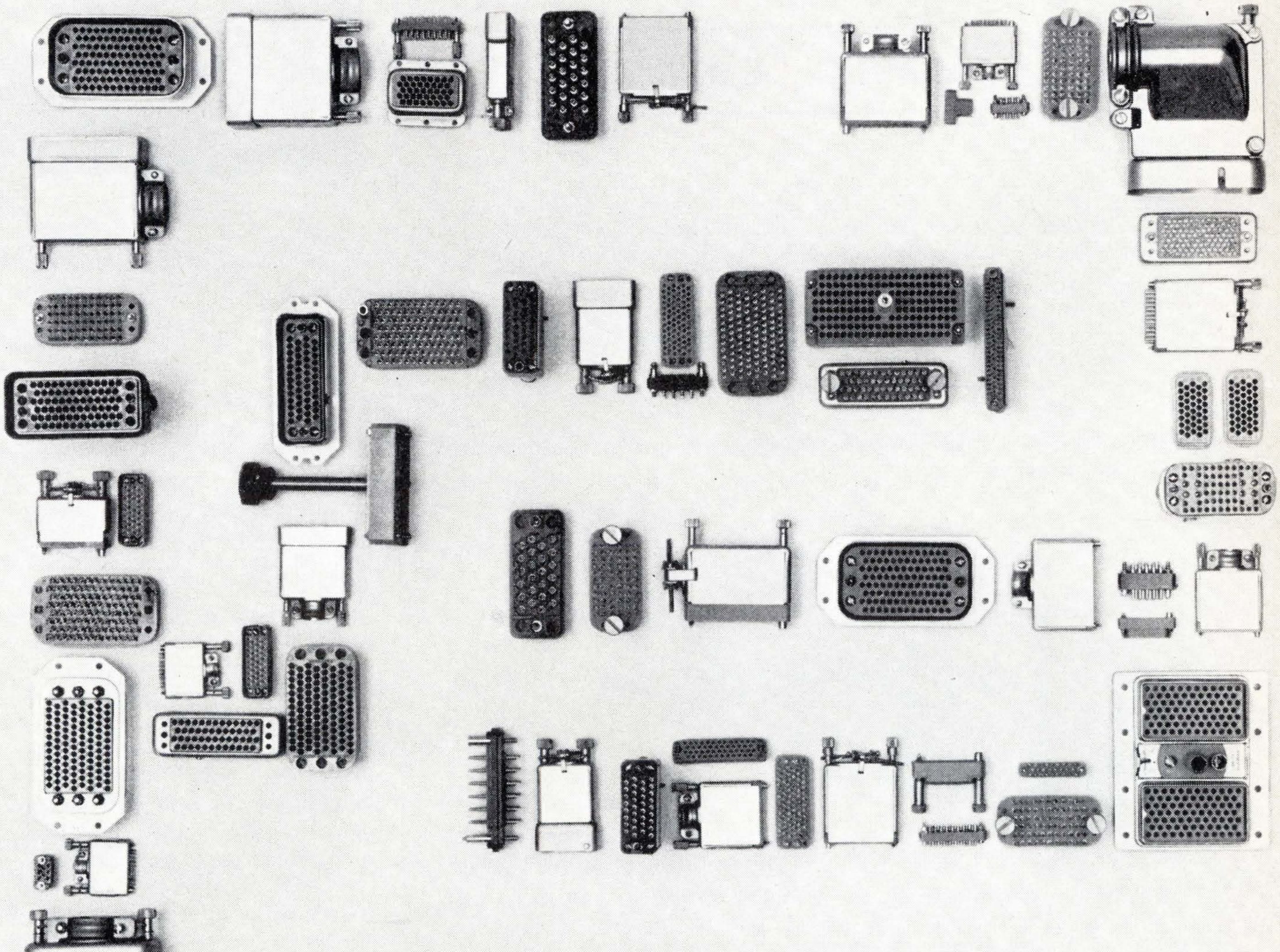

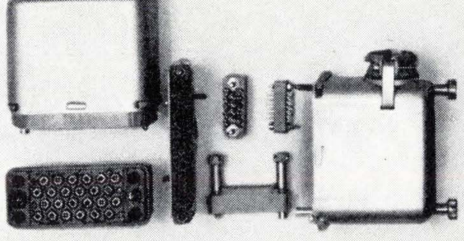

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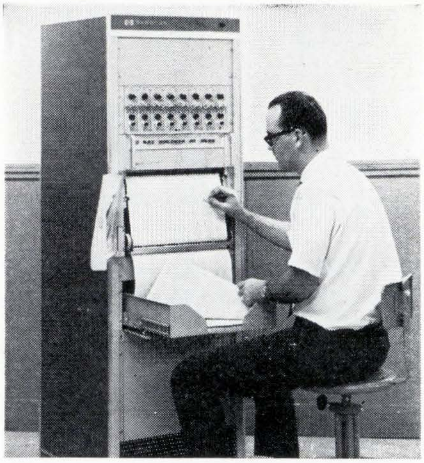


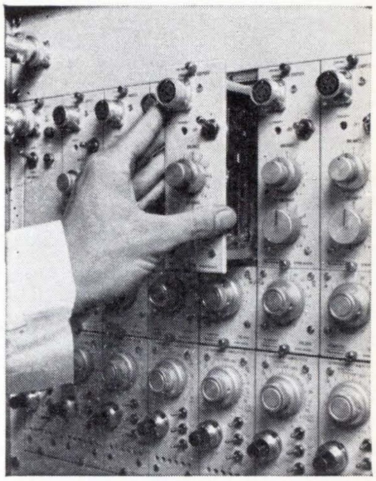
roll paper had to be used, but this made culling information from long-term experiments extremely cumbersome.

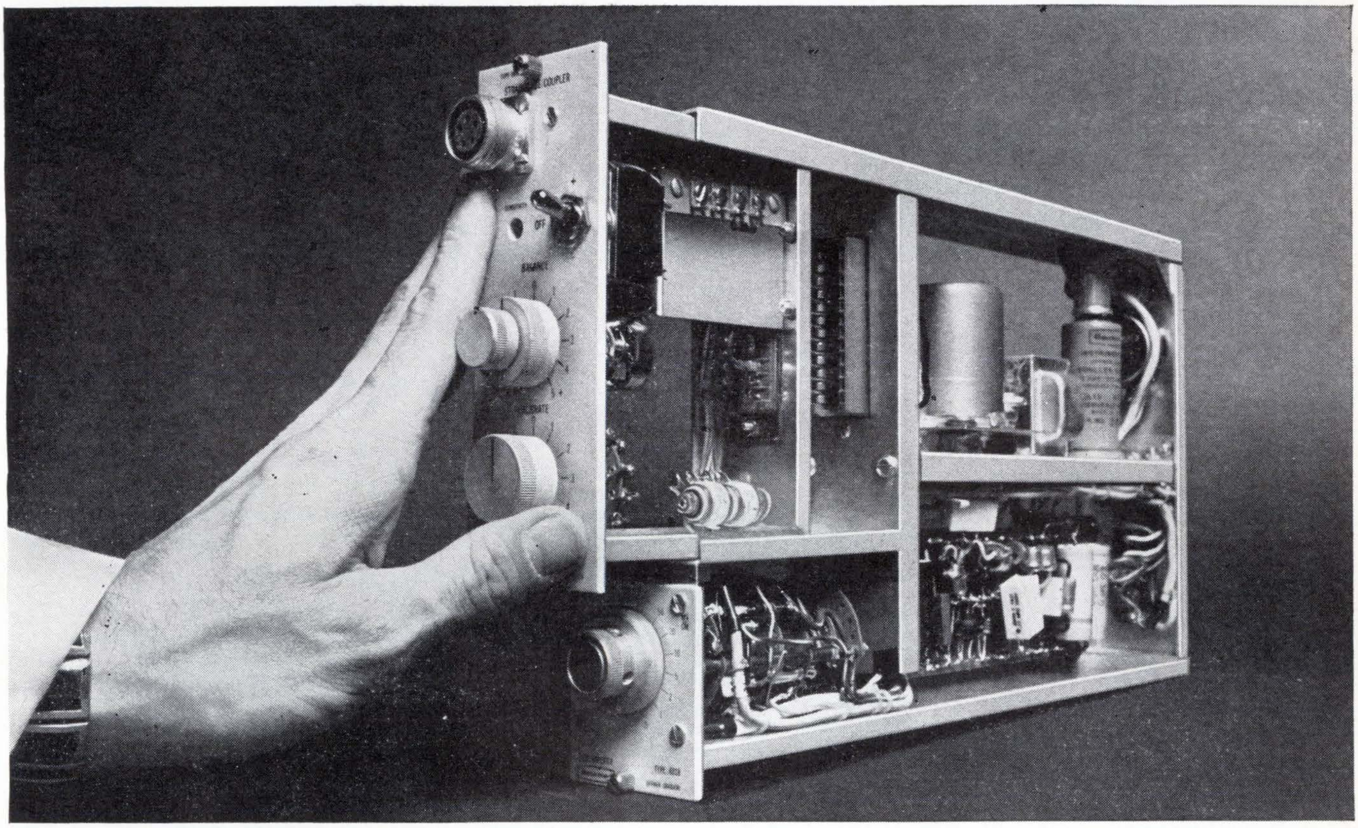
In the new recorder, model 7858A, the ink pressure is modulated to the input's frequency signal. At normal chart speeds and with a low-frequency input signal, the pressure is about 3 pounds per square inch. If there is no input signal and the chart's speed is slow—below 2 millimeters per second—the pressure drops to 1 psi. At higher frequencies the pressure is modulated to as high as 10 psi providing enough ink flow for the faster pen speeds. Each channel's modulating system operates independently.

The key element is a relatively inexpensive relay. The recorder's modulating pump is basically a relay driven by the current through the pen motor's armature. Above a threshold frequency, the relay squeezes the tube in which the ink flows and creates a pressure pulse in the ink. Two pulses are created during each sweep across the writing surface, one during pen acceleration and another during deceleration. A small hydraulic accumulator near the pen tip smoothes the two pressure pulses for clear writing.

A front-panel light indicates when the ink reservoir is empty. Ink is stored in a double-walled container and air pumped between the walls drives the ink into a diaphragm-type pressure regulator. When the reservoir is empty, the pressure differential will cause the warning lamp to light. However,

Signal conditioning is a push-in with these input couplers





Record directly . . . strain . . . pressure . . . displacement . . . temperature . . . or any other phenomena that can be transduced into an electrical signal. The Beckman 9800 Series Input Couplers (over 30 of them) plug directly into the preamplifier in the Dynograph® Recorder, averting heavy expenditures for specialized amplifier systems when your application needs change.

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there is sufficient ink left in the remaining regulator to write on any paper remaining in the recorder. The ink reservoir can be replaced while the recorder is operating.

There are eight interchangeable signal-conditioner amplifiers to choose from. Front-panel pushbuttons enable the selection of any of 14 chart speeds—from 0.025 to 200 mm per second. The recorder has a frequency response to 160 hertz. It can also be used for roll paper.

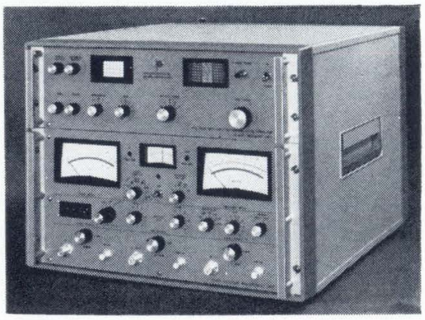
To be exhibited at the IEEE show.

Specifications

Frequency response	160 hz for 10 division peak to peak deflection
Response time (from 10% to 90% amplitude)	3 msec for 10 chart divisions 4 msec for 25 chart divisions 6 msec for 50 chart divisions
Drift	Less than 1/10 chart division over 20°C to 55°C temperature range and for line voltage variation from 103 to 127 voltage a-c
Gain stability	0.1% over same temperature and line voltage range
Sensitivity	±2½ volt full scale

Sanborn division, Hewlett-Packard Co., 175 Wyman St., Waltham, Mass. 02154 [370]

A new phase in antenna testing



A new test receiver for measuring antenna patterns has taken its cue from sophisticated telemetry gear. The receiver employs coherent conversion techniques and phase locked loops to increase sensitivity by 30 db and improve phase accu-

Circle 287 on reader service card→

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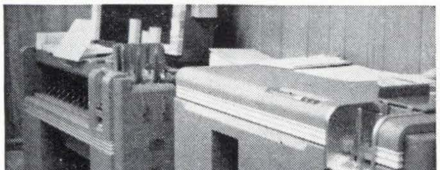

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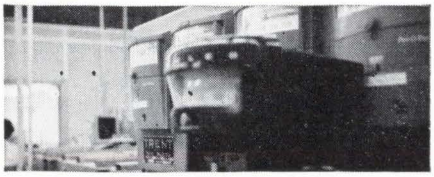

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racy by a factor of 10 over previous instruments. Developed by Scientific-Atlanta Inc., the new measurements receiver, series 1750, operates over a frequency range from below 100 megahertz to above 40 gigahertz.

In this coherent conversion system, heterodyning converts incoming reference and test signals to 45 Mhz and then to 1 kilohertz. The term "coherent" implies that an exact phase correspondence between the test signal and its 1-khz replica. That is, if the microwave signal's phase changes by 2°, the 1 khz signal's phase also changes by 2°. Phase locking insures that the 45-Mhz and 1-khz signals are exactly on frequency so there is no variation in phase as a result of frequency shifts.

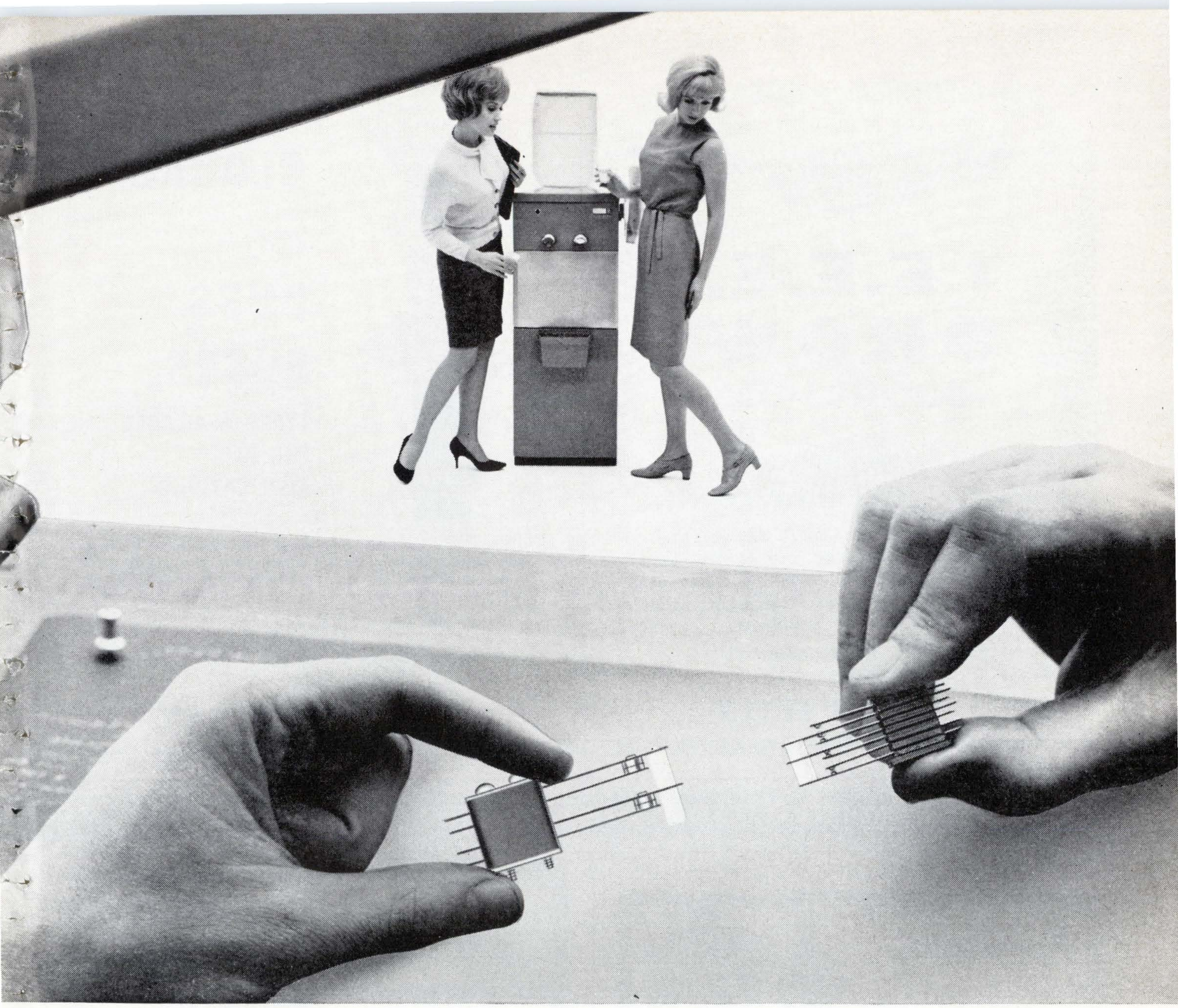
The new receiver, designed for use with antennas and microwave components, measured phase difference to approximately 0.1° when the signal and the reference are within 3 decibels of each other. When the signals differ by a full 60 decibels, phase is measured to within 5°. Amplitude is measured to 0.25 db for input signals that range over 60 db in level.

"Although coherent conversion isn't new in theory, it only now becomes practical because of improved phase-locking techniques," says Searcy Hollis, principal engineer at Scientific-Atlanta.

The technique increases dynamic range to 60 db from the 40 db of receivers using such square-law devices as bolometers and crystal detectors. The sensitivity of the new model is rated at 120 db below a milliwatt (dbm) at 2 Ghz and 110 dbm at 12 Ghz.

To minimize phase errors in this two-channel unit, signals from one channel appearing in the other are attenuated by at least 100 db. Components were chosen with a view to minimizing even slight shifts in phase caused by variations in signal amplitude.

The receiver can measure antenna patterns, the amplitude and relative phase of two antennas in an array, or the phase and amplitude of the electric field across the aperture of reflector-type anten-



It's time you learned the difference between MOLDED and STACKED

On the one hand, there's the molded switch. And on the other, the stack switch. Both extremely able performers. The stack switch, which is probably more familiar to most people, does the job it was designed to do—and does it well. Perhaps that's why it's always been (and still is) so popular.

Then, about a year ago, something new was added . . . the molded switch—which does everything the stack switch does, and because of its solid, one-piece design, is easier to handle. The molded switch not only saves time on your production line—cutting labor costs and speeding delivery—but it's so well put together that its alignment never wavers. No wonder the molded switch gained enthusiastic acceptance throughout the industry as soon as it was introduced.

We recently increased our molded switch line so that we now have models available to cover most requests for this type of switch. These switches can be used anywhere conventional-type switches with $1/4''$ or $3/8''$ mounting are now being specified. Models range in amperage from $1\frac{1}{2}$ to $12\frac{1}{2}$, and lifters from $1/16''$ to $1/2''$ can be supplied. A snap-on lifter is available for special applications.

We'd like you to see the difference in molded switches for yourself. Drop us a line, and we'll send you a free sample plus our new catalog, which gives a complete breakdown of all the contact combinations we currently have available.

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Circle 289 on reader service card

nas. It is also useful for reflectivity measurements and for gauging phase delay, impedance and insertion loss of microwave components.

In measuring phase with the series 1750, a comparison is made between the phase of a heterodyned 1-khz test signal and the phase of a second 1-khz signal derived from a reference r-f signal at the other input. The 1-khz phase reference can be delayed in steps of 0.1°.

Phase differences are converted to d-c voltages that are then displayed on the meter or are available at the recorder-output terminal. This d-c signal is linearly proportional to the phase delay between the two input signals.

Except for an oscilloscope monitor and a triode cavity local oscillator, all the circuitry in this receiver is transistorized. The new system weighs only 90 pounds, compared with the 500 pounds of Scientific-Atlanta's earlier 1650 series. Except for external mixer circuits to heterodyne to 45 Mhz, the receiver includes all circuits for measuring over the entire band.

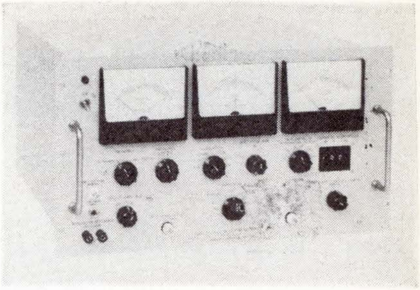
To be exhibited at the IEEE show.

