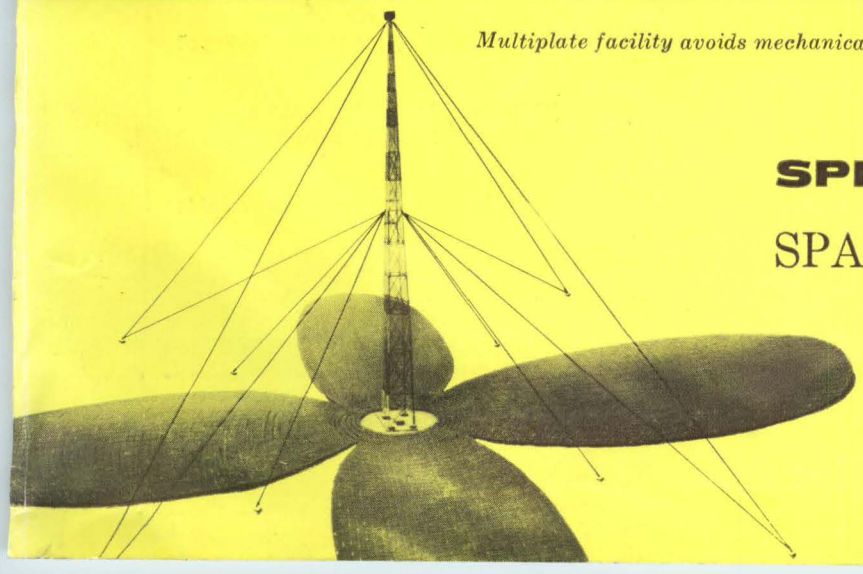
September 7, 1962

electronics

A McGraw-Hill Publication 75 Cents

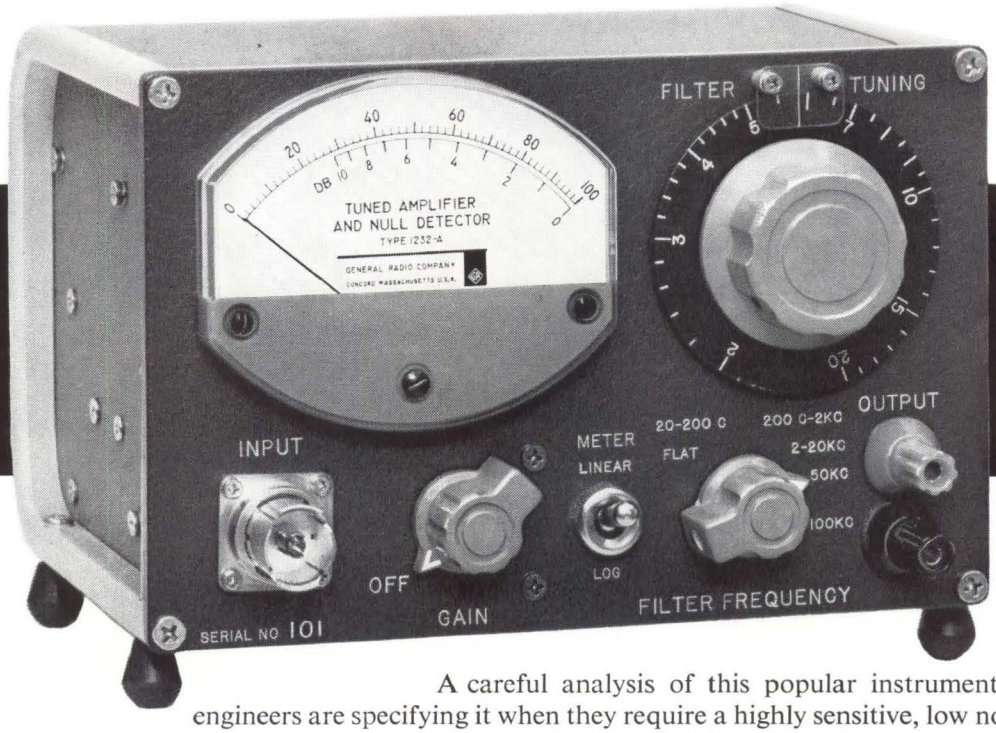
Multiplate facility avoids mechanical problems of steerable dishes, p 39



SPECIAL ANTENNAS IN SPACE COMMUNICATIONS

Looking for a Null?

This Detector's 1μv Sensitivity Will Find It



Fully Transistorized

Type 1232-A
Tuned Amplifier
and Null Detector
$360

A careful analysis of this popular instrument will reveal why engineers are specifying it when they require a highly sensitive, low noise, continuously tunable null detector. Extremely high sensitivity is attained by new circuits that stem from the application of a simplified noise theory* developed by GR engineers. Continuous tuning is provided by an RC null network that contains a potentiometer as its single variable element. This unique feature eliminates the alignment and tracking problems associated with conventional null networks using three variable elements. Other major features are listed below.

Although designed primarily as a bridge detector, the 1232-A can be used, as well, as a detector of high-frequency modulated signals (with a crystal demodulator), audio-frequency wave analyzer, and general-purpose tunable amplifier.