Specifications

Frequency range	100 Mhz to 40 Ghz
Typical sensitivity	120 db below a milliwat at 2 Ghz
Phase resolution	0.1°
Dynamic range	60 decibels
Size	15 x 20 x 22 inches
Weight	Approx. 90 pounds
Cost	Less than $20,000

Scientific-Atlanta Inc., Box 13654, Atlanta, Ga. 30324 **[371]**

Sensing envelope delay over extended range



An instrument to measure delay distortion over the entire 30-Khz to 5-Mhz range has heretofore been unavailable. Instruments manufactured in Germany cover only portions of the range. Now, a device developed by the Wiltron Co., employs crystal controlled frequency and counter techniques to obtain very stable and accurate time delay measurements. The instrument is specifically designed for delay distortion application.

The unit has crystal controlled reference delays in 10-μsec steps up to 200 μsec for use in offsetting the time delay. This permits precision measurement on a sensitive scale. The most sensitive scale is

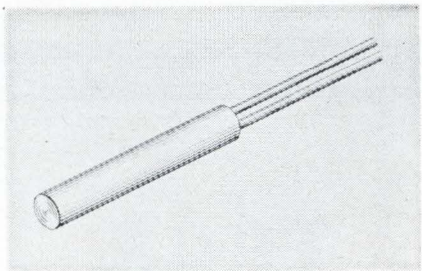
2 μsec full scale with 0.1 μsec calibrations.

The unit covers both group and supergroup frequencies for communications. The device was developed for telephone companies and has the desired transformer-coupled output with 135 ohms impedance. A transmitter and receiver make it possible to initiate a test as well as to provide the measurement and readout from a test signal. It can be used for either loop or straightaway measurements on telephone channels, tape recorders, and in telemetering.

Price is $6,900.

To be exhibited at the IEEE show. Wiltron Co., 930 East Meadow Drive, Palo Alto, Calif. [372]

Temperature sensors feature sensitivity



Industrial temperature sensors made with wirewound elements feature higher sensitivity than either thermistors or thermocouples. The sensors in the TS-103 line can be used for control or measurement.

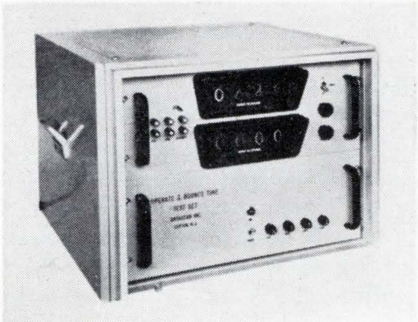
Remote temperature sensing is possible without the necessity for special lead wires. Temperature controllers used with them will also have inherently failsafe characteristics; that is, the controllers will turn off if the sensor circuit is opened.

Units measure 3/16 in. in diameter x 1½ in. long. They are available with a stainless steel jacket for water and other liquid baths or in an aluminum housing. Either type is suitable for operation over the entire temperature range from −125° to 500°F.

Prices in small quantities are $9.35 for the aluminum housing form and $11.35 for the stainless. Substantial quantity discounts apply. Delivery is from stock.

To be exhibited at the IEEE show. Harrel Inc., 16 Fitch St., E. Norwalk, Conn., 06855. [373]

Relay characteristics measured automatically



An automatic test set makes possible accurate measurement and visual readout of transfer time and bounce time of electromechanical relays. The equipment offers a clearly visible, in-line decimal readout in milliseconds of operate time (or release time) and bounce on two separate displays.

Operate time is the interval between the application of voltage to the relay coil and the first contact closures; bounce time is the interval from initial contact closure until the final contact closure. Operate times and bounce times from 00.01 msec to 99.99 are measured simultaneously, in one relay cycle. A $\times 10$ multiplier switch increases the maximum time for both measured times by a factor of ten.

The unit's circuitry is all solid state, including power supply, and is housed in a desk-top cabinet. It operates on 115 v a-c power. Panel dimensions are 8¾ by 19 by 17 in.

To be exhibited at the IEEE show. Datascan Inc., 1111 Paulison Ave., Clifton, N.J., 07013 [374]

Audio oscillator spans wide range

Band switching is not required in an audio oscillator that covers from 10 hz to 50 khz in one turn

of the frequency dial. The elimination of transients and multipliers or decimal points simplifies the interpretation of the frequency setting.

This oscillator, type 1313-A, has both sine- and square-wave outputs. The sine-wave output is continuously adjustable from 500 μv to 5 v open-circuit, and is held to within $\pm 2\%$ of its 1-khz value over the whole frequency range. The square-wave output has a typical transition time of 40 nsec into 50 ohms and an amplitude of over 5 v peak-to-peak.

The 1313-A can be synchronized to an external source or can provide a synchronizing signal for control of other devices.

The oscillator is priced at $325.

To be exhibited at the IEEE show.
General Radio Co., West Concord, Mass., 01781. **[375]**

Thermocouple gauge in solid state design

Accurate, repeatable, stable readout has been achieved in the pressure range between 1 and 10^{-3} torr with what is reportedly the first true temperature compensated thermocouple gauge control.

A thermistor is an integral part of the measurement system and compensates for the natural thermal drift of thermocouple gauge sensitivity. The use of a thermistor is a departure from the standard procedure of placing an extra thermocouple in the circuit to sense temperature.

Solid state design has reduced manufacturing costs while providing highest reliability. Model 801 is priced at about half the cost of competitive thermocouple gauge

controls. Line voltage regulation is provided by zener diodes.

Specifications include a lowest indication of 1 micron; sensitivity, 11 mv full scale; and weight, 14 oz.

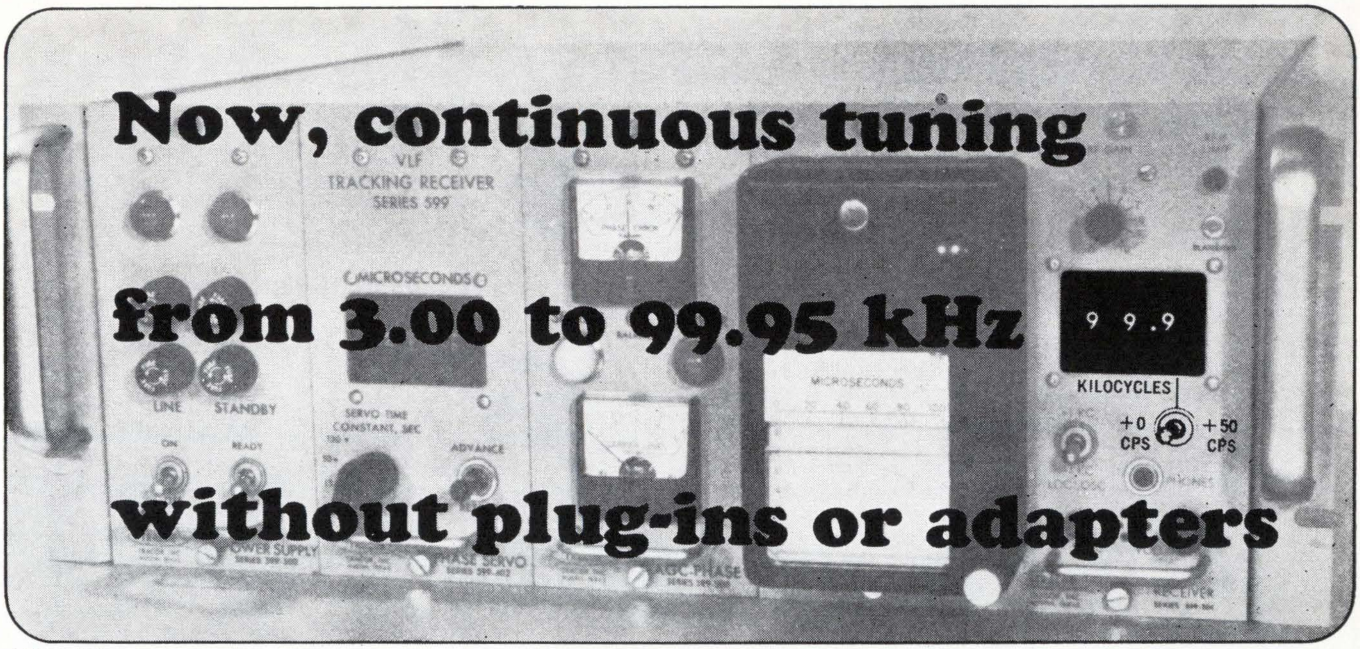
To be exhibited at the IEEE show.
National Research Corp., 160 Charlemont St., Newton, Mass., 02161 **[376]**

Counters operate in 2 directions

Bidirectional counters furnish accurate, high-speed determination of dimension, travel or position along one or two axes of motion. Primary application is for machine tools, layout and plotting machines and similar equipment where lead screw rotation can be monitored to provide a direct and continuous display between stationary and movable members.

Features of the series 6500 counters include a front panel and remote reset which can be set at any zero reference point. Counting and reversal speeds range up to 100,000 counts per second. Readout is by Nixie-tube display, including plus or minus signs, and indication is symmetrical both above and below zero.

With a built-in transducer power supply, the units are designed for use with Phototac bidirectional transducers, but can also be operated from switch closures, phased pulse generators or other transducers providing bidirectional information. Optional drives are available for printer or tape punch output. Plug-in circuit card construction is used and all counting and logic functions employ integrated circuits. Six basic single- and double-axis models are avail-



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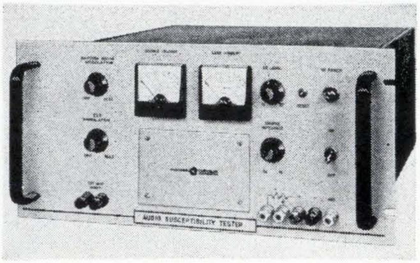
able with a choice of four-, five- or six-digit displays per axis.
Modular Instrument, 190 Michael Drive, Syosset, N.Y., 11791. [377]

Power source tests audio susceptibility



Two modulation-modes—random noise and external input—are available in a solid state 5 amp d-c power source that has output voltage adjustable from 18 to 37 v. The instrument is designed for electromagnetic compatibility testing and can simulate abnormal power supply conditions for checking equipment performance.

The internal white noise generator provides modulation frequencies from 10 hz to 100 khz. External modulation can be sine wave, square wave, transients, spikes, or any other waveform whose harmonic content does not require frequency response in excess of 150 khz. Magnetic tape recordings of power bus variations can serve as the external modulation source for the instrument.

The power source was designed primarily to provide a modulated voltage source for conducting audio susceptibility tests with certain NASA specifications. However, the model, CH-51, can facilitate performance tests on any item whose operation may be affected by conditions of noise and other variations on the power bus.

Other features are adjustable output impedance from 0.1 ohm to 16 ohms, short circuit protection, voltmeter and ammeter, rack mounting (8¾ in. high x 19 in. wide x 18 in. deep). Power required is less than 600 w at 117 v, 60 hz. The unit weighs 66 lbs.
Chrysler Corp., Space division, Dept. 4700, Huntsville, Ala. [378]

Lockheed's 417.
Lockheed makes the portable portable. At 28 pounds, including its self-contained batteries, the 417 recorder comes in at 50 pounds less than any comparable recorder. And the 417 measures up in more ways than weight. □ It starts off with a price tag as low as $7000. It operates on 110/220 volts AC/DC, with a power consumption that goes down to 10 watts. It has an exclusive, rugged low-mass differential capstan drive for precision operation under vibration in any position. It has phase-lock servomotor control; a simplified maintenance-free transport mechanism, frequency response of 100 kc direct 10 kc FM; and, scaling in at only 14" x 15" x 6", it can even fit under an airplane seat. □ We believe the 417 is the best portable recorder on the market. But check it out for yourself. □ Just ask for the Lightweight, one of a family of recorders for undersea, land, air and space applications.
The lightweight.
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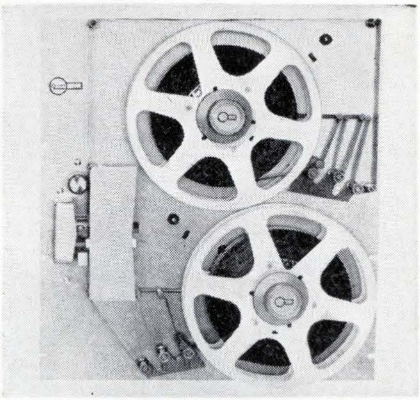
Tape reader-spooler is compact and fast



A compact, punched-tape reader and spooler reads 500 characters per second optically, and winds the tape on 10½-inch reels at 50 inches per second. The unit is only 21 inches high.

The all solid state electronics portion is in a common chassis with a choice of output signals available. The reader-spooler operates continuously at 500 characters per second or at any slower speed asynchronously. It is available in both unidirectional and bidirectional configurations and can read tape loops if required.

The spooler portion rewinds in either direction independently at high speed, and has a soft take-up feature that precludes the possibility of breaking the most fragile of paper tapes.

The RRS-502-10½ is priced at $3,435 in low quantities with substantial discounts available for higher quantities. Deliveries are 10 weeks after receipt of order.

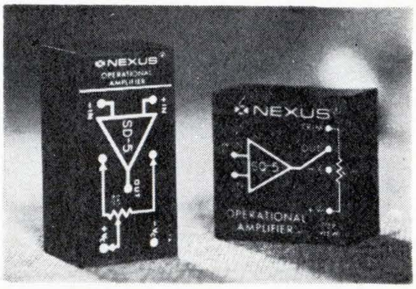
To be exhibited at the IEEE show.
Remex Electronics, a unit of Ex-Cell-O Corp., 5250 W. El Segundo Blvd., Hawthorne, Calif., 90250. **[378]**

Operational amplifier sells for under $10

Suitable for many noncritical industrial applications, a new general-purpose operational amplifier offers the peak performance among units in its price range. The SD-5 will sell for $9.75 in quantities of 10 to 99.

This encapsulated unit avoids the need for external components. It is fully protected for input overdrive and indefinite short circuit to ground. Stability with a variety of feedback elements is insured by internal compensation for a controlled —6 db/octave gain bandwidth roll-off.

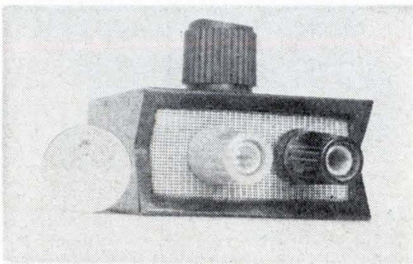
Typical performance of the SD-5 (at 25°C) includes a supply voltage of ±15 v; output, ±10 v at 2.2 ma; open loop d-c gain, 10,000; offset voltage change, 30 μv/°C; offset current change, 1.5 na/°C; input offset current, 200 na; frequency limit for full output, 20 khz; unity gain crossover frequency, 1.5 Mhz; common mode input im-



pedance, 20 megohms; differential input impedance, 200 kilohms. The unit measures 1.55 in. long, 0.78 in. wide and 0.60 in. high.

To be exhibited at the IEEE show.
Nexus Research Laboratory Inc., 480 Neponset St., Canton, Mass., 02021. **[379]**

Tiny circuit breaker protects power supply



A solid state circuit breaker smaller than a pack of cigarettes provides high speed overload protection for sensitive semiconductor circuits. Plugged into d-c laboratory power supplies, the Multi-Break unit responds in less than 10 microseconds. Its current overload threshold is set anywhere in a 100 to 1 current range starting at 0., 1.0 and 10 milliamperes. Voltage inputs must be between 4 and 35 volts, but wider range units are also available.

Operating power for the breaker (1 to 5 milliamperes) comes from the supply. It has dual banana plugs that are plugged directly into the supply's output binding posts. The load connects to another set of binding posts on the breaker.

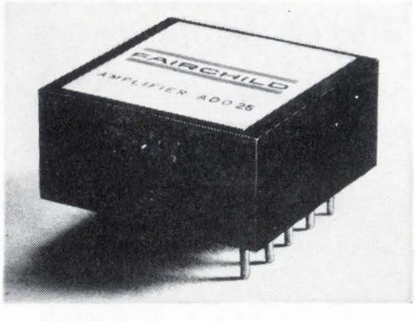
Dimensions of the unit are 2 x 2 x 1. Price is $39.50.

To be exhibited at the IEEE show.
Roveti Instruments, 1643 Forest Drive, Annapolis, Md. 21403. [380]

Operational amplifiers with FET's and IC's

Hybrid operational amplifiers, combining field effect input devices and high quality integrated-circuit amplifiers, are available in three types. Each is enclosed by a 1.13 x 1.13 x 0.5 in. plastic encapsulated case.

Drift characteristics of the ADO-26 are 1 μv/°C and 2 μv/8 hr. These low drift rates are obtained with a dual FET in the first stage and a monolithic IC amplifier in the second stage, with a special compensating technique during



manufacture. In addition, this ultra-low-drift amplifier gives 10^{12} ohms input impedance and 10-picoampere offset current.

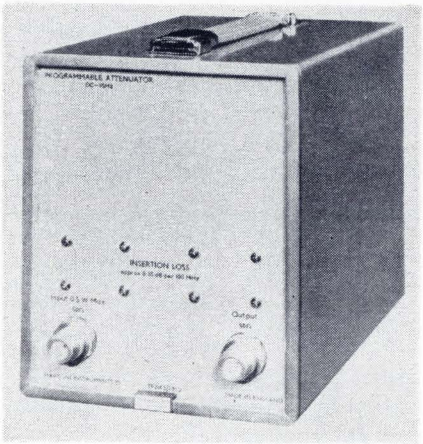
The ADO-27 has an input drift of 5 μv/°C and 5 μv/8 hr, with an open-loop gain of 140,000.

The ADO-29 economy version ($45) of the hybrid amplifiers has 25 μv/°C drift, a gain of 140,000, and the 10^{12}-ohm input impedance.

Price of the ADO-26 is $98; and the ADO-27 is $70 in quantities of 1 to 9.

To be exhibited at the IEEE show. Fairchild Instrumentation, a division of Fairchild Camera & Instrument Corp., 475 Ellis St., Mountain View, Calif., 94040. **[381]**

Programable attenuator is light & dependable



Intended for incorporation into sophisticated test and communications assemblies, a programable attenuator weighs only 12 lbs and measures 7¾ x 5½ x 10½ in.

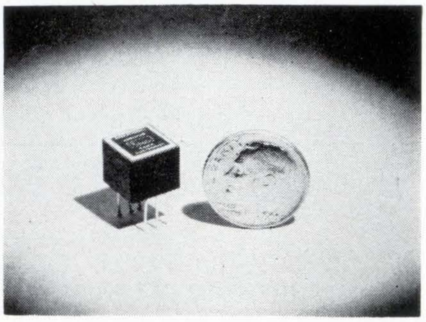
Model 2163/1M2 covers d-c to 1 Ghz, accepts 1-2-4-8 binary coded decimals, and has a range of 139 db in 1-db steps. Accuracy at 1 khz is ±0.5%, ±0.1 db to 120 db; at 1 Ghz it is ±1%, ±0.2 db to 100 db.

Setting speed is less than 100 msec and at no time during switching is the attenuation less than the initial or final programed value. High reliability is achieved since the only moving parts are a number of solenoid-microswitch assemblies having a maximum displacement of 0.015 in.

To be exhibited at the IEEE show. Marconi Instruments, 111 Cedar Lane, Englewood, N.J., 07631. **[382]**

Operational amplifier in minute package

The incorporation of thin-film hybrid circuitry has resulted in a

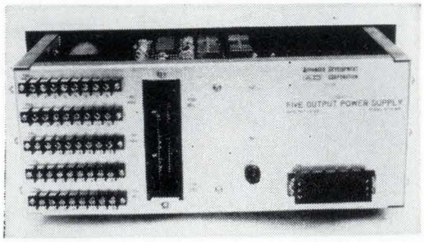


microminiature operational amplifier packaged in a case ⅜ x ⅜ x ⅕ in. Model KM-23M amplifier is designed for commercial and industrial use in analog computers, high-gain/low-drift servopreamps, high stability a-c amplifiers, voltage comparators, and similar applications.

Input impedance of the amplifier is 100 megohms. Typical open-loop voltage gain is greater than 200,000, and drift has been held to 10 μv/°C maximum. Frequency compensation networks provide stable operation in all feedback configurations; no external capacitors are required.