- **EXTREMELY HIGH SENSITIVITY** — one microvolt or better, full scale, over most of the frequency range.
- **EXCELLENT SELECTIVITY** — bandwidth at any frequency is about 5%. Second harmonic rejection is at least 35 db. Above 200 cps, 60-cycle rejection is at least 60 db.
- **LOW NOISE LEVEL** — less than 0.2 μv for most of the tuned range.
- **CONTINUOUSLY TUNABLE** — from 20c to 20 kc in three 10:1 ranges.
- **TWO FIXED-TUNED FREQUENCIES** — at 50 kc and 100 kc.
- **HIGH GAIN** — 120 db for tunable settings; 100 db for flat 20c to 100-kc position; 106 db at 50 kc; and 100 db at 100 kc.
- **CONSTANT OUTPUT** — ±3 db from 20c to 100 kc (FLAT position).
- **LINEAR OR LOGARITHMIC RESPONSE** — provided by meter switch. Compression adds 40 db to upper portion of meter scale for null measurements; does not affect sensitivity at bottom end of meter scale.
- **SMALL, COMPACT, AND LIGHTWEIGHT** — fully transistorized, unit measures 8 inches wide x 6 inches high x 7½ deep, and weighs 5¾ pounds.
- **FRONT LEGS EXTEND** — permits tilting for easier viewing of panel.
- **LOW POWER REQUIREMENTS** — 12 volts dc, from 9 mercury cells. Estimated battery life is 1500 hours at a cost of about 0.4-cent per hour.
- **RACK MOUNTING PROVISIONS** — panel extensions available for rack mounting.

*Available on request, reprint of "A Simplified Noise Theory, and its Application to the Design of Low-Noise Amplifiers", by A. E. Sanderson and R. G. Fulks, IRE Transactions on Audio, July — August, 1961, and NEREM 1960 Record

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS

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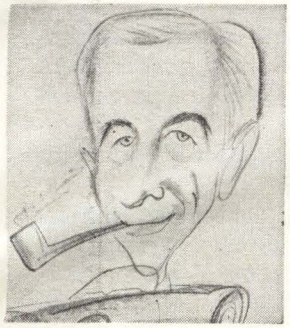
CIRCLE 900 READERS SERVICE CARD

September 7, 1962

electronics

A McGraw-Hill Publication 75 Cents



W. W. MacDONALD, Editor

Contents Continued

electronics

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CONTENTS continued

DEPARTMENTS

Something for Nothing

IN ELECTRONICS, as in every other business, charlatans sometimes get into the act, claiming "breakthroughs" and offering to share the secret —for a consideration.

The type of man who sold gold bricks in the last century, and pills that turned water into gasoline in the early 20th century, is now apparently turning to electronics.

The man in the FBI photos above is allegedly just such a person. His name is Anthony Romano, alias Tony Castollano, age 35. He was indicted by a Federal Grand Jury at Miami in March and is now a fugitive.

Romano is accused of using an interstate wire in bilking a group of Florida businessmen of $35,000. He allegedly showed them what appeared to be a transistor radio and claimed it operated without batteries, drawing its power from the air. They put up the money to form "Castollano Electronics."

Frequent attempts were made by the investors to have the "power pack" examined by an electronics expert, but Tony reportedly would stalk off, carrying it with him and muttering that the electronics man was attempting to steal his invention.

What is significant about this case is that the investors were not housewives. They were businessmen. They invested money without technical tests or verification, thought about checking later.

No knowledgeable electronics man would be caught like that, you say? Don't be too sure.

A well-known authority told us recently that the bunco element which attempts to exploit any spectacular new field may now be trying to cash in on the laser business.

How does he know? His company bought some highly-touted components from a supplier who had claimed "breakthroughs" while refusing to be specific.

The components were worthless.

VARACTORS. There are a variety of advanced components that behave much like everyday versions of the same device, except for a special feature, a technological twist analogous to a quantum jump in their level of usefulness.

To name a few: zener diodes that break down at a fixed voltage, semiconductor thermoelectric elements that unlike metallic devices prevent heat from rushing back to the region being cooled, and electrochemical integrators that put out signals proportional to the integrated quantity instead of indicating the quantity by a color change.

One of the outstanding examples of this addition of a new parameter to a component is the varactor diode, whose capacitance changes with applied voltage. This feature has made the parametric amplifier possible.

However, every rose has its thorns. New devices require new and equally ingenious test equipment and techniques. A varactor cannot be checked out with a simple capacitance bridge, because it has a whole range of variables all interrelated—capacitance-voltage relationship, variation of capacitance with frequency and dependence of capacitance on ambient temperature.

Recently we published (p 60, March 9, 1962) an article telling how to test varactors by applying a sawtooth bias voltage to the varactor and probing with a fixed high frequency. This week, on p 49, F. P. Chiffy and J. L. Gurney, Jr., of GE, describe how readings for bias voltage can be obtained by injecting a high-freqency signal into the varactor.

Next week—shifting from tests to applications of varactors—we will publish an article whose headline some reader may want to challenge: "Is this the Simplest Paramp Ever Built?"

The amplifier circuit, for use at vhf and lower microwave frequencies, contains only one varactor, a butterfly resonator and coupling loops for signal and pump frequencies, yet is tunable over a 2:1 frequency band. The author is R. J. Mayer, of Boeing, who provided us last year with a report on an earlier parametric amplifier (p 74, Dec. 15, 1961).

Other articles on parametric amplifiers using varactors, published this year, include a design for a troposcatter system paramp preamplifier for a military system using a circulator (p 38, March 2, 1962) and one that lowers noise by eliminating circulators (p 58, March 16, 1962).

COMMENT

Ancient History

I have noticed in several issues of ELECTRONICS that you have published a drawing of an old carbon filament light bulb, which has the same base as our present-day lamps, the screw base.

Enclosed is a picture of the first base used on the carbon lamps, with its socket. The lamp base is porcelain. A later model had a brass base with the same screw center and contact ring.

Later, the base was changed to the same as our modern bases, and adapters were sold to convert to the new type. These were screwed onto the old sockets to accept the new bases.

Thought you might be interested. Many people I have showed these to have never seen or heard of them.

C. E. HOOVER

Ames, Iowa

The lamp engraving is part of an advertisement for this magazine, and appeared most recently on page 67 of the July 27 issue. The lamp, as well as the electric chime (see p 174, Aug. 10), are both taken from a fascinating two-volume book, "Experimental Science," by George M. Hopkins, published by Munn & Co., New York, 1906. The edition we have, the 25th, was brought up to date from previous editions by adding "a full explanation of the Polyphase Generator, Induction Motors, and Rotary Transformers," and also describes "Edison's New Storage Battery."

The vacuum tube is not included in this book's index, and is mentioned only briefly in one paragraph, along with an engraving of "Figures Formed by the Electric Discharge in Vacuum Tubes." showing strings of arrow-head and elliptical shapes.

Capacitor Standards

Reference is made to Mr. William Clink's letter of August 3 (p 4) commenting on mine of June 15 (p 4).

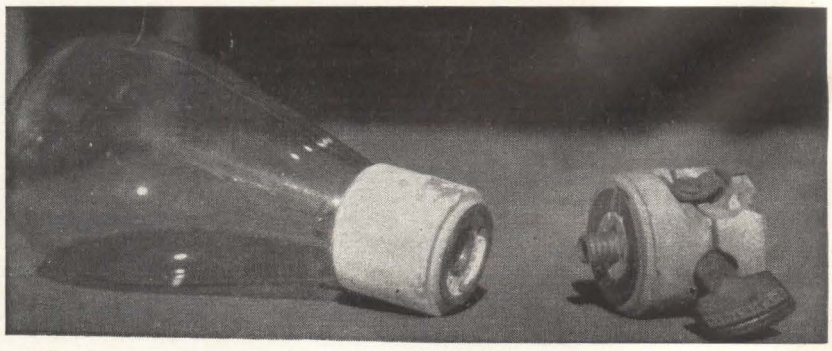
I do not maintain that 0.004 mfd is an officially standard value, but it certainly is a standard practice. Mr. Clink has only to look on page 77 of the 1962 Allied catalog 201A to find three cases where the 0.004 value replaces the "standard" 0.0039 size, and three instances where 0.04 is used instead of 0.039. This, of course, does not reflect on the Allied Radio Corporation or the manufacturer, as they must stock their inventories according to the practice of the field rather than its standard.

As to the acceptance of the pf designation for values below 1 mfd, why must 0.39 mfds be shown as 390,000? I don't think 390K would be ambiguous, especially since the K symbol is already widely used in resistor designation.

In conclusion, I suggest that one way to bring the practice in line with the standards is for design engineers to use only capacitor values whose sizes are also available in the corresponding resistor group; that is, for ±10% capacitor tolerance, see ±10% resistor table, etc. As the demand for the odd values slackens, I think capacitor manufacturers and distributors will be glad to abandon them in favor of fewer stock numbers with larger quantities of each.

A. HEMEL

The Hallicrafters Company
Chicago, Illinois



New Bourns Subminiature Relay— Its Reliability Is as High as Its Size Is Small

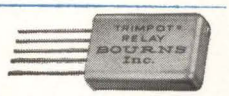
NUMBER 24—NEW PRODUCT SERIES

You can see that it's little, and you can bet that it's reliable. Only .2" x .4" x .6", but a steady performer even at 40 G, 55-2000 cps, this subminiature SPDT relay is designed to meet all environmental requirements of MIL-R-5757D. Its features include single-coil design, rotary balanced armature, hermetically sealed case and self-cleaning long-life contacts. Efficient coil design and packaging improve sensitivity to just 100 mw maximum.

By subjecting every unit to a 5000-operation run-in, Bourns precludes the possibility of relay "infant mortality." To further ensure consistent quality, Bourns conducts 100% final inspection for all important relay characteristics including mass spectrometer leak testing. The last and most punishing test of quality is the trip taken by monthly samples through the Bourns Reliability Assurance Program. This is one of the most extensive series of electrical and environmental tests in the electronics industry, and has long been the reliability double-check for the famous Trimpot® potentiometer. With Bourns relays, as with Bourns potentiometers, every possible step is taken to see that the quality you specify is the quality you get.