Unit cost of the KM-23M is $49.50. Discounts are available in quantity. Delivery is from stock.
K&M Electronics Corp., 102 Hobart St., Hackensack, N.J., 07601. [383]

Power supply suited for use in systems



Five voltages from +20 to −20 volts d-c at currents from 1 to 7 amps are produced by the model 11578 power supply. The unit can be adapted to specific system requirements.

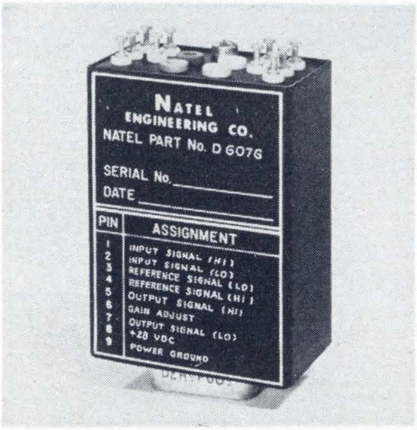
The supply accepts inputs of 100 to 250 v a-c at 47 to 63 hz, and incorporates four series regulators and one shunt regulator. Additional features include 1% envelope regulation, margin-checking, turn-on and turn-off sequencing, and remote sensing. Also provided are automatic current limiting, interlocks, and high pulse load capabilities.

All control components are mounted on two printed wiring boards that are removable through the rear panel. Designed for 19-in. rack mounting, the compact supply has a panel height of 7¼ in. and is 7½ in. deep.

Total power output is 312 watts, and the supply uses system air flow for cooling.

Advanced Development Corp., 2014 W. 139th St., Gardena, Calif., 90249. [384]

Amplifier-demodulator for control systems



A miniature, solid state a-c amplifier-demodulator performs in extreme operational environments with the accuracy of laboratory-type instruments. It weighs less than 6 oz and occupies only 2.5 cu in. The unit operates either as an a-c to d-c converter or as a phase-sensitive synchronous detector for gyros, synchros, and linear variable differential transformers.

Providing a high input impedance and low output impedance, with input, output, and power supply isolated, the unit converts phase-sensitive, suppressed-carrier a-c input signals into a linearly proportional bipolar d-c output signal.

Typically incorporated in control and instrumentation system applications, the unit can operate f-m subcarrier oscillators, meters, or recorders. The unit, D6076, also can serve as a linear differential d-c current drive for an integrating

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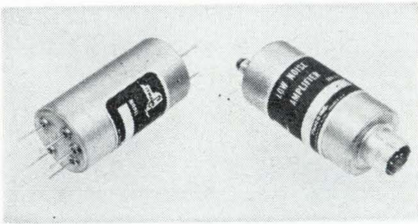
gyro torque-motor.

Linearity is ±0.5% of reading, and frequency response is ±3 db from d-c to 20% of carrier frequency. Quadrature rejection is 40 db minimum, while ripple is 0.5% peak-to-peak of full scale output. Conforming to the requirements of MIL-E-5272C, the D6076 will withstand vibration of up to 20 g at 50 to 2,000 hz, shock of 100 g for 11 msec, and temperatures from −55° to +71°C.

Natel Engineering Co., 7129 Gerald Ave., Van Nuys, Calif., 91406. **[385]**

Preamplifiers boast high input impedance



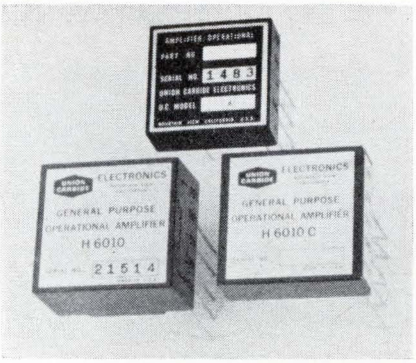
Preamplifiers with low noise and high input impedance are announced for use with hydrophones, accelerometers, infrared detectors, magnetometers, seismometers, biomedical sensors and other high-impedance transducers. Models 143 (20-db gain) and 144 (40-db gain) both come in four different package configurations.

The hermetically sealed, encapsulated, and electrostatically shielded modules are available with solder pins or connector terminals or with input at one end and power and output at the other for maximum isolation. Gain accuracy is ±0.5 db midband, and maximum distortion is better than 0.5% at 1 v rms. Typical long-term gain stability is 1%. In the standard bandwidth of 0.5 hz to 200 khz, broadband noise is 3 μv referred to the input with a 1,000-pf signal source. Noise figures of 1 db or better can be obtained with resistive signal sources in the 10-kilohm to 30-megohm range.

In addition, high and low current output stages are available and provisions are made for the

injection of precise calibration signals. Available modifications include controlled high- and low-frequency rolloffs; remote switching of gain and low-frequency rolloff and power output stages for driving very long lines.
Ithaco Inc., 413 Taughannock Blvd., Ithaca, N.Y., 14850. **[386]**

Operational amplifier develops low voltage



Low voltage and low current drift are offered in a general purpose operational amplifier. Type H6020 develops less than 5 μv/°C and 0.5 na/°C of voltage and current drift respectively.

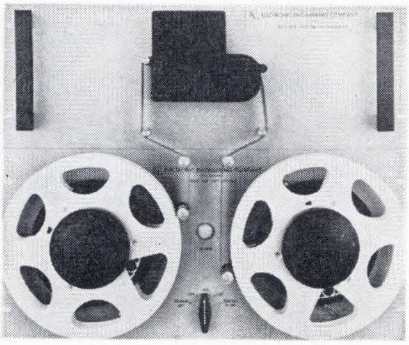
Bandwidth is greater than 5 Mhz; common mode rejection ratio, greater than 80 db; and input wideband noise, less than 5 μv rms. The output is ±10 v at ±2 ma.

The amplifier is available in three modular packages, the smallest measuring 1x1x2/5 in. Price, in quantities of 1 to 4, is $45.
Union Carbide Electronics, 365 Middlefield Road, Mountain View, Calif., 94040. **[387]**

Block tape readers improve programing

Photoblock punched tape readers can now be supplied with silicon latching output circuits. Block tape readers sense up to 40 eight-bit lines in each frame. This large frame capacity—up to 320 bits—provides an economical method of programing automatic test equipment and process control and is urgent when more information is required than can be obtained from a single-line punched tape reader. The new latching output cir-

New Subassemblies

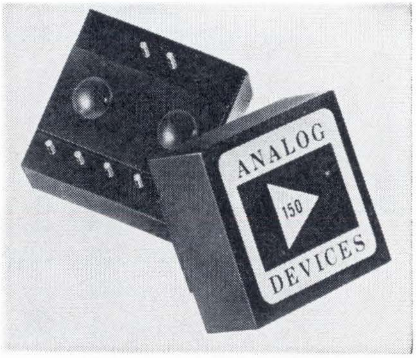


cuit holds the output transistor switches closed until the tape is positioned for reading the next frame. This eliminates all off time during tape advance. The reader retains information from the last frame while it is advancing the tape to the next frame. Updating to the new frame is instantaneous.

Latch output circuits can be supplied with the manufacturer's 2400, 5000, 6000, and 7000 series block tape readers.

Electronic Engineering Co. of California, 1601 E. Chestnut Ave., Santa Ana, Calif., 92702. **[388]**

Operational amplifier powered by batteries



Operation for 1,000 hours from a pair of standard mercury cells, in addition to small size and low cost, is offered by a d-c differential operation amplifier. The unit measures 1⅛ in. square by 3/5 in. high. It costs $30; batteries are $1 each.

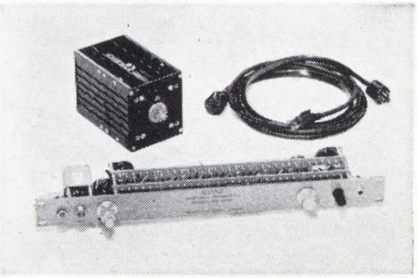
Performance figures include 10,000 d-c gain, 1.5 Mhz bandwidth, 50 Khz full power response, 1.2 v/μsec slewing rate, 1 msec overload recovery time, 20μv/°C and 0.1 na/

°C drift, 50 na initial offset at 25°C. The differential and common-mode input impedance is 1 megohm and 100 megohms and the output is ±1.5 v, 2.5 ma.

Besides conventional instrumentation uses, model 150 has a wide range of applications in upgrading or retrofitting existing instruments and systems. The inputs are floating with respect to ground (with the battery pack). The device can make measurements of high voltage cables; increase range, sensitivity and input impedance of d'Arsonval meters; turn d-c meters into wideband a-c instruments; raise input impedance of chart recorders and other apparatus; and operate remotely from sun-powered photovoltaic cells.

Analog Devices, 221 Fifth St., Cambridge, Mass., 02142. **[389]**

Low-noise amplifiers aid geophysical work



Nine high-gain solid state amplifiers can be used with acoustical instrument systems in the geophysical field and other applications. Series 505 amplifiers feature a wide dynamic range of 60 db which allows reception of greatly attenuated signals. The units can also handle large signals (200% overload) without blocking.

Typical amplifier gain is 10^6; response, 1 hz to 100 khz; noise, 0.1 v per 5,000 ohms output impedance. The input impedance on most models is adjustable from 50 to 1,000 ohms. Required power is 22.5 v d-c, 30 ma. With the company's 506 power supply the amplifiers can be operated on standard a-c current.

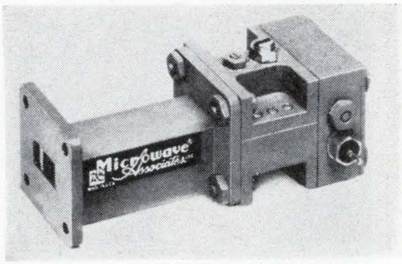
The amplifiers fit a standard 19-in. rack panel. They are 1¾ in. high and 4½ in. in over-all depth.

Prices range from $385 to $455.

Alpine Geophysical Associates, Inc., Oak St., Norwood, N.J. 07648. **[390]**

New Microwave

Tunable oscillator for airborne use

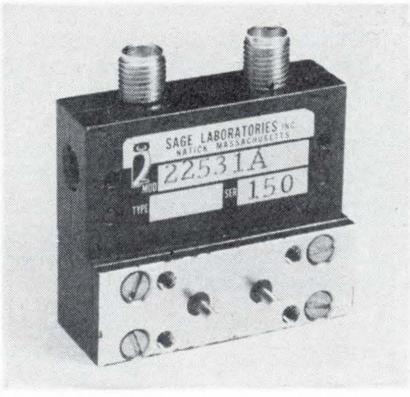


Mapping, terrain avoidance, target acquisition and general airborne systems are among the applications for a compact, lightweight, solid state source. The MA-82K04 operates in the 16.1 to 16.7 Ghz frequency range and can be electronically tuned ±100 Mhz. The unit operates from a simple low-voltage power supply, eliminating problems associated with power supply breakdown and suiting it for high altitude requirements.

Power output is a minimum of 3 mw but is typically 6 mw. Tuning sensitivity is about 10 Mhz/volt. Operating temperature is −50° to +85°C. Size is equivalent to a 3.7-in. length of Ku-band waveguide.

To be exhibited at the IEEE show.
Microwave Associates Inc., Burlington, Mass. [391]

Replaceable diodes in balanced mixers



An expanded line of miniature balanced mixers now includes eight models with replaceable diodes. Called the M-LINE the new devices cover 1 to 4 Ghz in two bands. In each band, dual and single i-f outputs are available with ¼-36 connectors or solder lugs.

Typical vswr is 1.3 and minimum isolation is 8 db for all models. Noise figure is typically 8 db from 1 to 2 Ghz and 8.5 db from 2 to 4 Ghz, with the point contact diodes that are supplied with each unit. Noise figures can be improved by approximately 1 db by using hot carrier diodes ($40 extra).

Price is $250 for dual-output models; $225 for single-output models. Delivery from stock is 30 days.

To be exhibited at the IEEE show.
Sage Laboratories Inc., 3 Huron Drive, Natick, Mass. [392]

Good signal acquisition in telemetry receiver

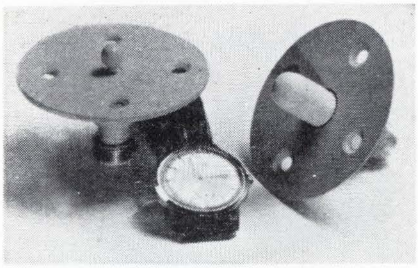
A field-proven telemetry receiver utilizes three plug-in front ends to operate over 225 to 315 Mhz, 1435 to 1540 Mhz and 2.2 to 2.3 Ghz bands. Designated the TMR-70, the unit is essentially a single-channel version of the TR-109 dual channel receiver used in the Apollo instrumented aircraft program. It is designed to meet aircraft, shipboard, and ground station telemetry requirements.

The unit reportedly combines features never before offered in a single receiver. Automatic frequency control, with a loop gain of 600 and with automatic search and lock, assures acquisition of signal levels coming out of the noise. A choice of three plug-in f-m demodulators with high capture ratios minimizes interference caused by delayed signals due to multipath transmission. Intermediate-frequency filters have linear phase characteristics to minimize distortion. An improved agc includes 80-db loop gain and switchable time constants from 0.1 to 1,000 msec.

Designed for maximum phase linearity, the unit provides for reception of both standard (IRIG) and nonstandard telemetry and communications signals. The receiver is capable of receiving frequency, phase, and amplitude modulated r-f carrier signals.

The modular construction affords modifications for a wide variety of special-purpose applications at minimum cost.
Defense Electronics Inc., Rockville, Md. [393]

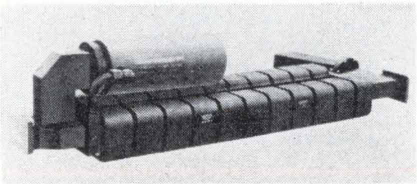
X-band antennas designed for aircraft



Beacon antennas—both stub and dipole—that operate from 8.5 to 9.6 Ghz are specifically designed for high performance aircraft.

The stub type has a pattern similar to a quarter-wave monopole. The dipole's pattern is similar to a half-wave dipole over a ground plane and provides excellent horizon coverage. Units weigh less than 0.4 lb each and are vertically polarized. Maximum vswr is 1.5:1.
Transco Products Inc., 4241 Glencoe Ave., Venice, Calif., 90291. [394]

High power capability in 4-port circulator



High peak and average power capability are features of a 4-port, liquid-cooled circulator. Model 336180 can handle 20 Mw of peak power and 20 kw of average power while maintaining a low insertion loss of 0.5 db maximum.

The unit can also be used as an isolator by terminating the appropriate ports. Operating in the fre-

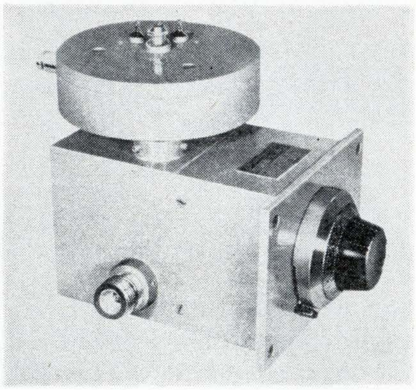
New Microwave

quency range of 2.8 to 3.1 Ghz, it has an isolation of 20 db minimum and a vswr of 1.2 maximum. It measures 55 in. in length.

Average unit price is $5,000, depending on quantity. Delivery is 120 days.

Airtron division, Litton Industries Inc., 200 East Hanover Ave., Morris Plains, N.J., 07950. [395]

Preselector-mixer in a tunable assembly



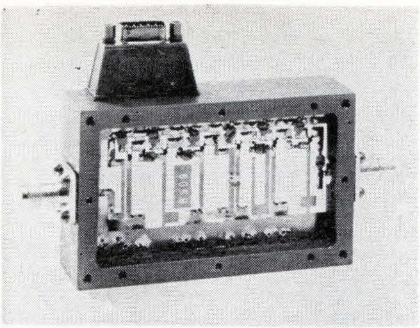
Designed for telemetry and general receiver applications, an integrated package contains a preselector, balanced mixer, and an adder network. It can also monitor individual crystal current.

Units can be supplied for operation over any 10% bandwidth between 1.4 and 2.4 Ghz. Preselector bandwidth (3 db) is 15 Mhz; local-oscillator input power, 1.5 mw maximum; noise figure, 8.5 db maximum. Image rejection at a 30-Mhz intermediate frequency is 60 db minimum; at a 60-Mhz i-f it is 80 db minimum.

Gombos Microwave Inc., Webro Road, Clifton, N.J., 07012. [396]

Microwave amplifiers feature low noise

Transistorized microwave amplifiers replace bulky, complex, and critical twt, parametric, and tunnel diode amplifiers in telemetry, communications, and radar systems. The BB series feature noise figures to 4.5 db, gain of 20 db minimum,



and frequency coverage from 0.5 to 2.4 Ghz.

The amplifiers are small, reliable, have low power drain and are unaffected by temperature and other environmental conditions. Using microminiature silicon transistors and what are claimed to be unique stripline and printed circuit techniques, mean-times-between-failures of over 10 years are achieved. All units are packaged in rugged machined aluminum housings.

Prices start at $695. Delivery takes 4 to 6 weeks.

RHG Electronics Laboratory, Inc., 94 Milbar Blvd., Farmingdale, N.Y., 11735. [397]

Microwave transistor intended for S band

Development of a microwave transistor that offers a maximum frequency of oscillation (f_{max}) of 4.5 Ghz is announced. An f_{max} specification rather than f_t is used because it is more indicative of power capability at any frequency. Maximum power dissipation at 25°C case temperature is 300 mw.

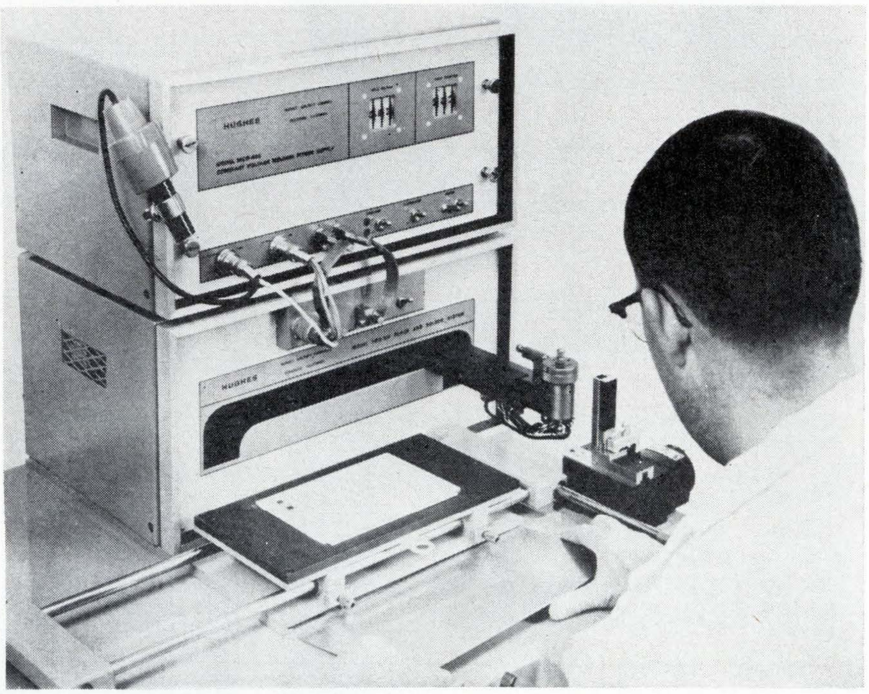
Model MT1062 is intended for use in preamplifier and local oscillator applications through S band. It can deliver a calculated maximum available gain of 7 db at 2 Ghz and 3.5 db at 3 Ghz. This is achieved by the manufacturer's ability to photomask very narrow base-widths of about 2 microns (in production quantities) which reduce collector-to-base time constants, yielding higher f_{max} values.

Guaranteed over the full military temperature range of −55° to +125°C, the MT1062 in the TO-51 stripline package is priced at $42.50 each in lots of 10 to 99.

Fairchild Semiconductor, a division of Fairchild Camera and Instrument Corp., 313 Fairchild Drive, Mountain View, Calif. [398]

New Production Equipment

Assembling flatpacks—but tenderly



Machines that automatically feed and place flatpacks on printed circuit boards haven't panned out, largely because girls with tweezers excel at gently handling the fragile IC packages.

The Hughes Aircraft Co. says it now has the answer—a "tender touch" feed system, part of a semiautomatic IC assembly machine that, in only 8 seconds, picks up a flatpack, places it on the board and solders all 14 IC leads to the printed wiring.