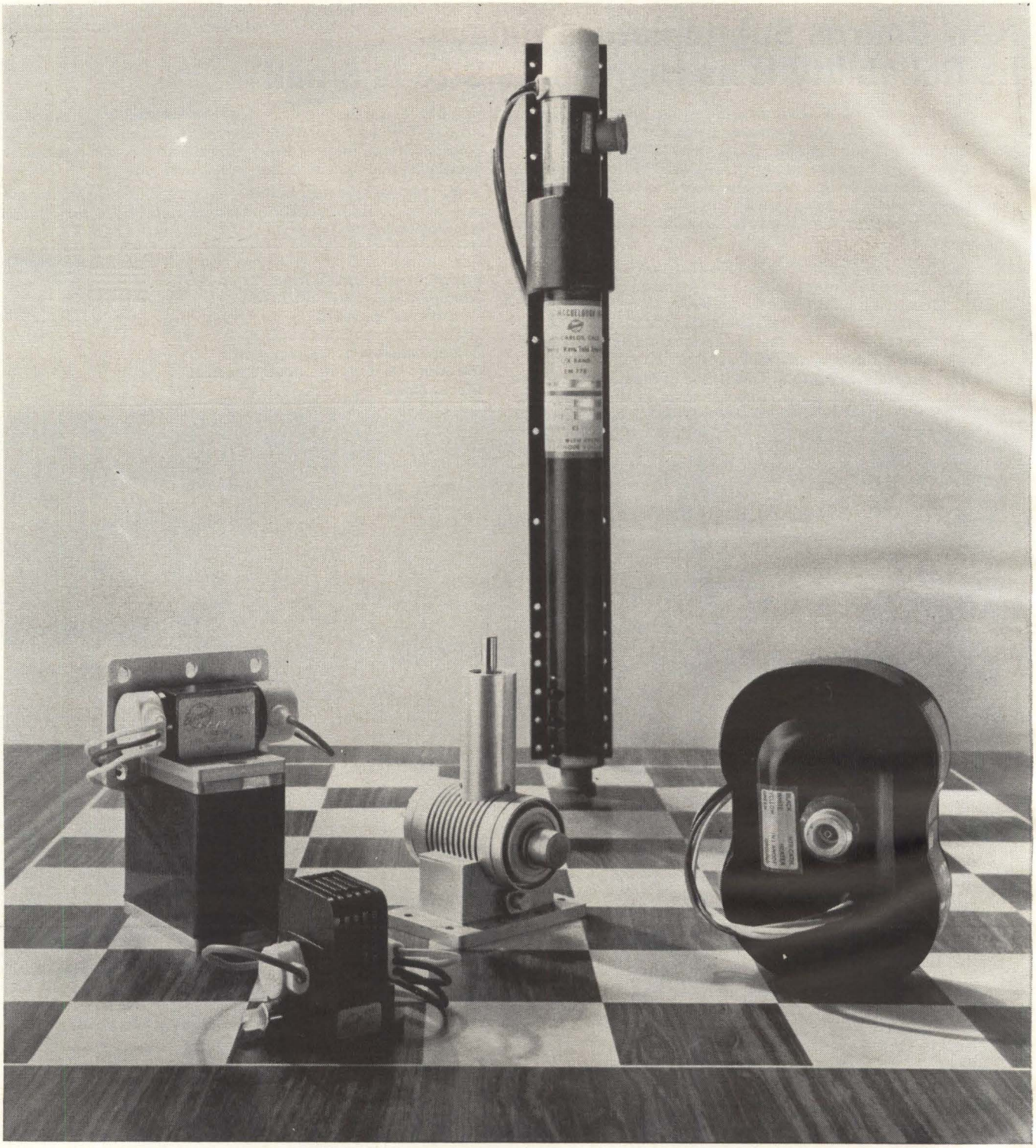
Units are available now from the factory, and will soon be available through Bourns distributors as well. Write for complete technical data.

Size: .2" x .4" x .6"
Maximum operating temperature: 125°C
Contacts: SPDT; Rating: 1.0 amp resistive, 26.5 VDC
Coil resistances: 50Ω to 2000Ω
Pick-up sensitivity: 100 milliwatts
Vibration: 40 G standard, 60 G special
Shock: 150 G



ACTUAL SIZE

Manufacturer: Trimpot® potentiometers; transducers for position, pressure, acceleration. Plants: Riverside, California; Ames, Iowa; and Toronto, Canada



Your move is to Eimac for winning microwave tubes.

Advanced microwave tubes? Eimac has them. And not a losing number anywhere. Whole families of new traveling wave tubes, voltage-tunable magnetrons, reflex klystrons and iso-klystrons all share outstanding characteristics. The hard-to-make types combine reliability and superior electrical performance under the most severe environmental conditions. With refreshingly quick reaction time to your special design requirements, Eimac is able to meet tomorrow's tube needs today. Another reason to keep your eye on Eimac for advanced microwave tubes, high power klystrons, power grid tubes, accessories. Eitel-McCullough, Inc., San Carlos, Calif. Subsidiaries: Eitel-McCullough, S. A., Geneva, Switzerland, National Electronics, Geneva, Ill.

Eimac can supply microwave tube types on fast delivery schedules: (front row) reflex klystron; (second row) iso-klystron — factory matched reflex klystron and isolator, reflex klystron, VTM; (back row) Traveling Wave Tube — of military ruggedness.

KEEP YOUR EYE ON Eimac®

ELECTRONICS NEWSLETTER

Army Going into Production on Micromodules

CHIEF SIGNAL OFFICER said last week that the micromodule program begun in 1958 is a success and that it is going into production of micromodule equipment and systems. The Army anticipates spending $8 million on the program in fiscal 1963, double 1962, and production will be stepped up to 250,000 units a year by next March.

Production of 1 million micromodules a year is expected by June, 1964, and the rate will reach 3 million to 5 million in 1965. Micromodules are composed of small wafers carrying components (see p 62, May 15, 1959, and p 51, May 22, 1959). Production facilities have been set up by RCA, prime contractor, P. R. Mallory & Co., and Paktron division of Illinois Tool Works. Some 61 other firms supply elements.

Among the Army's 1962 micromodule contracts are orders for 350 portable transceivers and a mobile computer employing some 10,000 micromodules, from RCA, and 400 i-f amplifiers, from Mallory. Chosen for R&D in 1964 are an airborne h-f, single-sideband radio, a hand-held radar, gun-flash detection and ranging set, an electronic typewriter and a production version of a small field computer that is now being built in prototype by RCA.

Two Big Antennas Near Completion After Delays

BOSTON—Advanced Research Projects Agency's ionospheric observatory at Arecibo, Puerto Rico, originally scheduled for operation in late 1961, is now due to be completed next spring. It is a 1,000-foot reflector made of wire mesh placed in a natural bowl.

The line-feed mechanism, to be suspended 435 feet above the reflector, has just been shipped to Arecibo. It was built by Technical Research Group (for details, see p 46, July 7, and p 43, this issue).

In other antenna news, a 150-foot steerable dish will be hoisted next week to its tower at Air Force Cambridge Research Labs' radio astronomy facility at Sagamore Hill, Hamilton, Mass.

This project, delayed many months by lack of funds, and its twin at Stanford take on added significance since the Navy cancelled the 600-foot telescope at Sugar Grove (p 22, Aug. 3). The two antennas are now the nation's largest-aperture steerable antennas. However, a 300-foot antenna is under construction at Green Bank, Va., for use by the National Science Foundation.

Quick Photos of Radar Help Ship's Navigators

P&O-ORIENT liner *Canberra*, which made its first cruise last month, uses a radar photo projector to simplify navigation plotting. The equipment automatically makes successive films of a 3-inch radar screen, then projects a 2-foot diameter image onto plotting paper. Time lapse between radar scanning and display is adjustable between 3.5 seconds and 1 minute.

P&O says the system simplifies navigation. The display can be black-on-white or white-on-black, is bright enough for viewing in normal lighting, can be used to amplify weak signals or show movement of targets by having the camera photograph successive radar sweeps on one film, and provides a permanent record of the ship's movements. P&O said the equipment was made by British Kelvin Hughes.

Central Monitors Will Check Polaris Naviation

NAVIGATION systems in 10 new *Lafayette* class Polaris submarines, scheduled to join the fleet by the end of 1964, will be checked out by consoles to be produced by Sperry Gyroscope. Sperry said the consoles will enable monitoring of the navigation systems at a central point and cut checkout time by 80 percent. The new submarines will carry the 2,500-mile version of Polaris, requiring greater precision in navigation. Sperry will build 14 consoles under a $3.1-million Navy contract. The other four will be used on shore for training, test and study.

Ring-Shaped Motor Can Double as Powered Gimbal

BALTIMORE—Martin's Electronic Systems and Products division has developed a toroidal-shaped motor that is, in effect, an electrical actuator. It has only two moving parts, including integral gearing, and a response time of 2 msec from stop to full speed. It can be built in sizes to 10 horsepower and can also be used in applications formerly restricted to small servo motors, Martin said.

Anticipated applications include as a torquer for inertial platforms

Free-Loader Swipes Power from Line's Field

DENVER—Bureau of Reclamation engineers have invented a device, nicknamed Free-Loader, that can by capacitive coupling collect electrical energy in the field surrounding high-voltage power transmission lines. The device is still experimental.

It is reported to offer a potentially inexpensive source of power for remote installations such as microwave relay stations, other communications equipment and aircraft warning lights.

The device has virtually no effect on transmission-line performance. It will collect only 1.9 Kw from lines carrying 150 Mw. Bureau engineers said it would be about $5,000 cheaper than conventional methods of tapping 230-Kv lines with even more savings when tapping the new 345-Kv lines

or gyro gimbals. Because the housing is ring-shaped, it can also be used directly as the gimbal ring of a radar antenna, gyro, ir equipment, or rocket engine to simplify system design, Martin said. A pulse ratio controller provides a 1,000:1 speed ratio with linearity of 0.01 percent without feedback, and a variable reluctance circuit permits starting and reversing current to vary between 20:1 and 1:10, it was reported.

Telstar Synchronizes Clocks in U. S., Britain

DEFENSE DEPARTMENT'S master time clocks in the U. S. and England are being synchronized with Telstar. The first demonstration was made last Saturday. DOD said that the satellite provides greater accuracy —about 10 μsec—than can be obtained using conventional radio.

In another demonstration last week, the satellite was used to relay a transatlantic telephone call from TWA jet, flying over New York, to London. The route used was AT&T's Skyphone service (p 30, May 25), the Andover, Me., ground station, Telstar and the Goonhilly Downs ground station in England.