The prototype (which has already been sold) was shown for the first time at the National Electronics Packaging and Production Conference in Long Beach, Calif. Duplicates, the company reports, can be provided in 12 weeks for $16,450 each.

The machine consists of a feed mechanism (at the right in the photograph), a vacuum pickup flanked by reflow soldering bars, a power supply, and a manually operated x-y positioning table. The table can be replaced, at additional cost, by one of several numerically controlled positioning systems also shown by Hughes at the conference.

The vertical magazine slips onto the feed mechanism, and the bottom flatpack in the stack is pushed by a tiny slide to a positioning stop in the shape of the flatpack, which is at the back end of the feed plate. The package is not forced into position; a delicately balanced mechanical override stops the sliding action if the flatpack is cocked or misaligned.

Once situated, each flatpack is carried a fixed distance from right to left by the vacuum chuck of the pickup and positioning mechanism and released on the board. Reflow soldering bars on both sides of the pickup solder the IC's leads simultaneously to pretinned pads on the p-c board. The reflow technique is similar to one used in a solderer introduced last year [Electronics, June 13, 1966, p. 228]. A power supply of constant density sends current through the bars only, not the leads, to prevent shorting the IC's.

Compliant suspension of the heating bars provides uniform pressure on leads during the soldering process. The bars can be rotated 90° for soldering leads in x or y directions, and the spacing between

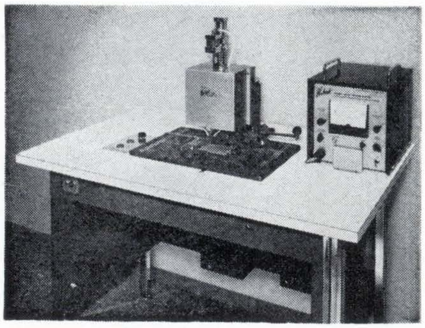
the bars is adjustable.

In the semiautomatic version of the machine, the operator controls the flatpack's soldering location by moving the table that carries the p-c board. The table can move 12 inches from right to left and 6 inches from front to rear. A metal template with detent holes for each flatpack location is placed in a slot under the table, and then moves with it. Under the template, in a fixed position corresponding to the vacuum pickup's release point, is a stylus. The operator moves the x-y table until the stylus slides into a detent hole and presses a button to start the automatic pickup cycle. If the stylus is not seated properly, an electrical interlock lights a red warning lamp. After one flatpack is soldered, the operator triggers a stylus release and moves the table and template to the next soldering position.

The operator's maneuvers are guided by an x-y position-pointer and a beam of light under the pickup head that is the size of a flatpack. This illumination permits a check of flatpack placement and aids manual positioning of other components. Tolerances are so accurate, Hughes says, that lead and pad alignment will never vary by more than 0.002 inch.

Welder Department, Hughes Aircraft Co., 2020 Oceanside Blvd., Oceanside, Calif. 92054 **[401]**

Solder reflow unit for flatpack jobs



Joining flatpacks to p-c boards becomes a quick and easy operation with a semiautomatic solder reflow machine. It is designed for medium to high volume production of printed circuits using flatpacks or other miniature multiple-lead components.

The model 950, SRM/FPR contains an a-c power supply, a programer-controller for actuating the head, a dual reflow solder head that will handle all 14 leads of a flatpack at one time, a holding and locating fixture for the board, a swing-away component loading device, cooling equipment, and a console-type work table.

The operator manually positions a flatpack in the loader and moves it under the reflow head. The machine is actuated for automatic pickup of the component, positioning, and reflow soldering at a predetermined location on the board. The entire cycle, including loading, takes from 10 to 15 seconds, depending upon the dexterity of the operator. The basic machine will accommodate a printed circuit board up to 5 x 7 in. in size, although it may easily be modified to hold a much larger board.

A special feature of the model 950 allows the machine to be reversed in cycle so that it can be used to remove multiple-lead components for repairs.

Price is $6,360; delivery, six to eight weeks. The manufacturer also offers a free course in microjoining processes for purchasers of the machine.

To be exhibited at the IEEE show.
Weltek, a division of Wells Electronics Inc., 1701 S. Main St., South Bend, Ind., 46623. **[402]**

Rapid testing, sorting of diodes in production

Testing and classifying diodes and rectifiers on production lines and at incoming inspection stations is done with a family of instruments. Designed for application with fast automatic handlers and automated production lines, the D200 series will classify 10,000 diodes per hour. The two tests of final inspection can be made at 20,000 diodes per hour.

In manual operation, a single operator can test 2,000 to 3,000 diodes per hour. Four operators using the manufacturer's multiplexing system can process up to 8,000 to 10,000 diodes per hour.

The D200's perform the standard d-c forward voltage, reverse current and peak inverse voltage tests, identify shorts or opens and the polarity of diodes, and permit loading in either polarity.

Programing the conditions of each test is done at a single switch register on the front panel. Any test may be performed at any position in any sequence of from four to 14 tests. A front-panel, pin-board matrix translates test results into locations of bins.

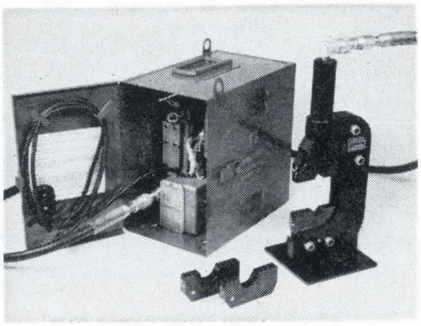
The manufacturer guarantees for ten years the performance of critical circuits such as power supplies, comparators, and sequencing circuits. The instrument is warranted for one year.

The eight-test D200 is 17½ x 24 x 24 in. and weighs 62 lbs. Power input is 105/115/130 v, 60 hz a-c, or 220 v, 50 hz a-c, at 50 watts.

Price is $11,200; delivery 90 days after receipt of order.

Teradyne Inc., 183 Essex St., Boston, Mass., 02111. **[403]**

Crimper terminates cable shields

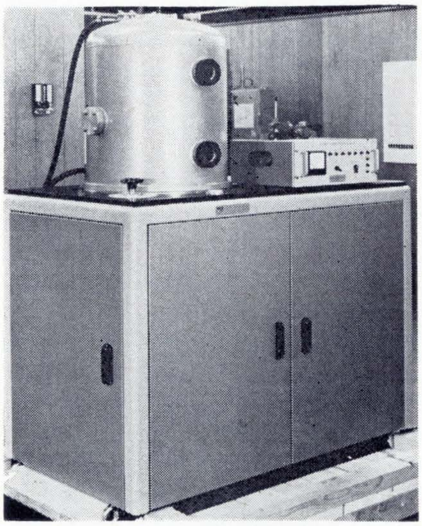


Both the inner and outer shields of multiconductor shielded cable are terminated by a new lightweight crimping tool. The Y40LH Hypress has an extremely narrow "C" type head for easy accessibility and unlimited visibility. Quick change, positive-locking, color-coded dies cannot be installed incorrectly. In addition, the tool is designed for both automatic and manual operations.

Featured with the Y40LH Hypress is a line of termination rings for the cable shields called Hyring. The rings come in 22 sizes and are capable of terminating conductor bundles ranging from 0.430 in. to 2.905 in. in diameter. The Hyring line is color-coded with an ink that will not chip, flake, or peel after crimping, or in any way interfere with the conductivity of the crimped assembly.

Burndy Corp., Norwalk, Conn. **[404]**

Automatic, high-speed thin-film evaporator



A fully automatic high-vacuum evaporator for producing thin film components can reach to pressures of less than 5 x 10^{-8} torr in a 20-inch diameter bell jar. Fast cycling time is achieved with liquid nitrogen and a 1900-liters-per-second oil diffusion pumping system. The pumping system is made fail-safe with an interlocked automatic valve control.

The model BA-510A's many accessories include single or multiple electron sources, an 8-position mask-substrate changer, optical and conductance thin-film monitors, rotary cage motor and planetary gear drive.

Bendix-Balzers Vacuum, Inc., 1645 St. Paul St., Rochester, N.Y. **[405]**

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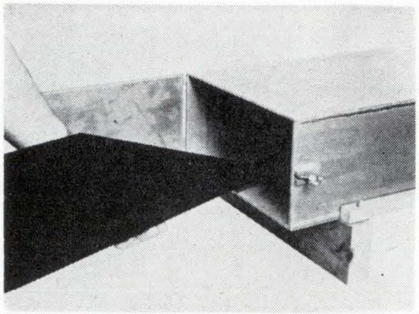
New Materials

Termination material for uhf waveguide



Rigid, flat sheet material extends the range of Eccosorb termination materials into the uhf range. Terminations made of Eccosorb LF are useful down to at least 300 Mhz.

Eccosorb LF is available in 12 x 12 in. sheets with nominal thicknesses of ⅝ and ⅜ in. The material is made from special ceramic tiles laid in a high temperature resin, both of which exhibit high values of magnetic loss factor in the uhf range.

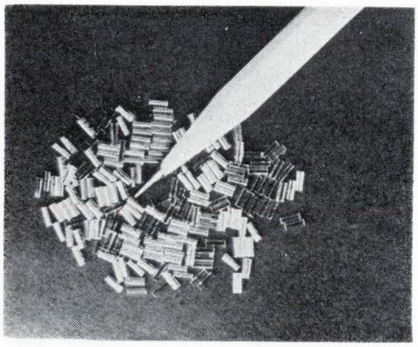
Terminations for a WR1150 waveguide (inside dimensions 5.75 x 11.5 in.) have been made from a 12 in. long rectangle and a 12 in. long triangle of Eccosorb LF giving a 24-in. long termination. Vswr was less than 1.1 for ⅝ in.-thick material, and less than 1.2 with ⅜ in.-thick material at 640 Mhz. At 960 Mhz, the same terminations yielded vswr's below 1.03. For use at frequencies below 500 Mhz the ⅝ in.-thick Eccosorb LF is recommended.

For low power applications the termination may be held in place with rigid lightweight foam blocks. For high power use, metal clips can be used. Power handling capabilities are limited only by the maximum operating temperature of 500°F.

Eccosorb LF is priced at $320 per sq ft for the ⅝ in.-thick material and $190 per sq ft for the ⅜ in.-thick material.

To be exhibited at the IEEE show.
Emerson & Cuming Inc., Canton, Mass., 02021. **[406]**

Sealing glass has high resistivity



Semiconductor manufacturers will benefit from an alkali-free sealing glass for use with Kovar or molybdenum. The material, called AFG-47, not only is alkali-free but also has a high lead content providing much greater resistivity at elevated temperatures, and has a longer working range. Resistivity, expressed as the logarithm of ohm-centimeters is 11.8 at 250°C and 10.2 at 350°C; thermal expansion is 49×10^{-7} in./in./°C; and softening point is 683°C.

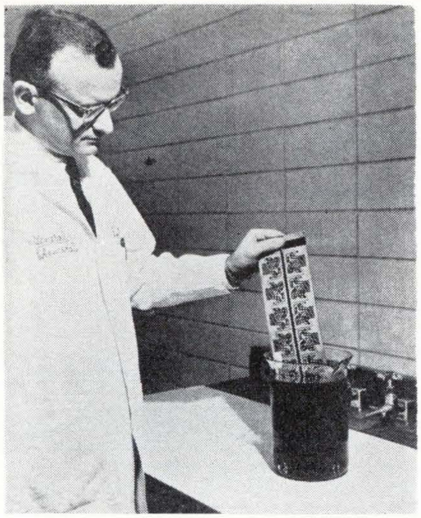
In production, it is easy to work and considerably lessens the possibility of damage to the diode's components. The absence of alkali in the glass is necessary with new diode designs to prevent parameter changes caused by the presence of sodium ions.

Described as the ideal glass for double-plug or whiskerless diode casing, the new glass is available drawn and cut to any diameter up to 0.100 in.

Hanibal Glass, Inc., 1639 E. Edinger St., Santa Ana, Calif., 92705. **[407]**

Stripping solutions clean p-c boards

Two new solutions remove photosensitive resist films from p-c boards and metals used in transistor and IC manufacture. Designated the B&A stripping solutions, they are



mixtures of high-purity organic solvents and activating ingredients. The nonflammable liquids remove resist films quickly and completely without causing damage to delicate surfaces.

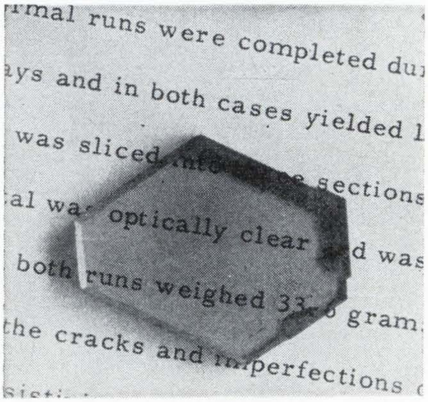
Solution CB-1 was especially formulated to strip Kodak Photo Resist and other photosensitive resists of this family from p-c boards. Solution A-20 was developed to strip Kodak Metal-Etch Resist and Kodak Thin Film Resist from silicon, silicon oxide, aluminum and other metals commonly used in manufacturing both discrete semiconductor components and integrated circuits.

While CB-1 is used full strength at room temperatures, A-20 is most effective when used full strength at 90° to 100° C. The latter solution, however, may be used at a lower temperature if the characteristics of the polymerized resist film permit. With both solutions, the product to be stripped is immersed in the solution for several minutes, then washed in a direct stream of ordinary tap water. Mechanical scrubbing is not necessary for complete cleaning of the p-c boards.
Allied Chemical Corp., Industrial Chemicals Division, P.O. Box 353, Morristown, N.J., 07960. **[408]**

Zinc oxide crystals show high resistivity

Large single crystals of zinc oxide have been grown by the hydrothermal method which allows a doping agent to be added during the growth process to control con-

New Materials



ductivity. Typically, the dopant is lithium. Resistivities of 1 ohm-cm to as high as 6×10^9 ohm-cm have been obtained.

The properties of crystalline zinc oxide offer many advantages for high-frequency amplification and delay devices and in transducers. An outstanding characteristic is its high coupling coefficient, usually 40% in the C direction.

The price of experimental quantities of zinc oxide is from $25 to $50 per gram. Exact cost depends on size, orientation, dopant level and other factors. A variety of crystals is on hand and can be cut to order within one or two weeks.

Airtron Division of Litton Industries, 200 E. Hanover Ave., Morris Plains, N.J. **[409]**

Epoxy coating powder insulates components

Components such as slot cells of motor stators and rotors can be effectively insulated with a Dri-Kote powder. The Underwriters Laboratory has approved DK7 Green coating on motors for operation to 130° C.

The powder reportedly has excellent spraying characteristics. The finished coating requires no post-cure, has very high cut-through temperature and superior resistance to high temperatures. A 15-mil film gives a dielectric strength of 800 volts per mil. The powder is available in standard packaging of 50-lb cartons and 250-lb. drums.

Hysol Corp., 1100 Seneca Ave., Olean, N.Y., 14760. **[410]**

New Books

Semantic arbiter

Electronics and Nucleonics Dictionary, third edition
John Markus
McGraw-Hill Book Co., 743 pp., $16.50

Language changes, warns an ad for Merriam-Webster's newest desk dictionary, adding that your dictionary should change too. As every electronicker knows, this warning is even more pertinent for that segment of the language describing electronic phenomena and devices than it is for the language as a whole. And now, Cooke and Markus' excellent dictionary, first published in 1945 and revised and expanded to include nucleonic terms in 1960, has been revised again, this time by Markus alone.

It is regrettable that books are not published with more speed. Markus continues to use "cycles per second" instead of "hertz." He is, however, fighting a battle that has already been decided. Although the dictionary received, in late December, a 1966 copyright date from the Library of Congress, the book reflects usage common in early 1966. That's why the old definition of hertz still stands. It is also the reason why the book doesn't differentiate between "integrated electronics" and "microelectronics" as recommended by the Institute of Electrical and Electronics Engineers last fall. Fortunately, we have grown up expecting hysteresis in hard cover books and are accustomed to relying on periodical publications for news of changes in approved terminology.

The book's type is easy to read, and items being defined are printed in bold letters. The drawings are clear, and the paper used is heavy enough to minimize printthrough from the other side. Markus' spelling and hyphenation of terms, while not necessarily that employed by a particular magazine or company, has the decided virtue of consistency. He also clearly marks commonly used words which are trademarks, to avoid, as he says in the preface, "unpleasant correspondence with lawyers representing the owner of the trademark."

The following comments are quibbles—nitpicking, so to speak—and are prompted only by a hope for an impossible perfection. Why is a phonograph record a "disk," when Webster, the New York Times and this magazine (to name just three authorities) distinguish it from other types of thin, circular objects by calling it a "disc"? Why does the definition of "umbilical cord" mention only the type used to test a missile and not include the lifeline that connects an astronaut to an orbiting spacecraft?

There is an error in the definition of picosecond; it is called one-millionth of a second, instead of one-millionth of a microsecond. The prefix "nano-" is curiously defined as "one-thousandth of a millionth," instead of the simpler "one-billionth."

The dictionary, Markus states in his preface, is meant for technical writers and advertising copy writers as well as for engineers and technicians. Hence, one questions the omission of "trade off"—a term which engineers know, but one which is not in the latest Webster's dictionary. The definitions of "electrical" and "electronic" are adequate for the engineer, but a paragraph elaborating the difference would greatly aid a new man in a public relations department.

The electronics engineer who wants to find out about some nucleonics terms may be similarly confused. For example, the definition of a "quark" as "a postulated but as yet undiscovered heavy triplet" makes sense to a high-energy physicist who knows that a heavy triplet is one of three nuclear particles, each of which is heavier than a proton. But "triplet" is defined only as "three radio navigation stations operated as a group"; "heavy triplet" is not defined.

Markus also falls into the trap of too narrowly defining some terms. For instance, after a clear explanation of how the Gunn effect works, he adds the gratuitous comment that "frequencies range from 500 to 7,000 Mc, depending on the thickness of the block." Recently one company built a Gunn-effect device which oscillates at 30 gigahertz [Electronics, Jan. 23, p. 26] and

New Books

another company is selling a similar device designed to operate from 7 to 12 Ghz. [Jan. 9, p. 214].

Despite minor flaws, this is an excellent reference and the vast majority of definitions should prove valuable in settling arguments.

Jan Rahm

Required reading

Designing Transistor I.F. Amplifiers
W.Th.H. Hetterscheid
Philips Technical Library,
Springer-Verlag New York Inc.,
330 pp., $12

The simple, foolproof design approaches given in this book make it a must for all receiver designers. The step-by-step procedures leave no question unanswered and, if followed, unfailingly result in the best possible design. Although some minor areas of i-f amplifier design have been omitted, and the use of field effect transistors is not discussed, the approach to the broad range of subjects covered is unusual and effective.

The usual approach to intermediate-frequency amplifiers is based on a stage-by-stage design, with each stage considered separately. That method, however, ignores the interaction between transistor stages and forces the designer to attempt to reduce this interaction by, for example, mismatching. In contrast, Hetterscheid has not compromised. His approach allows a rapid step-by-step design to the most exacting specifications, with no characteristics of i-f amplifiers, such as envelope delay, left to chance. The text is aided by 96 pages of two-color design charts, three fold-out charts, and numerous illustrations.

All of the graphs have been computed according to a specific tuning procedure chosen as the best of several possibilities. This method involves connecting a high-impedance indicator to the amplifier's output and applying a low-impedance generator to the tuned circuit preceding the circuit which is to be aligned. The author explains that other tuning procedures will require the computation of different curves, to account for

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New Books

the changes in interaction between stages as alignment proceeds.

The amplifiers discussed range from simple ones with single-tuned circuits through the most complicated, such as an amplifier containing one single-tuned circuit and four double-tuned circuits. Practical examples, fully calculated with measured data, include an amplitude-modulated radio receiver, a frequency-modulated tuner, a television receiver, and a 35-megahertz amplifier. Also discussed thoroughly are the parameters and tolerances of transistors and components.

The treatment of automatic gain control includes dual-delayed and forward and reverse AGC amplifiers. A subject which is, unfortunately, not covered is passive AGC, where the AGC signal controls the insertion loss of a variable attenuator rather than controlling the gain of a transistor circuit. This technique permits the transistors to be biased at the optimum point and feed a constant impedance, two factors of special importance in designs demanding low distortion, low noise, or constancy of other characteristics.

One other subject—the detector circuit—should possibly have been mentioned. An amplifier's signal-handling capability is related to envelope distortion—a problem of the last i-f stage and best treated in conjunction with the detector.

For a full understanding of the mathematics presented (something not required for the practical design of i-f amplifiers) the reader should be familiar with the general theory of cascaded, synchronous, and staggered radio-frequency amplifiers and basic transistor circuitry. Knowledge of determinants, matrixes, and complex algebra would also be helpful. The mathematical derivation of some of the design theories and the basis for the computation of the design charts are contained in the author's earlier book, "Transistor Bandpass Amplifiers," to which he frequently refers.

William A. Rheinfelder
Anaconda Astrodata Co.
Anaheim, Calif.

Technical Abstracts

From theory to practice

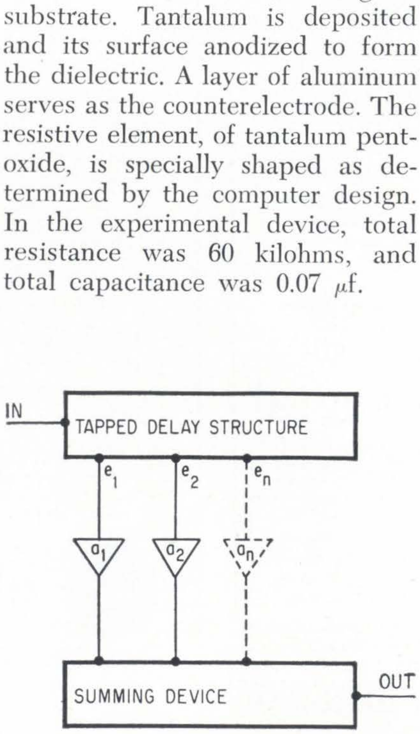
Transversal RC filter
R.C. Levine, Columbia University, and
W.I.H. Chen, Bell Telephone Labs.

The idea of synthesizing linear filters by time domain techniques dates back to the 30's. Later, LC versions were proposed. Now, through the judicious combination of computer-aided design and the tantalum thin film technology, a practical RC version looms on the horizon.

Such a device is based on a 3-layer sandwich consisting of a high resistance sheet and a ground conductor, separated by a dielectric layer. The device, called a transversal filter, has the general characteristics of a delay structure that is tapped at appropriate points. Intermediate outputs picked off at the tapped points are amplified according to predetermined weighting factors, and the resultant signals combined in an output summing device to achieve the high- or low-pass filter characteristics.

Uses are predicted for the tantalum film filters as equalizers in communication channels, for generating optimal waveforms in data transmission systems, and in matched filters.

Experimental units have been constructed on a 1 x 3 inch glass substrate. Tantalum is deposited and its surface anodized to form the dielectric. A layer of aluminum serves as the counterelectrode. The resistive element, of tantalum pentoxide, is specially shaped as determined by the computer design. In the experimental device, total resistance was 60 kilohms, and total capacitance was 0.07 μf.



The computer program is used to combine the independent time functions that arise at each electrical tap. In the future, work may be undertaken to synthesize band-pass filters. However, such filters require a large number of resistor taps. An even more serious limitation is the number of waveforms that can be accommodated in a computer program.

The frequency domain specification can be used directly in an alternate synthesis scheme which first expresses the frequency domain response as a partial fraction expansion.

Each pole term is related to a previously computed general form for synthesis of a damped sinusoid, and the linear combination of these results relates directly to the desired array of tap coefficients.

Presented at the 1967 Integrated Circuit Seminar, Stevens Institute of Technology, Hoboken, N.J., Feb. 1

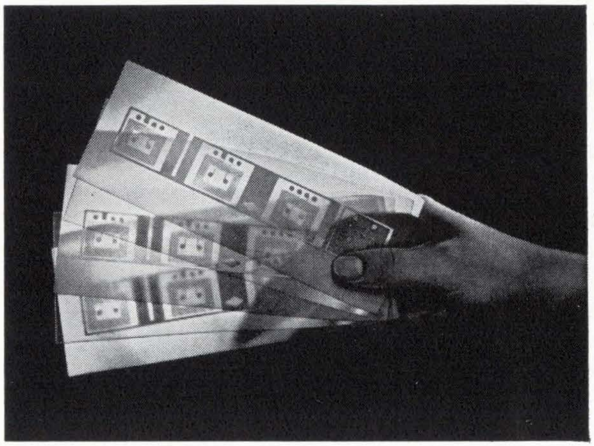
Stripless welding

Insulated wire welding as an interconnect technique
Robert E. Morris and John R. Sosoka
TRW Systems, TRW Inc.,
Redondo Beach, Calif.

New equipment and techniques have been developed for welding through the insulation on wire. The changes allow a freer choice of electrode tip configurations, making the technique more adaptable to production use and allowing closer control of the process. They also reduce electrode maintenance.

Welding through the insulation is becoming popular because it does not require stripping of the insulation. It has been used for several years to weld leads to components and for point-to-point wiring, including microminiature backplane wiring [Electronics, Nov. 1, 1965, p. 82]. The method allows welds to be made in the middle of a wire and avoids the hazards of using bare wire.

The process depended in the past upon the use of specially shaped welding electrodes. One contained a V groove to position the wire; the groove is difficult to keep clean. The other electrode acted as an anvil; it had a short



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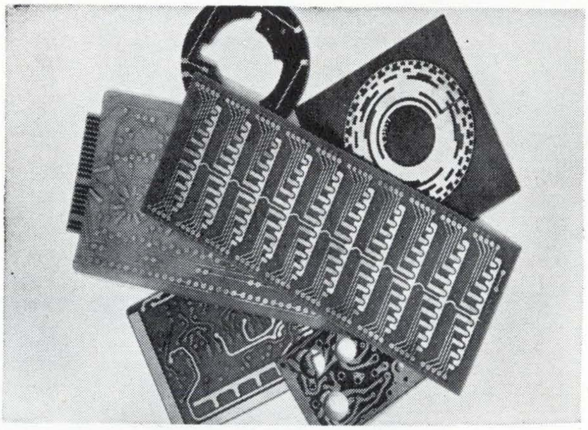

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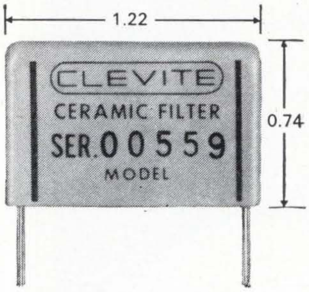
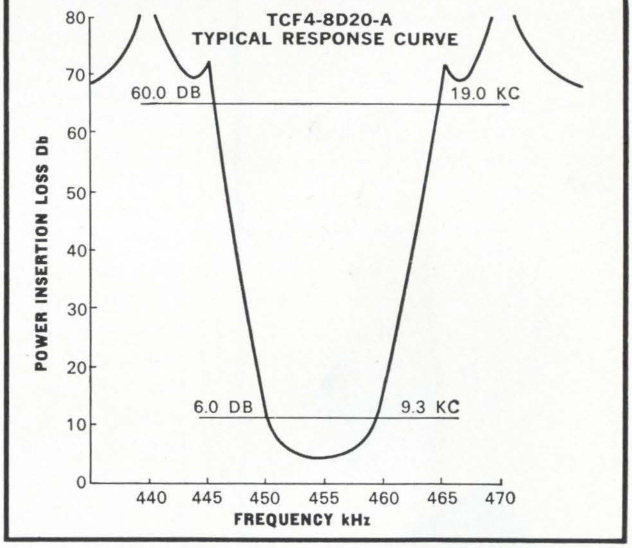


Clevite's computer-designed TCF ceramic filter.



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Technical Abstracts

life because the anvil shape could not be maintained through frequent tip dressings. The groove and anvil combination was needed to apply pressure that forced aside the insulation during the welding cycle.

Aside from the electrode maintenance problem, the dependence on pressure between the anvil and groove complicated the process when insulation thickness and hardness varied and required close alignment of the electrodes and the materials being welded.

These disadvantages have been overcome by softening the insulation with a preheat cycle that can be varied to allow for differences in insulations. This approach is implemented by modification of the weld power supply and the incorporation of a heating element in one electrode holder. The heating element contains a thermocouple for monitoring and controlling the temperature. In addition, a pressure limiting device is provided in the welding head.

The authors give examples of types of welds and wire insulations that can be used and they explain the procedures used to determine weld schedules and tip configurations. For instance, if the operator has to make welds to a large circuit board, the positioning problem will be eased if the electrodes have large, flat tips.

Presented at the National Electronic Packaging and Production Conference, Long Beach, Calif., Jan. 31-Feb. 2.

Compatible films

Silicon compatible thin film microcircuits
LeRoy A. Darling
TRW Systems, Redondo Beach, Calif.

For a long time, the penetration of monolithic integrated circuits into analog applications was hindered by the difficulty of producing both active and passive components on the same silicon substrate with the required precision. For example, high resistance values with close tolerances and low temperature coefficients are impossible to attain using conventional diffused techniques.

The solution lies in the development of a thin-film technology

Technical Abstracts

which permits resistors and capacitors to be deposited on the same wafer on which diodes and transistors have already been diffused. The major difficulty, which the author reports has been overcome at TRW Systems, has been the development of semiconductor processes capable of producing microwatt transistors of high quality, and compatible thin-film techniques for the production of highly stable and accurate passive components on silicon.

The author describes in detail a family of compatible device geometries and materials that have been employed to realize monolithic analog circuits, with special emphasis on very high frequency applications.

For precision resistors, TRW uses either cermet or nichrome thin films, which provide a sufficient range of electrical characteristics and satisfactory performance for most of their requirements.

For capacitors, the family includes diffused-junction isolated types, diffused types with dielectric isolation, metal-oxide semiconductor (MOS) diffused-junction and dielectric-isolation types and silicon-oxide thin film types.

Active devices developed for the compatible family include two types of transistors—a general-purpose, h-f junction-isolated device and a vhf/uhf unit with dielectric isolation.

As a typical example of the compatible process, detailed steps in the fabrication of a d-c amplifier under a NASA contract are given. The circuit was produced by combining bipolar transistors and diodes formed in monolithic silicon blocks, with deposited cermet resistors etched to give the desired values. The dielectrically isolated MOS capacitors are added. Final metalization forms the interconnections and plates of the MOS capacitors. These capacitors are credited with controlling the amplifier gain and phase in such a way as to eliminate oscillations and reduce h-f common mode gain.

Presented at the National Electronics Packaging and Production Conference, Long Beach, Calif., Jan. 31-Feb. 2.

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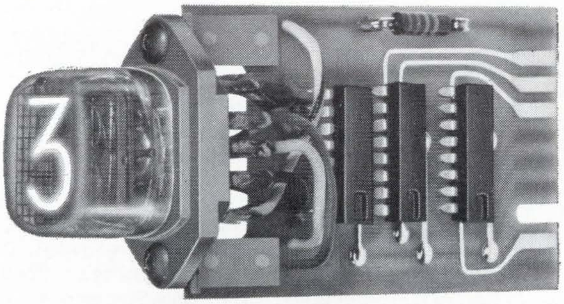

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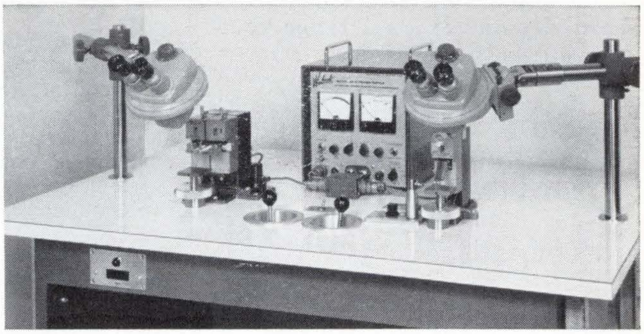

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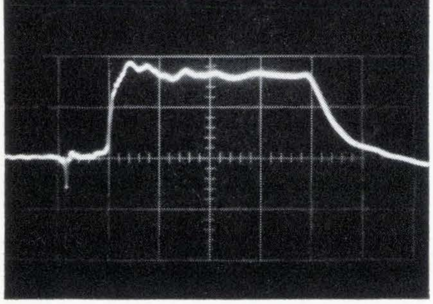

New Literature

Coaxial switches. Microwave Associates, Inc., Burlington, Mass., has published a single-sheet bulletin on the MA-7530 series coaxial switches that offer high r-f performance and mechanical reliability in a subminiature package. Circle **[420]** on reader service card.

Flashing indicator light. Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y., 11237, offers catalog sheet L-202 describing an indicator light that provides instant, intermittent lighting-flashing on connection to an ordinary a-c circuit at nominal 117 volts. **[421]**

Sound and vibration analysis. Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, Calif., 92112. A short-form catalog covers an expanded line of instruments and systems for the analysis of sound and vibration in structures and machines. **[422]**

Air-cooling electronic enclosures. McLean Engineering Laboratories, Princeton Junction, N.J., 08550, has available a 12-page brochure of technical information on air-cooling electronic enclosures. **[423]**

Thermistors. General Electric Co., P.O. Box 72, Edmore, Mich. A four-page application data bulletin covers description, performance characteristics and applications of thermally sensitive resistors. **[424]**

Transistor amplifiers. Aertech, 250 Polaris Ave., Mountain View, Calif., has issued a data sheet covering specifications for vhf L- and S-band transistor amplifiers. **[425]**

Microwave communication systems. Airtron division of Litton Industries, 200 E. Hanover Ave., Morris Plains, N.J., 07950. A 16-page brochure describes all the components required for a microwave communication waveguide system, from radio equipment output to antenna feed. **[426]**

Vane axial blowers. Eastern Air Devices, 385 Central Ave., Dover, N.H., has published a data sheet on a series of 2-in. vane axial blowers designed for military and precision commercial ground and airborne equipment. **[427]**

Sweep generators and accessories. Telonic Instruments, division of Telonic Industries, Inc., 60 No. First Ave., Beech Grove, Ind., 46107, has issued a catalog covering its entire product line of sweep generators and accessories, and has included a section devoted to application techniques in sweep generator measurements. **[428]**

Flexible cables and circuitry. Methode Electronics, Inc., 7447 W. Wilson Ave., Chicago, Ill., 60656, has released an information booklet on applications and manufacturing techniques for flexible cables and circuitry. **[429]**

Low-level choppers. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. A four-page brochure describes the models 80, 81, 90 and 91 Vibrachoppers, which are solidly encapsulated units designed to alternately connect and disconnect a load from a signal source. **[430]**

Precision resistors. Vishay Instruments, Inc., Resistor Products division, 63 Lincoln Highway, Malvern, Pa. An eight-page brochure covers designs and techniques that produce noiseless, non-inductive precision resistors that feature a tolerance to 0.01%, high stability and zero temperature coefficient. **[431]**

Data set. Rixon Electronics, Inc., 2120 Industrial Parkway, Silver Spring, Md., 20904. A product information bulletin deals with the PM-24 data set, a model capable of transmitting data over a type 3003 (4A) telephone circuit at 2400 bits per second without adjustment due to its high tolerance to delay and amplitude distortion. **[432]**

Avalanche silicon rectifiers. Syntron Co., 241 Lexington Ave., Homer City, Pa., 15748, has issued a 44-page catalog on its entire silicon line which includes diodes, power rectifier assemblies, Rectipoint assemblies, high-voltage rectifier tube assemblies, octal base assemblies and encapsulated assemblies. **[433]**

Transformer catalog. Microtran Co., 145 E. Mineola Ave., Valley Stream, N.Y. The 1967 catalog is a 34-page listing of an expanded line of transformers and toroids in MIL-T-27B and commercial/industrial constructions. **[434]**

Infrared photo sensors. Sensor Corp., 97 Indian Field Rd., Greenwich, Conn., 06830, has published two technical bulletins; one on the series 12201 infrared sensor heads, and the other on the series 22102 infrared input module. **[435]**

Phase-to-voltage converter. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif., 91343. A technical data sheet describes the model 791 phase-to-voltage converter which utilizes a solid state silicon design to provide a d-c output voltage that is proportional to the absolute phase difference between two a-c signals. **[436]**

Operational amplifiers. Analog Devices, 221 Fifth St., Cambridge, Mass., 02142. An economy-line catalog gives full specifications on nine operational amplifiers costing from $13 to $68. **[437]**

Radar altimeter. LFE Electronics, a division of Laboratory for Electronics Inc., 1075 Commonwealth Ave., Boston, Mass., 02215, has available a 12-

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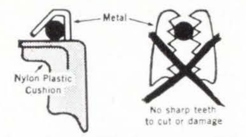

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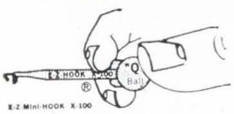

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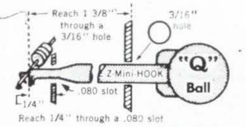

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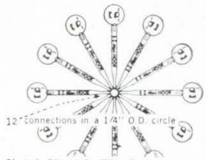

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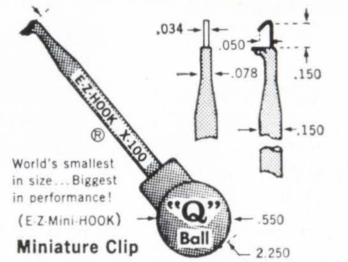

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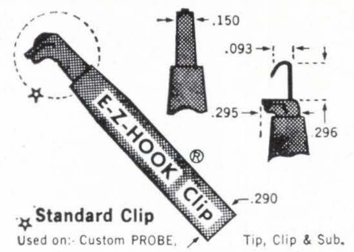

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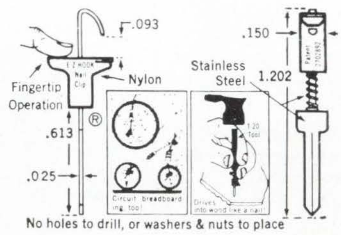

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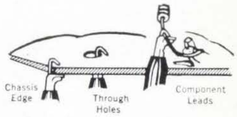

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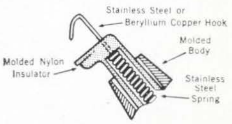

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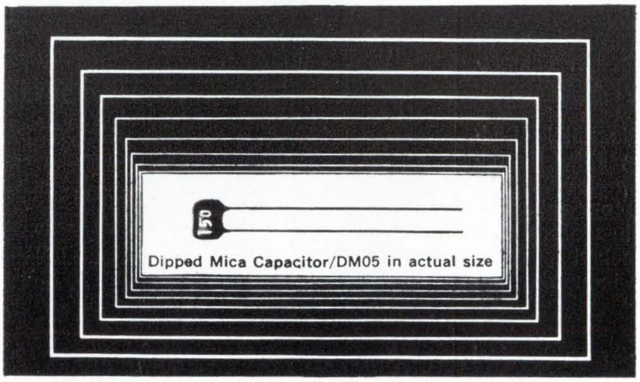

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DM 05	200	130	—	7.0	5.0	3.5	7.0	5.0	3.5	—	—	—
DM 10	440	390	330	8.5	5.5	3.5	8.5	5.5	3.5	8.5	5.5	3.5
DM 15 (CM05)	2000	1200	510	13.0	11.0	6.5	12.5	10.5	6.0	12.0	10.0	5.5
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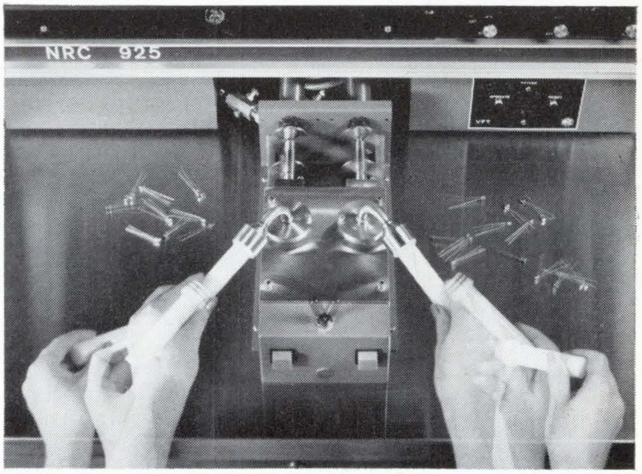

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New Literature

page technical brochure covering the AN/APN-141(V) radar altimeter equipment. **[438]**

NPN transistors. Industro Transistor Corp., 35-10 36th Ave., Long Island City, N.Y., 11106. Specifications for a complete line of high-voltage npn transistors are detailed in a six-page catalog. **[439]**