Mariner II Deep-space Experiments Turned On

HIGH GAIN antenna of Mariner II has been pointed toward the earth, the first step of midcourse correction maneuvers (p8, August 31). However, Jet Propulsion Laboratory scientists were not sure at press time Tuesday morning whether the spacecraft had locked on to the earth or the moon. This information is vital in determining what signals to send to Mariner II to change its Venus miss distance from 233,000 miles to 10,000 miles.

Signals sent from NASA's Johannesburg, South Africa, ground station have switched on the four deep-space experiments aboard the ship. The experiments include instruments to measure changes in interplanetary magnetic fields, intensity and distribution of charged particles, density and distribution of cosmic dust, and intensity and velocity of low-energy protons from the sun.

Ocean-Bottom Seismographs To Check on Bomb Tests

TEXAS INSTRUMENTS will build five more ocean-bottom seismographs and conduct a worldwide data collection program under a $496,529 extension of its Project Vela-Uniform (detection of underground nuclear weapons tests) contract for Advanced Research Projects Agency.

The new seismographs will be able to operate at a depth of 20,000 feet and withstand pressures of 10,000 psi—twice the capabilities of two earlier units (p 33, April 27). The seismographs digitally record data from four sensors, for later recovery and analysis.

Monitor for Snap System To Use 1,000-F Detectors

ATOMIC POWER EQUIPMENT department of General Electric is developing a monitoring and telemetering system for AEC's 500-watt Snap 10A, the first nuclear reactor power system for space. The monitor will include neutron and gamma detectors designed to operate at temperatures up to 1,000 F. If Atomics Internation, AEC's prime contractor, finds a prototype acceptable, the monitor will be tried out in space as part of a Snap flight test.

Eighth Cosmos Satellite Is Launched by Soviets

VIENNA—The eighth in the series of Cosmos satellites was launched by the USSR August 18. Tass, Soviet news agency, reported in the *Rabochaya Gazeta* that electronic instrumentation aboard the satellite included a multichannel radio telemetering system, radio instruments for measurement of the trajectory and a beacon transmitter operating on 20.00504 Mc and 90.02268 Mc. An on-ground coordinating computing center is receiving and processing information telemetered by the transmitter.

In Brief . . .

MASER OPTICS, Inc., of Boston, has announced a $995 laser. Timing of bursts depends on charging power buildup—up to 45 seconds for 400 joules. Nominal output is 0.5 joule.

TOSHIBA reports it has developed a ruby laser, also low-cost. The company said it also used the ruby in a three-level uhf maser and obtained amplification of 25 db.

GRUMMAN is giving a model of the Orbiting Astronomical Observatory a 1,000-hour test in a chamber simulating an altitude of 300 miles.

J. C. PENNEY is using a data-processing system based on an NCR 315 computer to coordinate replenishment of 20 million stock items in its 1,700 stores, expects to cut records-keeping cost by 70 percent.

SILICON TRANSISTOR CORP. has purchased all the stock of another New York power transistor maker, Secoa Electronics.

PURDUE and Indiana Universities are cooperatively presenting a new course in radio astronomy, using closed-circuit tv to link classrooms 100 miles apart.

AIR DEFENSE COMMAND'S bomb alarm system developed by Western Union is undergoing operational tests. ADC has activated a centralized troubleshooting center at Ent AFB, Colo.

VOICE OF AMERICA authorizations for radio facilities acquisition and construction totaled $96 million through June 30.

AVCO has received a $7.6-million contract from Army for AN/VRC-12 communications systems parts.

AIR FORCE has ordered $1.1 million in single-sideband modification kits for the GRC-26D radio sets, from Manson Labs.

COLLINS RADIO reports $1 million in orders for navigational equipment to be used on Boeing's new 727 jet liners.

NEW 2N2511

SOLVES LOW LEVEL AMPLIFIER PROBLEMS

(Min h_{FE}, 80 @ I_C = 1μa. Min h_{FE}, 40 @ I_C = 10μa & T_C = −55°C)

Other Amelco Silicon Planar Transistors:

Amelco also offers these transistors in production quantities:

2N709	2N929
2N760	2N930
2N760A	2N1613
2N2049	2N1711
2N2453	2N1893
2N998	2N2060

The 2N2511 is one of three new Amelco NPN silicon, planar transistors designed to provide useful current gain down to the microampere level in the temperature range of −55° C to +125° C. Other transistors in the TO-18 packaged, low noise, high gain series are the 2N2509 and 2N2510.

For differential amplifier applications, the 2N2453 is now available. This six terminal device contains two isolated very high gain NPN silicon planar transistors in a hermetically sealed TO-5 type case. Transistors are matched for current gain and base on voltage over the same temperature range (−55° C to +125° C). Typical noise figure for each transistor is 3 db with a current gain of 150 at a collector current of 10μa.