Oscillators. Accutronics, Inc., 12 South Island, Batavia, Ill. A short-form catalog contains a sampling of the many hundreds of oscillators currently available with frequencies ranging as high as 125 Mhz. **[440]**

Production equipment. Universal Instruments Corp., East Frederick St., Binghamton, N.Y. Numerical-control and pantograph-operated p-c board assembly machines, component sequencers, axial-lead component reel packaging equipment, and axial- and radial-lead component processing and production systems are described in a 12-page condensed catalog. **[441]**

Materials for photoelastic use. Photoelastic Inc., 67 Lincoln Highway, Malvern, Pa. Bulletin P-1120 devotes eight pages to materials for photoelastic coatings (sheets, liquid plastics, spray, adhesives) and photoelastic models (sheets, liquid plastics, cast blocks). **[442]**

Photoelectric shaft encoders. Wayne-George Corp., Christina St., Newton, Mass., 02161. Technical bulletin 1110A describes the Digisec RA series of natural binary, photoelectric shaft encoders which feature completely self-contained electronics. **[443]**

Miniature preamplifiers. Applied Cybernetics Systems, Inc., 880 Bonifant St., Silver Spring, Md., 20910. Ultralow-noise, solid-state preamplifiers in miniature size are described in a single-page catalog sheet. **[444]**

Mica insulators. Magnetic Shield Division Perfection Mica Co., 1322 N. Elston Ave., Chicago, Ill., 60622, has issued data sheet K-10 on a line of lower cost PMR mica insulators that can be hand cut or punched into any size, shape or form for industrial and commercial use. **[445]**

Analyzing arbitrary waveforms. Spectral Dynamics Corp., P.O. Box 671, San Diego, Calif., 92112. New methods for analyzing arbitrary waveforms are discussed in detail in technical publication PS-2, a 38-page monograph. **[446]**

Spectrophotometer accessories. Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif., 92634. Liquid sampling accessories for infrared spectrophotometers are the subject of bulletin 7000-42. **[447]**

New Literature

Crystal growing crucibles. Aremco Products, Inc., P.O. Box 145, Briarcliff Manor, N.Y., 10510. Product bulletin 112 describes a line of standard high purity alumina crucibles designed for high-temperature crystal growing. **[448]**

Sonar system. Westinghouse Defense and Space Center, Westinghouse Electric Corp., P.O. Box 1797, Baltimore, Md., 21227, has available a four-page booklet describing the TIP (transponder interrogator processor) sonar system. **[449]**

Flexible cable thermopile. Science Products Corp., Route 46, Dover, N.J., announces a bulletin on the flexible cable thermopile, a sensor that is useful in R&D, and where temperature measurement is of primary interest. **[450]**

Beacon magnetrons. Microwave Associates, Inc., Northwest Industrial Park, Burlington, Mass. Illustrated booklet SF-1503 describes the company's complete line of fixed frequency and tunable beacon magnetrons. **[451]**

Crt display system. Electronic Associates, Inc., West Long Branch, N.J. Bulletin AC66420 contains technical details on a 16-inch crt display system that provides instantaneous visual presentation of several computer variables simultaneously. **[452]**

Timing devices. General Time Corp., Thomaston, Conn., 06787. Catalog HD12 presents representative Haydon control devices for time measurement that are available as stock items. **[453]**

Test instruments. Fairchild Instrumentation, a division of Fairchild Camera and Instrument Corp., Mountain View, Calif., has available a 16-page condensed catalog describing its complete test instrument line. **[454]**

Laser products. Raytheon Co., Laser Advanced Development Center, 130 Second Ave., Waltham, Mass., 02154. An eight-page brochure describing portions of the company's extensive laser product line may be obtained by writing on company letterhead.

Bobbin selector. Wilcox Products Co., 1201 South Fifth St., Hopkins, Minn., 55300. A six-page bobbin selection chart of over 300 stock bobbins for electrical-electronic application is available to all prospects writing on their company letterhead.

Indicators and readouts. Transistor Electronics Corp., Minneapolis, Minn. Data sheet 571 describes a complete line of transistor controlled indicators and readouts designed to operate from typical IC logic levels. **[455]**

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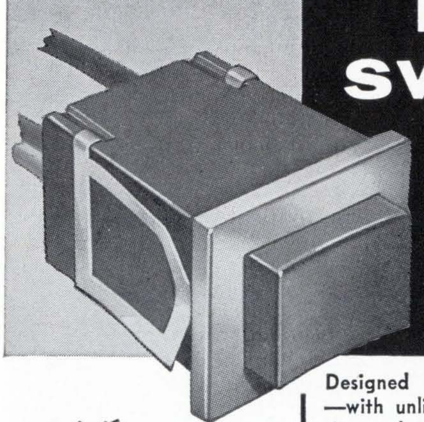

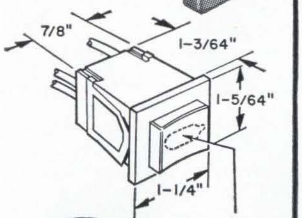

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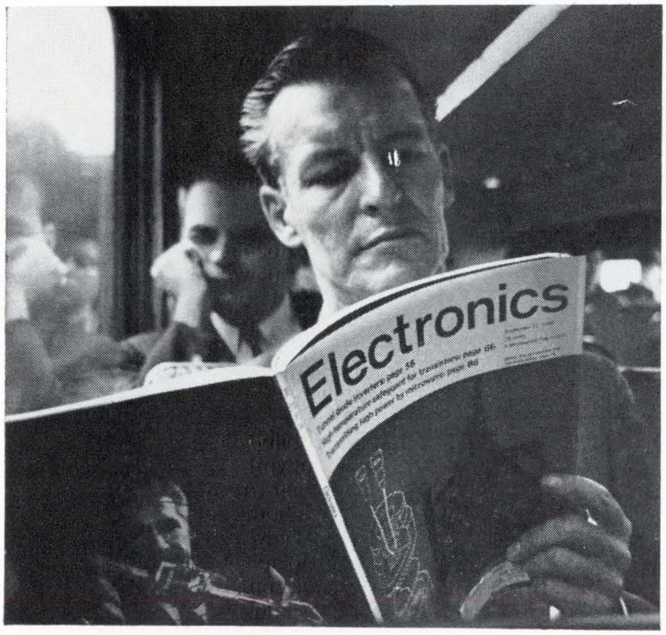

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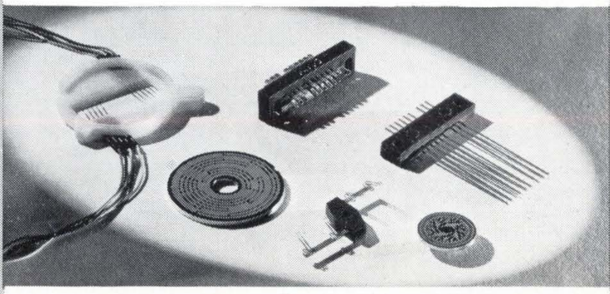

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New Literature

Inc., Microelectronics division, Danbury, Conn., 06810, has issued a data sheet on thick-film circuit modules for hybrid integrated circuitry. **[456]**

Torque motor. D.G. O'Brien, Inc., 500 Cochituate Road, Framingham, Mass., 01701. A four-page technical brochure covers the company's flat armature, limited stroke torque motor used in proportional servo control systems. **[457]**

Tape recorders. Ampex Corp., 401 Broadway, Redwood City, Calif., 94063. Catalog D067 provides a quick-reference description and specifications on laboratory, portable/airborne, wideband and loop instrumentation tape recorders, plus accessories and instrumentation tape. **[458]**

Integrated operational amplifiers. Radiation Inc., Microelectronics division, P.O. Box 37, Melbourne, Fla. A 91-page manual is entitled "Integrated Operational Amplifiers—Technical Information and Applications." **[459]**

Photodetector. United Detector Technology, P.O. Box 2251, Santa Monica, Calif., has available literature on the PIN Spot/10, a sensitive, large area, silicon photodetector that provides two electrical output signals specifying the X and Y positions of the center of an input light spot relative to fixed internal coordinates. **[460]**

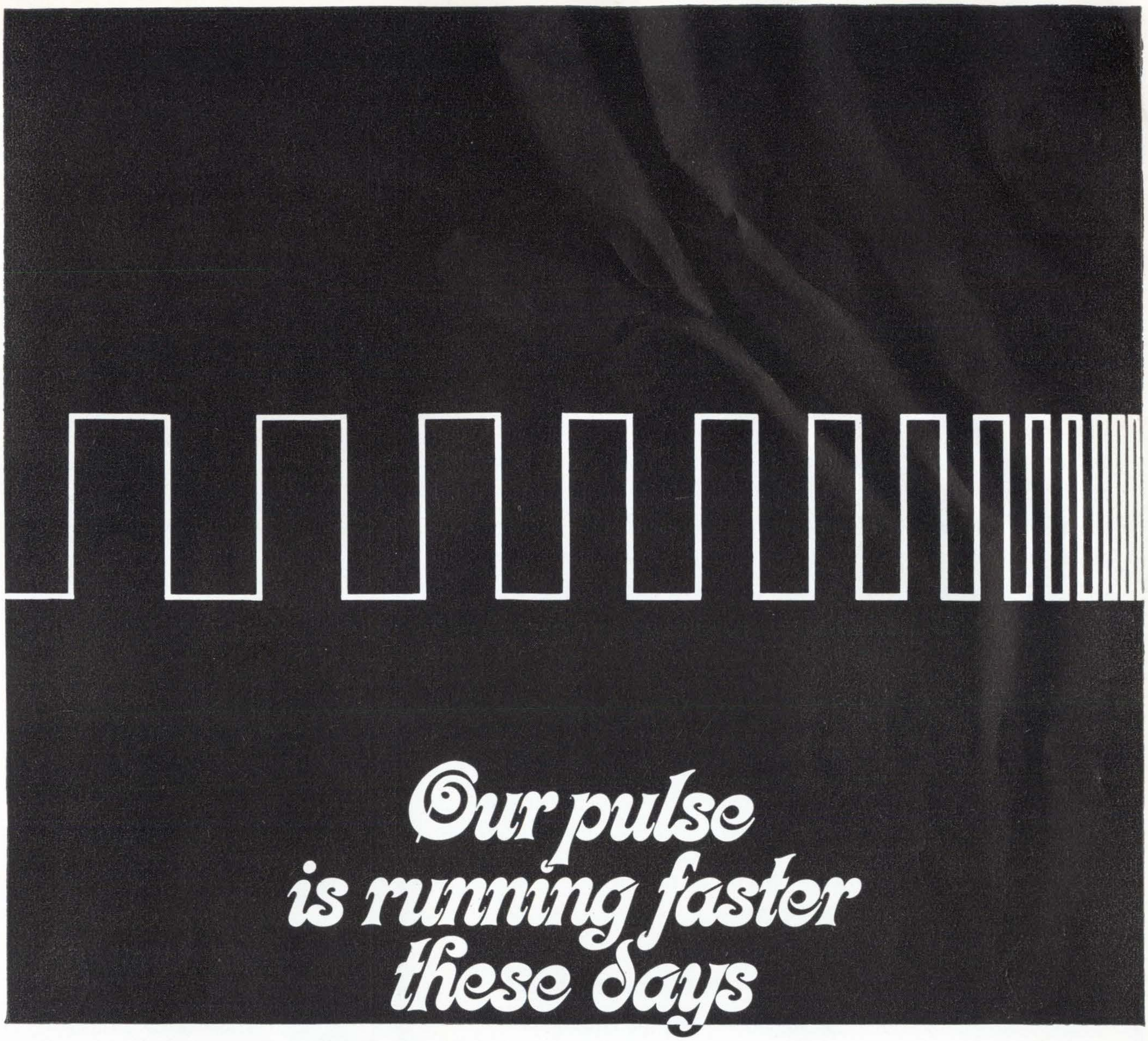
Computer tape. Memorex Park, Santa Clara, Calif., 95050, has published a six-page brochure describing MRX-III, a new generation of precision tape for the new generation of high-speed computers. **[461]**

Numerical control. Westinghouse Electric Corp., Box 868, Pittsburgh, Pa., 15230. Brochure DB22-750 describes the model 20 numerical positioning control that uses integrated circuits. **[462]**

Motor catalog. General Precision, Inc., Aerospace Group, 1150 McBride Ave., Little Falls, N.J., 07424. A 32-page catalog details almost 200 different motors and related components, and includes data on a wide variety of types and sizes arranged in eight separate functional categories. **[463]**

Snap-off varactors. Microwave Associates, Inc., Northwest Industrial Park, Burlington, Mass., has released a technical bulletin describing in detail a series of nine snap-off varactors. **[464]**

Single-gang capacitor. TRW, Electronic Components division, Camden, N.J., 08103, offers a product specification sheet on a compact, single-gang capacitor for low-power transmitter tank circuits. **[465]**



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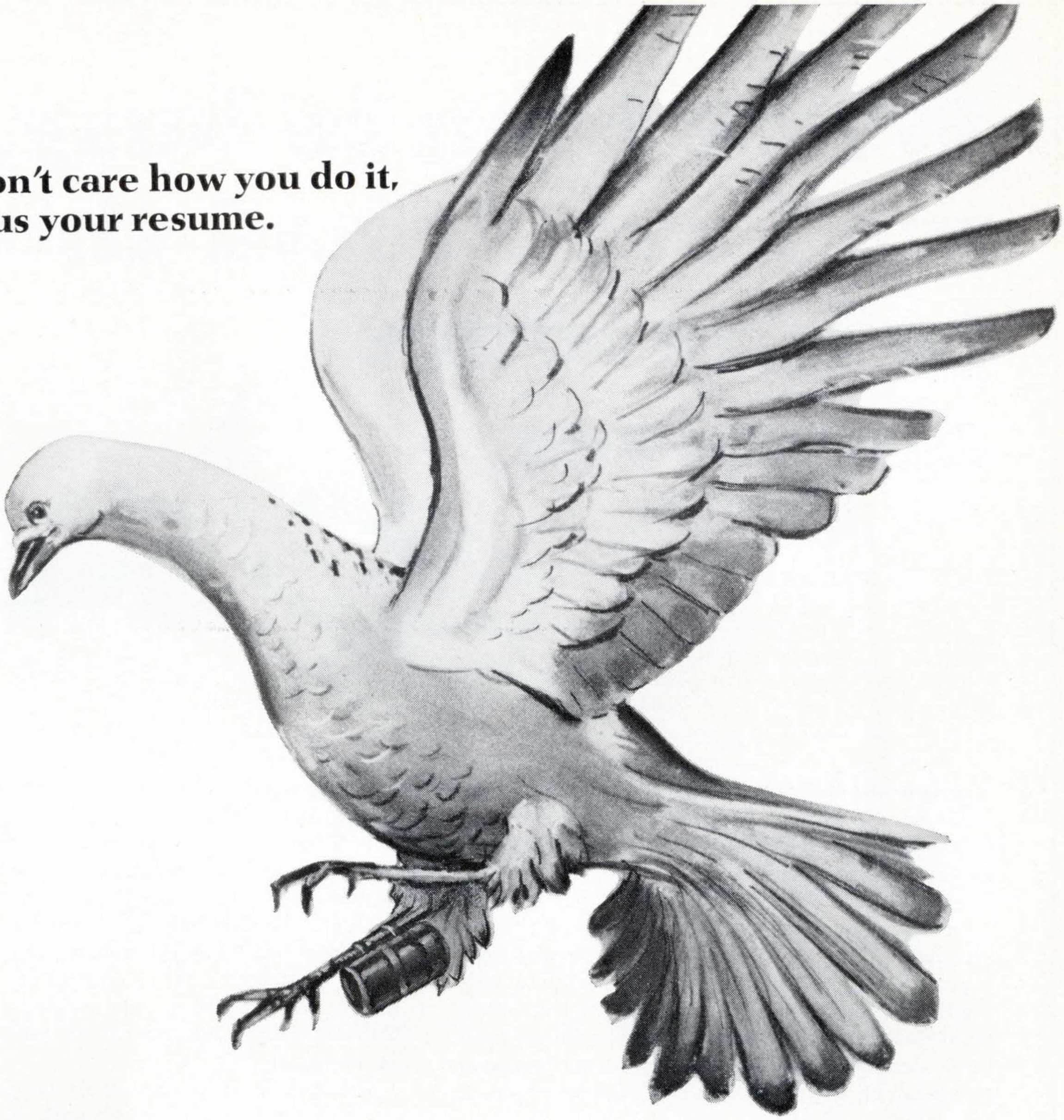

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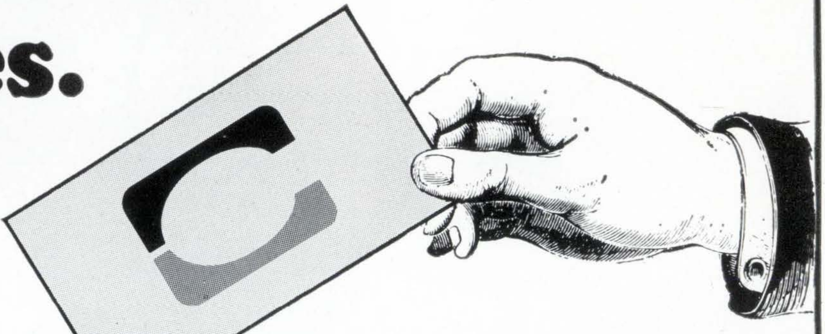

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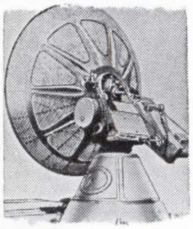

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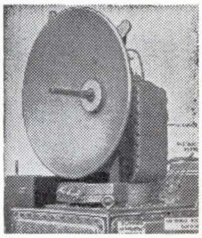

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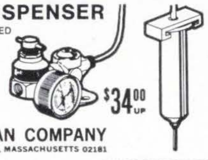

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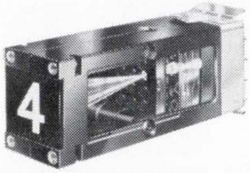

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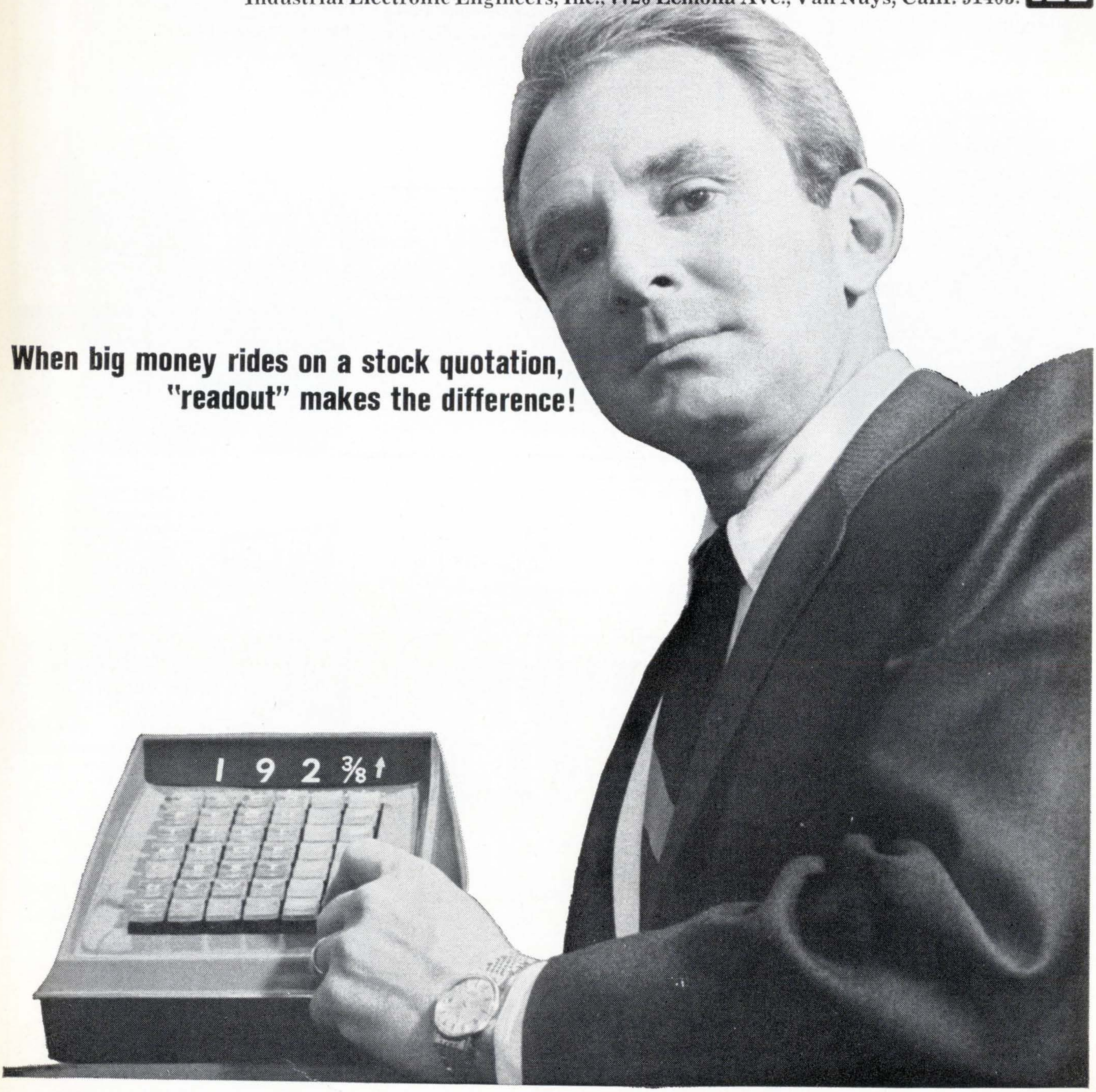

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Newsletter from Abroad

March 6, 1967

Five nations plan '69 communications satellite launch

There's a good chance that the first all-European telecommunications satellite will be in service before 1970. **The Scandinavian countries, together with Italy and Belgium, expect to nail down an agreement next month with the European Launcher Development Organization for a mid-1969 launching of an experimental satellite the five nations plan to build.**

The booster would put the satellite—dubbed F-9 because it will be the ninth ELDO launch—into a polar orbit with an apogee of 2,500 miles and a perigee of 250 miles. Because of the varying altitude, the capacity of the satellite would range between 60 and 240 channels.