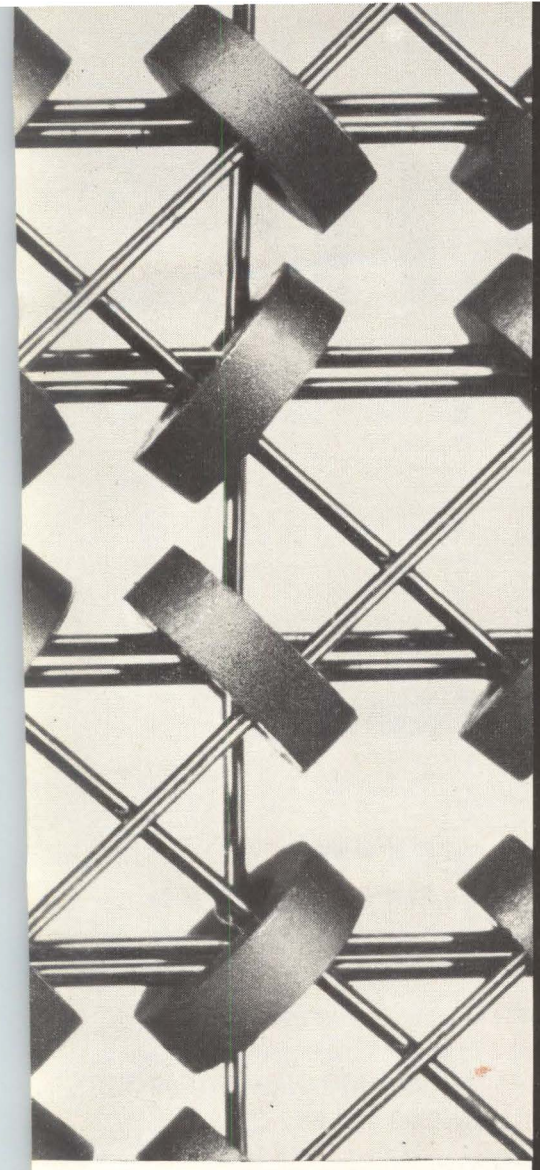
		2N2509		2N2510		2N2511		2N2453	
Parameter	Test Conditions	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
h_{FE}	I_C = 1 μA, V_{CE} = 5V					80			
h_{FE}	I_C = 10 μA, V_{CE} = 5V	25		75		120		80	
h_{FE}	I_C = 10 μA, V_{CE} = 5V, T = −55° C			25		40		40	
V_{CEO} (sust)	I_C = 10 mA, I_B = 0	80V		65V		50V		30V	
I_{CBO}	I_E = 0, V_{CB} = 0.8 BV_{CB}		2 mμA		2 mμA		2 mμA		5 mμA
C_{ob}	I_E = 0, V_{CB} = 5V		6.0 pf		6.0 pf		6.0 pf		8.0 pf
Noise Figure	I_C = 10 μA, V_{CE} = 5V, Rg = 10 k, f = 1 kc		4.0 db		4.0 db		4.0 db		7.0 db
h_{FE1}/h_{FE2}	I_C = 1 mA, V_{CE} = 5V, T = −55° C to +125° C							0.85	1.0
$V_{BE1} - V_{BE2}$	I_C = 10 μA, V_{CE} = 5V								0.003V

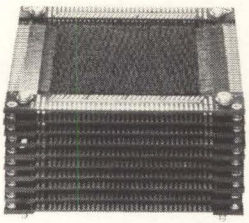
For technical and sales information, please write to Amelco, Inc., Electron Devices Division, 341 Moffett Blvd., Mountain View, California, (408) 739-0851, TWX: 415-969-9112

AMELCO, INC.

MOUNTAIN VIEW, CALIFORNIA

CIRCLE 9 ON READER SERVICE CARD





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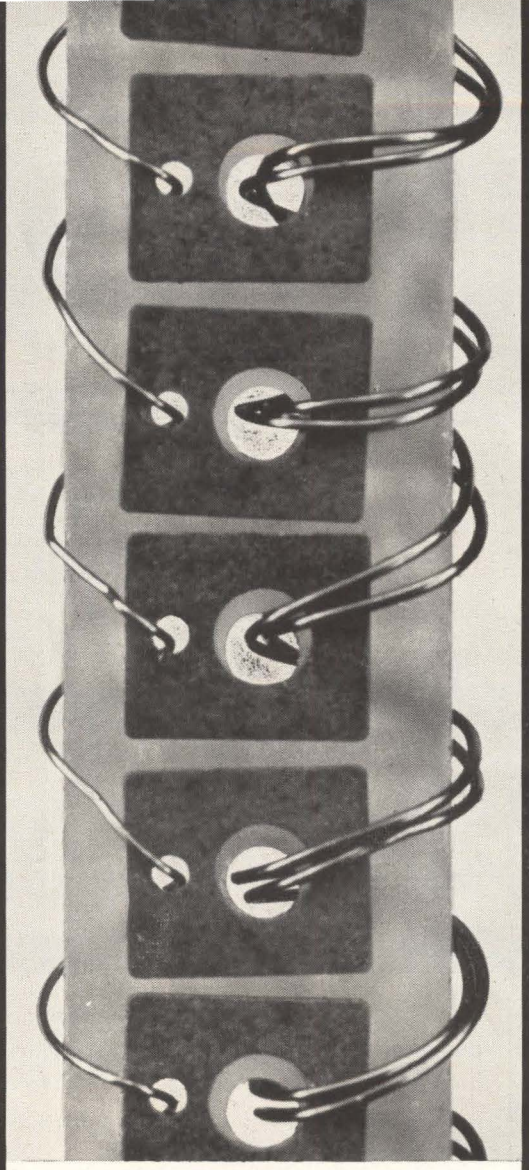