Instead of the traveling-wave tubes used so far for satellite transmitters, **the F-9 will have a solid state transmitter built by Sweden's L.M. Ericsson Co.** The associated receiver will come from the Danish government's microwave laboratory, and the microwave beacon from the Bell Telephone Mfg. Co., a Belgian subsidiary of the International Telephone and Telegraph Corp. The Italians will build the satellite airframe and a second transponder unit. The Norwegians will supply the telemetering facilities.

Defense R&D cuts hurt West German avionics producers

Most West German electronics companies expect their avionics business to plummet this year. **Some anticipate a drop of as much as 60% in their sales to the aircraft industry, and several are shifting emphasis to the production of tank equipment.**

The dismal outlook stems from a decision by the Kiesinger government to cut back sharply on development of military aircraft. This year's budget earmarks only $75 million for R&D in this field, compared to $89 million last year. And $45 million of the 1967 allotment will cover work done last year. Because the remaining $30 million can't support the aircraft industry's current research effort, the government urged aerospace firms to trim their work forces by 15%. **As a result, some 1,200 scientists and engineers will be laid off by the end of this month. Another wave of layoffs may follow in June.**

Rental returns worry Japanese computer makers

A rise in turnbacks of rented machines in recent years has Japanese computer makers uneasy. For the fiscal year that ends this month, returned data-processing equipment will total about $12 million, compared with an estimated $80 million of new machines leased. **The percentage of returns—15% this year—has been increasing steadily since the first turnback of a rented machine in 1961.**

To ease the sting, Japanese computer firms are plumping for a faster writeoff of rented units. The government-sponsored Japan Electronic Computer Co., which buys computers from the six native computer makers and leases them, currently depreciates new equipment at a rate of 15% over the first six years and 10% for the seventh year. **The computer makers are pressing for a five-year writeoff. At the same time, they have asked the Ministry of Finance for a tax writeoff on returned computers they carry in stock or resell at a loss.** Japan Electronic Computer has the right to unload a returned computer—at its depreciated value—on its manufacturer.

The six Japanese computer makers last fall moved to forestall future turnbacks of small computers with a time-payment plan [Electronics, Oct. 3, 1966, p. 251], but only two computers have been sold so far under the scheme.

Marconi stabilizes quartz oscillator with IC heater

Britain's Marconi Co. has come up with an eye-opening application for integrated circuits—heaters for tiny quartz crystal oscillators designed for single-sideband miniature receivers. **The IC keeps the crystal's short-term stability at 1 part in 100 million over temperature swings from −55°C to 90°C.**

The crystals used in the oscillator measure about 0.1875 inch in diameter, small enough for thermal control by an IC. The heater circuit consists of an amplifier with a thermistor bridge input stage. The chip is mounted in the same can as the crystal and when can temperature drops, the input to the amplifier rises and it heats up. **Maximum dissipation of the IC is only 500 milliwatts but this is adequate for stabilization since the can is mounted inside an evacuated glass envelope.**

Marconi, one of the companies in the English Electric group, has in production an IC-stabilized oscillator package whose frequency can be preset between 10 and 15 megahertz. The output is 1 volt peak-to-peak into a load of 50 ohms. Later, Marconi will adopt the IC heater technique for oscillators with other frequency ranges.

Vlf broadcasts from Red China threat to Navy

A powerful long-wave transmitter "somewhere on mainland China" may mean trouble for the communications base the U.S. Navy will put into service this month at North West Cape in western Australia.

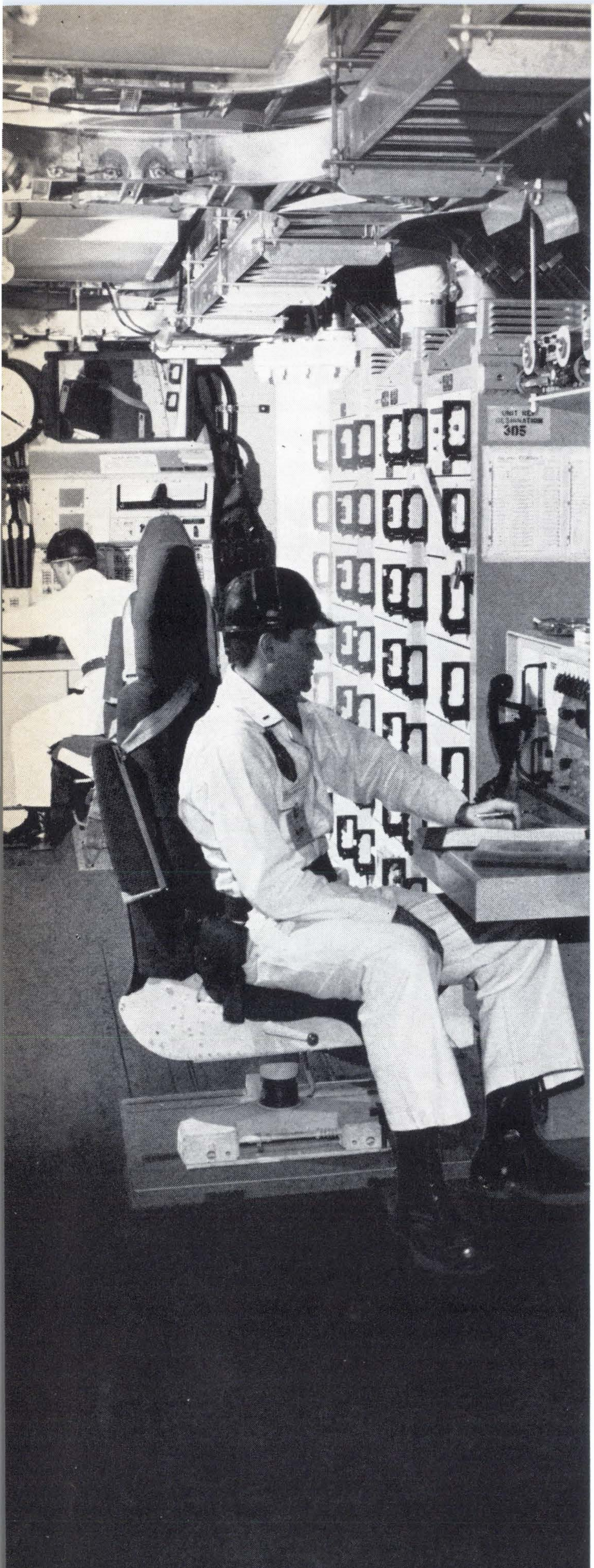
The Red Chinese station has broadcast, off and on, in the 16 megahertz band—used for military communications—and swamped receivers in Tokyo and Brisbane. In some cases, Chinese interference of broadcasts from the very-low-frequency transmitter at Rugby, England, has been picked up at receiving stations from the Arctic Circle to Argentina.

As yet, there is no indication that the Red Chinese deliberately jammed the British vlf broadcasts. The interference so far has lasted only a few minutes at a time. **But the Chinese presumably could raise hob—if they ever decided to—with vlf transmission to submarines from the base at North West Cape.** Navy spokesmen in Washington refuse to comment on reports from Sydney, Australia, that their new transmitters could be jammed.

Color-tv skirmish intensifies in Spain

The jockeying between France and West Germany to capture the Iberian color television market is entering its final phase with France apparently out in front.

Spain's state-owned network started experimental color broadcasts last month, airing programs using both the French Secam system and the West German PAL system. **But the French had color receivers in all the key ministries of the government while the best the Germans could do was to get one PAL set installed at the information ministry.** What's more, the French reportedly have offered to install receivers widely throughout Spanish government offices and leave them behind as a gift if Spain adopts the Secam system. Spain will make its color-tv choice by the end of this year and regular broadcasts will start in 1968.



ECI receivers, transmitters and test signal generators for Minuteman ICBM launch control facilities are designed for three-year maintenance-free operation and ten-year life. Photo courtesy The Boeing Company.

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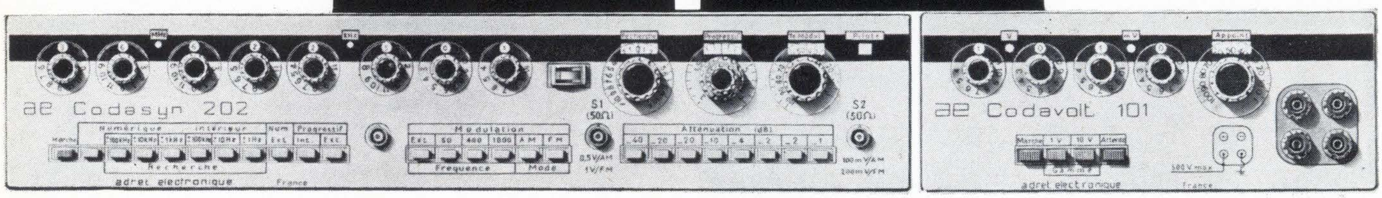

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Electronics Abroad

Volume 40
Number 5

Switzerland

IC time

New timekeeping techniques, now in the research stage, will depend heavily on integrated circuits for extremely low-power logic.

At the Neuchâtel Horological Electronics Center, the research and development arm of the Swiss watchmaking industry, engineers are working on a timepiece based on a small quartz-crystal oscillator. It will make obsolete "electronic" tuning fork wristwatches like the Accutron of the Bulova Watch Co. and the Horological Center's own improved versions of the Accutron which the Swiss will show next month at Expo 67, the Montreal World Fair.

The Swiss versions use integrated circuits and have tuning forks with a circular or H-shape rather than the U-shape of the Accutron's fork. For its part, Bulova sees no particular advantage in an IC for a tuning-fork watch. William O. Bennett, the company's vice president for research, points out that the circuit has only three components: a transistor, a capacitor, and a resistor. He maintains IC's have an edge only for circuits with many components. Bulova incidentally, owns a Swiss watch company and thus indirectly has a hand in the Neuchâtel work.

Divide and conquer. The all-electronic watch the Swiss have as their goal will use an 8.2-kilohertz quartz oscillator as the basic timekeeping element. The crystal output will be counted down to one hertz by binary dividers.

"This is the classical way of dividing down," says project engineer Fred Leuenberger, "but the power consumption goal is quite unique." The aim is to do the whole thing with 10 microwatts. "We are now high by a factor of two," says Leuenberger, "because we have not yet optimized the circuits."

The next-generation timepiece will use integrated circuits fabricated by quartz isolation techniques adapted from the "epic" technique of Motorola Inc. [Electronics, April 6, 1964, p. 29]. The Swiss use a single crystal material on a polycrystalline substrate and the two are insulated by a thermally grown silicon dioxide layer.

The crystal now being developed is three-quarters of an inch long, suitable for use in a man's watch but too big for a woman's. A 1.3-volt battery provides power.

Hands off. At present, says Leuenberger, there are no short-term plans for "display" beyond the conventional hands. The quartz oscillator divides down to the low frequency, and this triggers a step motor that moves the hands.

But eventually, says Leuenberger, the all-electronic watch will have no moving parts. Techniques for converting electricity into light require too much power, so other possibilities are under study.

These include such electro-optic techniques as using crystals to control the incidence of ambient light and change angles of diffraction in such a way that the pattern will give a readout of time. Also under study is an electro-capillary technique, using a liquid such as mercury in a shaped capillary tube. By application of an electromagnetic field, the liquid metal can be made to appear in small windows to indicate minutes and hours.

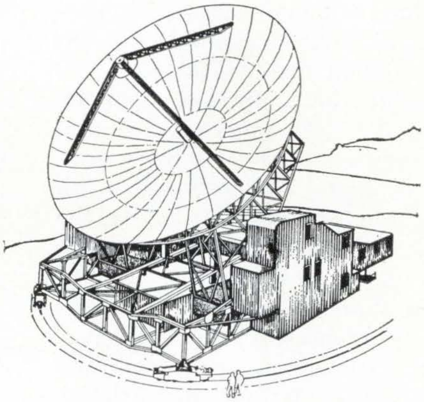
"The principle is not new, but this sort of thing is a long way off as far as power requirements are concerned," says Leuenberger of the capillary readout. The IC logic available to control it requires too much power. One low-power avenue the Swiss are trying is complementary metal oxide semiconductor circuits, using a pulsed power mode and therefore essentially zero standby power.

Great Britain

Dishing it up

An inordinate bustle is in store for the Marconi Co. over the next 13 months. Marconi in mid-February landed a $4 million contract to add a new terminal with a 90-foot antenna to Britain's satellite communications station at Goonhilly Downs in Cornwall. Marconi has to turn over the station—ready to work—to the government-run telephone system by April 1968.

Although the job involves the biggest antenna dish ever built in Britain, Marconi executives are confident they can make the deadline with a crash production program. Marconi, one of the companies in the English Electric group, previously rushed through four satellite communications terminals with 40-foot dishes in less than a year.



British dish. To tie into the Intelsat 3 satellite system, Goonhilly Downs ground station in Cornwall next year will have a new terminal with a 90-foot diameter stainless steel antenna.

Underlying reason for the tight deadline is Britain's fast-growing overseas telephone traffic. Post Office officials who run the phone system estimate they'll need about

100 new channels annually over the next four or five years to meet the demand. Presently, about half the transatlantic traffic is handled via the Early Bird satellite and the original Goonhilly terminal. Although built originally for experimental use, this terminal can handle 180 telephone channels.

From scratch. Conceived from the outset for round-the-clock commercial service, Goonhilly 2 significantly differs in design from its experimental predecessor. Although its antenna dish will be slightly larger (85-foot diameter for Goonhilly 1), the new terminal's moving structure will weigh only 550 tons, half as much as Goonhilly 1. As for capacity, the new terminal will be able to handle upwards of 500 telephone channels plus one television channel. And unlike its forerunner, Goonhilly 2 will have two complete transmitting and receiving chains plus a monitoring system to cut-in the standby chain when the operating one fails.

The terminal will cover the entire satellite communications band—5,925 to 6,425 megahertz for up transmission and 3,700 to 4,200 Mhz for down transmission. Its figure of merit—gain over temperature induced noise—will be 40 decibels or better at 4,000 Mhz with the antenna pointed 5° above the horizontal, about the worst possible position for reception.

The Post Office plans to use the new terminal with the Intelsat 3 satellite scheduled to be put into stationary orbit over the Atlantic Ocean in the spring of 1968. After Goonhilly 2 goes into operation, postal officials will shut down Goonhilly 1 and rebuild it to work with the Intelsat 3 satellite planned for stationary orbit over the Indian Ocean. However, the steering range of the new terminal will be large enough to point it at the Indian Ocean satellite.

The dish. To withstand Cornwall's windy and damp weather, Goonhilly 2 will have a dish made of stainless steel rather than aluminum, which has been used thus far for ground-station antennas in the U.S. (Goonhilly 1 originally had a mild-steel dish but it since has been lined with stainless.)

Although a stainless dish is heavier than an aluminum one, it distorts less in high winds. The Goonhilly dish will have an over-all accuracy of 0.040-inch root-mean-square at any elevation in still air and a maximum distortion of 0.200-inch in gusts to 70 miles per hour. To compensate in part for the added weight of the dish, the Post Office has opted for a lighter-than-usual support structure with elevation pivot points well down on the dish instead of at the mid-point.

Going up. At the outset, Goonhilly 2 will be using three up-carriers. Marconi, though, will build the transmitter so it can be expanded to handle up to nine carriers.

To cover the entire 500 Mhz bandwidth allotted for up transmission with a single high-power amplifier, Marconi will use traveling-wave tubes for the transmitter. With klystrons, a complete transmitter would have been needed for each carrier. The Goonhilly transmitter will have peak power output of 10 kilowatts. Except for the traveling-wave tubes, the transmitter will be all solid state.

Coming down. To pick up the transmission from the satellite, the receiving system will be set up initially to handle seven down-carriers. The receiver will be built around a parametric amplifier operating at about −250°C, very close to liquid-helium temperature. The parametric amplifier will have three identical gallium arsenide varactor diode stages, connected in cascade. Each stage will be pumped with 30 milliwatts of power at 3,400 Mhz by a klystron source working through a three-way passive splitter.

Brighter color

The consumer electronics industry in Britain long has counted on the coming of color television to spark its lackluster market. And now it looks like a mass market may develop sooner than it was thought.

In a decision that makes the prospects for color tv rosier than ever, the Wilson government last month announced it would authorize both BBC-1 and the Independent Television Authority to telecast color "within three years."

It was a happy surprise for the industry. In a White Paper released at year end, the government stated that color for a long while would be limited to a single network, BBC-2, with the first programs to start this fall. Like BBC-2, BBC-1 and ITV will air their color programs on a 625-line standard using the ultrahigh-frequency band. Both now broadcast in the very-high-frequency band on 405 lines.

Payoff in sight. For equipment makers, the decision will bring a windfall of some $135 million over the next two years or so. The British Broadcasting Corp., which already has invested heavily to prepare for color on BBC-2, will need some $50 million worth of additional transmitters and studio equipment to get BBC-1 on the air with color on a 625-line standard. Since ITV will have to start from scratch on 625 lines, its tab will run even higher, some $85 million.

For set manufacturers, the boon will be bigger—how much is imponderable—although later. Sales of color sets, at prices around $840, will begin this summer. But no one expects the market will start to move before 1968.

Even though color on BBC-1 and the independent commercial network most likely won't start until late in 1969, the fact that the pair will get color authorization figures to be a tonic for set sales as early as next year. Many set makers felt that color sets would be slow sellers as long as the only color programs in the offing were the highbrow telecasts of BBC-2. With popular programs now slated to follow, dealers will have a stronger sales pitch.

Eye exports. The decision also should give set manufacturers a better chance in export markets. Except for France, the major Western European countries will use the same 625-line phase-line-alternation (PAL) color system as Britain. The bigger the home market, the more competitive the British can be in markets abroad.

And the decision points to the end of Britain's out-of-date 405-line black-and-white standard in from 10 to 15 years. Both BBC-1 and ITV will have to broadcast in black-and-white on 405-lines the same programs they air in color for perhaps another decade. But after that, the government plans to phase out the 405-line standard.

Japan

Light touch

Even though it cranks out radios, television sets and desk calculators by the thousands, the Hayakawa Electric Co. has become something of a specialist in photoelectric components. At this month's Institute of Electrical and Electronics Engineers convention in New York, Hayakawa will be out to make U.S. equipment makers see the light its way.

The company is introducing a silicon solar cell with a response that peaks in the visible part of the spectrum rather than in the infrared region as conventional units do. Another new Hayakawa device that will bow at the show is a tiny phototransistor that develops an output signal strong enough to drive a relay directly. And Hayakawa will display building blocks that have been used to make up some of the largest earthbound solar batteries yet.

Blue cell. Hayakawa put a twist on a widely used passivation technique to get a "blue" silicon solar cell that has its peak response to light at a wavelength of 0.56 micron, in the visible region. Peak outputs of ordinary silicon solar cells occur at wavelengths between 0.80 and 0.90 micron.

With its fast response to visible light—the rise time is less than 10 microseconds—the blue cell may find wide use in electronic shutters. Other potential applications are exposure meters, flame detectors and spectrum analyzers.

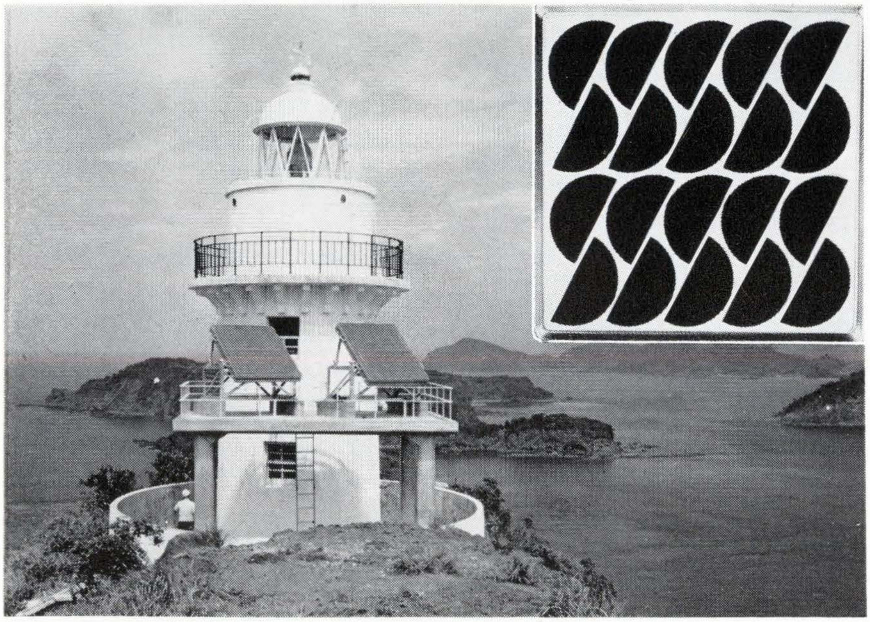
To make the cell, Hayakawa starts with p-type silicon and grows a thermal silicon-dioxide layer atop it—the usual passivation layer. In the process, an n-type inversion layer 0.3 micron thick forms directly beneath the passivation layer. The n-p junction thus lies much closer to the surface than does the junction in an ordinary solar cell, and this results in less attenuation of shorter wavelengths.

To further improve the cell's response to light in the visible spectrum, Hayakawa deposits by vacuum over the thermally grown silicon dioxide layer a second silicon dioxide layer and finishes off the cell with a proprietary epoxy coating. The coating is designed to pass visible light and block out most of the infrared. Optical interference between the three layers gives the cells their blue color.

Miniscule. Hayakawa also has an apparent winner in its minute phototransistor, a chip 650-microns square packaged in a pin-head-size mount. There are many photodiodes as small, but this transistor has a big plus: for many applications, its output needs no amplification. With an illumination of 5,000 lux, for example, the transistor's output current is at least 3 milliamperes, enough to operate a small relay.

Although the device will make its public debut at the IEEE convention, it's already been adopted by one Japanese manufacturer for a card reader. And it seems a likely component for infrared communications gear, control equipment, and pattern-recognition units.

King size. In contrast to the tiny phototransistors, the solar-cell battery packages are king size, each made up of 20 semicircular silicon wafers of 23-millimeter diameter. The package is shatter-resistant plastic, sealed to make it weathertight. Power output is better than 360 milliwatts. From these packages Hayakawa has built panels with outputs as high as 225 watts to power unattended lighthouses off the Japanese coast.



Alone under the sun. Unattended lighthouse off Japanese coast is powered by solar panels that generate 225 watts. Panels are built up of 20-cell packages shown in inset.

France

Millimeter waveguide

Blue-sky thinkers already foresee a time when city dwellers will need transmission lines with megacycles of bandwidth to handle the flow of data for computer-run electronic households. The household hardware still is a long way off, but a likely candidate for the transmission line is in sight.

In a project that's been kept largely under wraps so far, the Centre National d'Etudes des Télécommunications (CNET) is installing an experimental millimeter-wave trunk three miles long on the outskirts of Paris. The trunk, a circular electric waveguide with a 2-inch inside diameter, will handle a minimum of 50,000 frequency-modulated telephone channels at carrier frequencies of 35 gigacycles or higher.

The center, which is the research arm of the Ministry of Posts and Telecommunications, doesn't want to talk about the waveguide until it actually starts transmitting over it later this year. But it's a good bet that the center's researchers have developed a solid state multiplier with at least 100-milliwatt output to transmit millimeter waves over the waveguide. The underground millimeter trunk links the research center at Issy-les-Moulineaux to a microwave tower near Meudon, hub of telephone transmission between Paris and other major cities in France.

Spiral. Cables de Lyon, a subsidiary of the Compagnie Générale d'Electricité, is supplying the waveguide. It is made up of sections about 10 feet long with an inner conducting wall of wound copper wire. The wire is wrapped inside a fiberglass-epoxy tube encased in a steel tube.

Made this way, the waveguide is flexible enough to wind around curves with radii down to 165 feet. For sharper bands, and there are many of them to cope with in the Issy-Meudon run, the project engineers have taken a design-as-you-go approach. When they can't get around the bend by a switch to a more flexible cladding, they use smaller waveguide diameter and even copper mirrors to bounce signals around sharp corners.

The higher the better. The telecommunications center opted for $TE_{0,1}$ circular mode for the millimeter waveguide because with it signal strength increases as frequency does. Other transmission modes have the opposite effect. And signal strength also increases with the waveguide diameter when the mode is $TE_{0,1}$. There is a drawback, however. Even very slight variations in the waveguide cross-section set up parasitic modes, a problem that becomes more and more serious as the diameter of the guide increases.

The best tradeoff among these factors came at an inside diameter of 2 inches. With acceptable loss set at 3 decibels per kilometer the lowest frequency that can be used is 35 Ghz. The upper limit for the guide runs above 120 Ghz. At that level, the center expects the number of telephone channels would top 120,000.

Both frequency modulation and pulse code modulation were considered for the millimeter wave trunk but f-m apparently won out for the initial installation because phase distortion stays within reason over the relatively short run. But the agency still is working on pulse code technique for eventual application if it moves on to longer millimeter-wave guides.

In the whirl

Ordinarily, about the only coverage a 120-man electronics company can expect in the daily newspapers is a very few lines buried on the business page. But late last month, France's small Société d'Exploitation et de Recherches Electroniques (Serel) was on the front pages. The story: Serel's sale of $400,000 worth of closed-circuit television and telemetry equipment for a new cosmonaut training center in the Soviet Union.

Always ready to bolster the national ego with tales of Gallic technical prowess, the French press treated the Soviet buy of sophisticated hardware as big news. The equipment will be used to pick up physiological data on Russian cosmonauts as they whirl in a centrifuge to simulate weightlessness in space.

Along with Serel, the industry giant CSF-Compagnie Générale de Télégraphie sans Fil will help outfit the training center. CSF will deliver two mass spectrometers to analyze respiratory gases of cosmonauts as they spin around.

CSF's penetration into the Russian space market isn't surprising since the company has played a major role in the French space program. And it already has a contract to supply the Soviets with know-how and equipment for a color-tv tube plant. But for a small company like Serel, cracking the Soviet market is indeed rare. Serel's annual sales run about $1.6 million.

Doing the difficult. Georges Duteau, Serel's sales manager, says the company's strategy for success is specializing in the difficult. "We get the business that no one else wants, either because it's too difficult or because it involves production of only a few units," Duteau says. The strategy has led to a small but lucrative government market in closed-circuit tv and telemetry for Serel. The company's customers include the French air force, navy, atomic energy commission, railroad system, and the Paris airport authority.

The electronics Serel will supply for the Soviet centrifuge includes a 1,029-line tv camera with definition up to 1,000 points per line. Its control circuits give a constant video output at light levels down to 10 lux. The telemetry equipment has 31 channels and converts analog physiological data like heart beat and blood pressure into a digital output at a rate of 10 million bits per second.

Although the equipment that Serel will ship to the Soviets is designed strictly for ground use, Duteau says the company already has started to develop similar—but smaller and lighter—hardware for use in manned satellites.

West Germany

Solar storm clouds

One of the major hazards astronauts will face on flights to the moon and beyond are proton showers resulting from outbursts of electrified particles from the sun's surface. Concentrated proton radiation can cause infertility and could eventually destroy body cells. But astronomers believe the showers can be predicted if the temperature distribution over the solar disc is known.

To collect and forecast data on solar proton activity, the Max

Planck Institute for Radio Astronomy near Bonn is now using a radio telescope that "takes the sun's temperature" at points across the solar surface. With a 33-foot-diameter antenna dish, the telescope picks up signal strength caused by the different levels of light intensity. These readings are then plotted. From the plottings, maps are drawn showing the contours of the sun's hot and cold zones. Daily shifts of these contours—sometimes called coronal condensations—may indicate impending proton shower activity. The telescope is atop Stockert Mountain, about 20 miles southwest of Bonn.

Round the clock. Similar work is being done in the U.S. Under an Air Force sponsored program, the Prospect Hill Radio Observatory at Waltham, Mass., has plotted a number of sun temperature readings using a radio telescope operating on an 8.6-millimeter wavelength and having a 29-foot-diameter antenna dish. By coordinating solar research with observatories around the world, it is possible to provide round-the-clock forecasts as the sun moves across the sky, says Otto H. Nachenberg, the Bonn institute's technical director. But so far the Waltham and Stockert installations are the only ones built for this purpose.

The West German telescope has an aluminum antenna dish whose shape varies by no more than 0.5 mm from that of an ideal parabola. The antenna is equatorially mounted—one axis in the north-south direction and the other perpendicular to it. The telescope has a beamwidth of 3.5 minutes of arc.

As the sun moves across the sky, the antenna automatically follows it. The feedhorn scans the sun in discrete steps of 2.5 minutes of arc from top to bottom in columns from right to left. In this raster-type motion, 80 regions are scanned. It takes about three minutes to cover the solar surface. The antenna movement is controlled by a synchromotor-driven quartz clock, supplied by West Germany's Rhode and Schwarz AG.

Clearer picture. The receiver—designed by the institute—has a 10 decibel noise level and a bandwidth of 10 megahertz. Eight mm signal operation was chosen because absorption by the earth's atmosphere is relatively low at that wavelength, thus giving astronomers a better picture of solar storm activity. High temperature areas on the sun result in strong signals and the signal strengths drop sharply when cold zones are encountered.

Presently, signal intensities are recorded by hand. But soon—probably within a few weeks—an electronic recorder to be supplied by a U.S. firm, Scientific-Atlanta Inc., will take over this function.

The automatic scan feature can be overridden and a television camera mounted on the edge of the antenna dish can be pointed toward the sun for steady observation.

Construction of the telescope was financed by a $100,000 grant from the German Research Society, a quasi-government foundation.

Finding faults

Costly and time-consuming methods of inspecting high-grade paper for flaws are being erased by automated equipment. The newest electronics device to spot defects and eliminate faulty sheets from the good ones is being introduced by Kiel's Firma Dr.-Ing. Rudolf Hell. Making its bow this spring at an international exhibition of paper and printing machines in Dusseldorf, the machine—called the Hell Electronic Paper Monitor—puts the firm in competition with U.S. and Canadian companies now producing similar devices.

Basic to the new German equipment is a unit that scans the paper as it moves by. It uses photodiodes as sensors to detect discolorations, corrugations, folds and wrinkles. The paper can be checked at web speeds of up to 2,300 feet per second.

Defect signals. The paper web is illuminated by gas-discharge lamps which give the brightness required for detecting defects. Silicon photodiodes, each covering an area of about 2 millimeters, scan the width of the web. A bias adjustment in the scanning unit suppresses the noise level caused by the paper's structure.

The light reflected into the photodiodes is continuously checked against the average light level. When a flaw cuts down the amount of light hitting a photodiode, it generates a defect voltage. Typically, a dark spot approximately ¼ square millimeter in size generates about 30 millivolts. In cases of corrugations and folds, the diodes detect the differences in distance between the paper surface and the diode face.

Defect signals whose amplitude exceeds a specific preset limit cause the rejection of the sheet. The defective sheet is guided by electromagnetic, pneumatic, or hydraulic deflectors onto the reject pile.

Signals of an amplitude smaller than the limit are fed to a summation unit. All defects in the moving web are counted by a digital counter and a second digital counter records the passing paper length. If the number of defects counted in a given length does not reach a preset maximum allowable number of defects, both counters are reset to zero. But if the number of defects reaches or exceeds the maximum, a reject pulse is generated. The "maximum allowable defect" control thus determines the grade of paper being scanned. If, for instance, high-grade paper is desired in which, say, no more than four defects per a given length of paper is permissible, the control would be set accordingly.

Total count. Each scanning unit covers a web width of about 2½ feet and the working width of the equipment can be increased by adding more scanning units. If the paper is checked at other production stages where, for instance, paper is being wound from one reel to another, the total defects in each reel are continuously indicated by a digital counter and are printed out for each rewound reel.

If the German firm wants to get its share of the market, it will have to scramble. Canada's Nash and Harrison Ltd. has its Eldema 109 units operating in U.S., Canadian, and European plants. The Columbia Controls Research Corp. of

Glen Cove, N.Y., and Electronic Associates of Canada Ltd. are also manufacturing paper-monitoring devices.

Around the world

Sweden. Saab AB has developed a television tracker to guide missiles and aircraft. With the system, an operator views target sectors on a tv screen and sets a contrast control to select targets. The system then locks onto the target automatically.

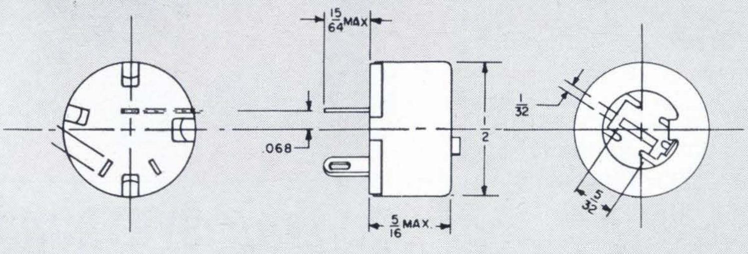
Italy. The first satellite launching from Italy's San Marco Texas-tower platform off the coast of Kenya is scheduled for late April. The Italian-built 250-pound satellite—San Marco 2—will be put into an orbit of 155 to 185 miles by a NASA Scout rocket. San Marco 1 was launched in the U.S. in December, 1964, by an Italian crew.

Great Britain. The General Electric Co. (not connected with its U.S. namesake) has found the computer business too rough. The company last month sold its computer-making subsidiary to Elliott-Automation Ltd. for approximately the value of the contracts it had in progress—some $5.5 million.

France. The first phase of France's space program ended last month with two launches and mixed success. The first satellite sent up, D-1C, went into a lower orbit than planned and the French had trouble tracking it with laser stations set up in France, Algeria, and Greece. The second satellite, D-1D, went into an orbit with a 1,900-kilometer apogee. This was not as high as planned but high enough for laser tracking from the three stations. The next all-French satellite launching is expected in the spring of 1969 from the new space center in French Guiana.

Japan. The Keihanshin Kyuko Railway Co. will soon have an unmanned station on one of its commuter lines. The station will have five ticket-vending machines, a bill changer, 10 automatic ticket checkers, and an automatic commutation ticket puncher.

TRIMMED



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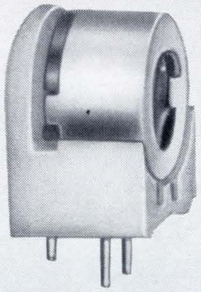

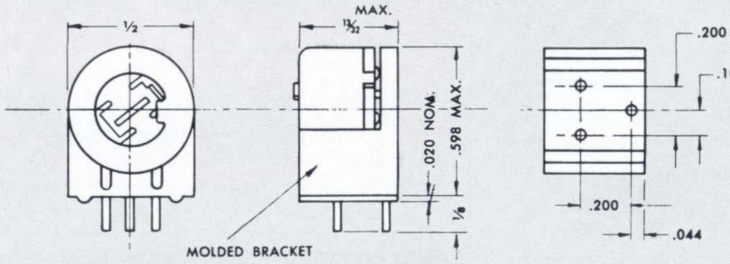

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Taper: Linear.
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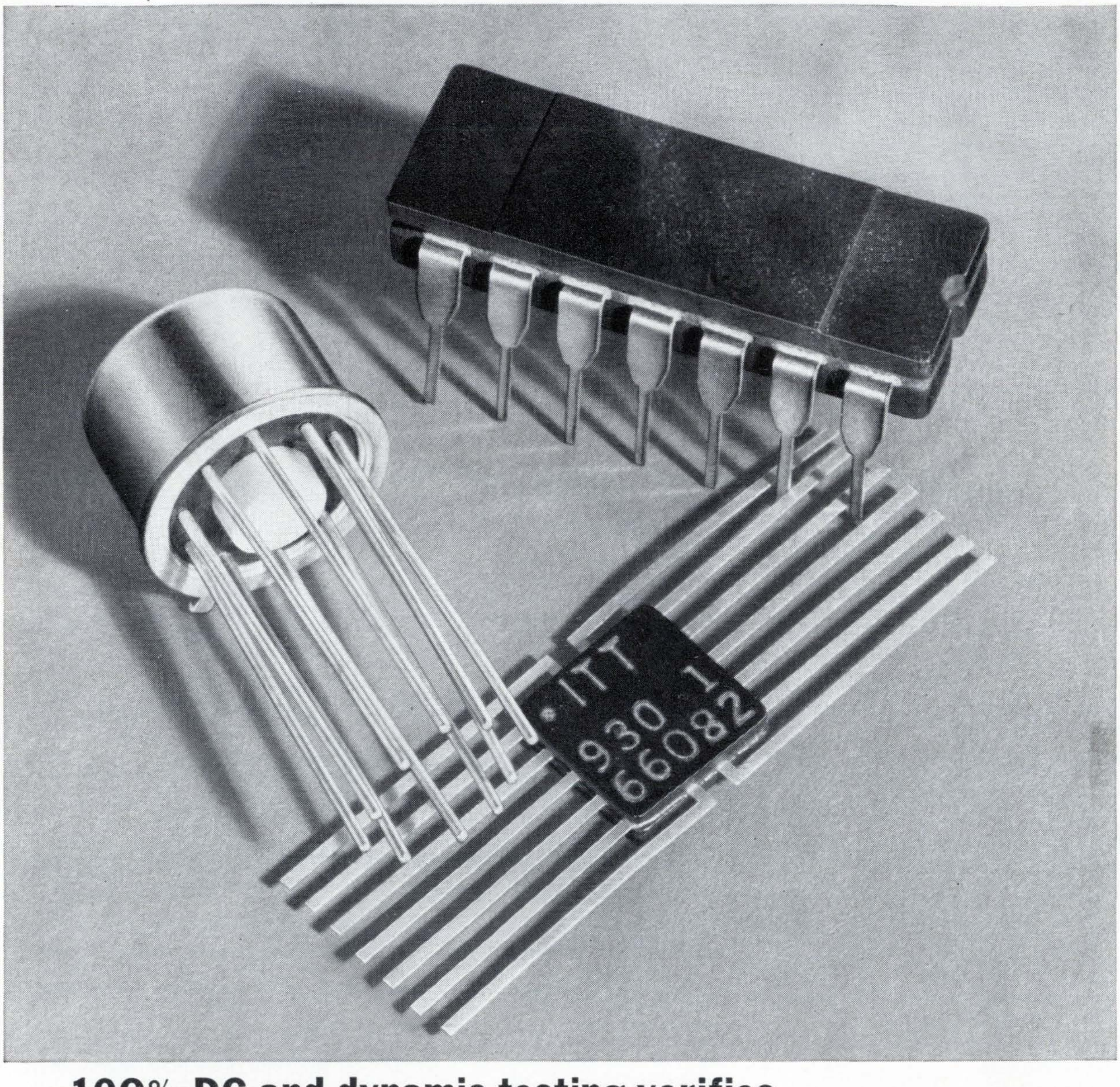

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