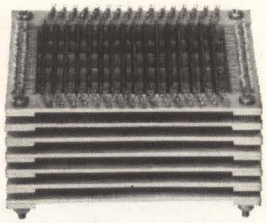

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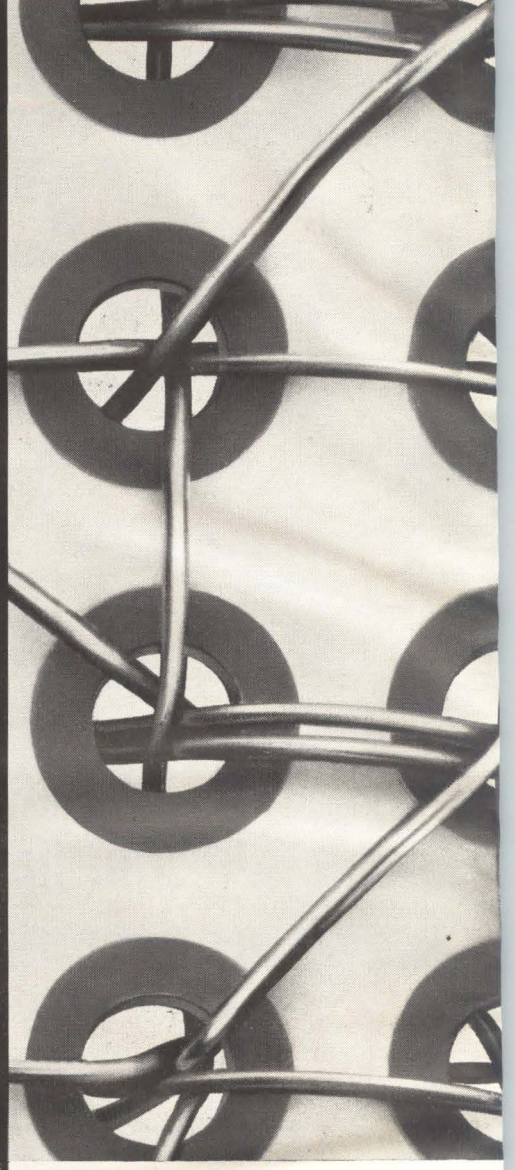
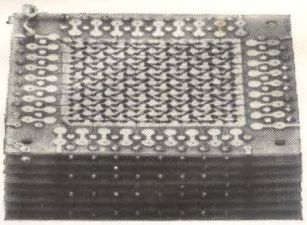




3.

PRODUCTS PHOTOMACROGRAPHED APPROXIMATELY 30 TIMES ACTUAL SIZE

close-up of maximum reliability

Lockheed Electronics' in-house capability produces ferrite cores, multi-aperture devices, printed circuit boards, memory planes and stacks, plug-in circuit modules, and fabricated metal casings. Every step from design through test is under one management to assure maximum quality control and minimum cost.

The enlarged photos above show three of the many types of memory plane assemblies produced by Lockheed Electronics.

1. Standard commercial open frame ferrite core memory plane utilizing either coincident current or linear select wiring.

2. Lockheed designed memory array using multi-aperture cores to provide non-destructive readout. This unique method of mounting and wiring provides the necessary rigidity for severe environmental applications.

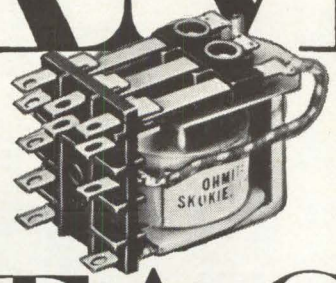
3. Memory plane with conventional ferrite cores using imbedded assembly and wiring techniques to meet exceptionally high environmental shock and vibration requirements of military specifications.

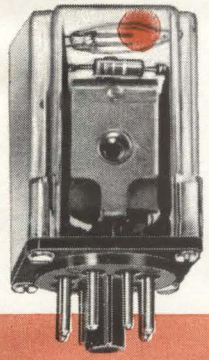
For further information on Lockheed cores, memory planes and stacks, or printed circuitry to fill your particular requirements, write: Lockheed Electronics Company, 6201 East Randolph Street, Los Angeles 22, California.

LOCKHEED ELECTRONICS COMPANY

A DIVISION OF THE LOCKHEED AIRCRAFT CORPORATION

10-AMP CONTACTS





NEW INDICATOR LIGHT, TOO

now available in Ohmite GPR relays

■ Model GPR relays represent a fresh design approach in the field of good, economy-type relays. Construction is simplicity itself, and with the elimination of complexity has come compactness, versatility, and unusual ruggedness.

CONTACTS: 5 and 10 amps at 115VAC or 32VDC (non-inductive). Gold flashed, fine silver (5-amp); silver cadmium oxide (10-amp).

COILS: Up to 230VAC, 60 cycles, or 115VDC; DC, 1.4 watts; AC, 2 volt-amperes (AC latching type, 3.7 volt-amperes).

CONTACT COMBINATIONS: SPDT, DPDT, and 3PDT for single relays; 4PDT and 6PDT on latching relays.

ENCLOSURES: Clear plastic.

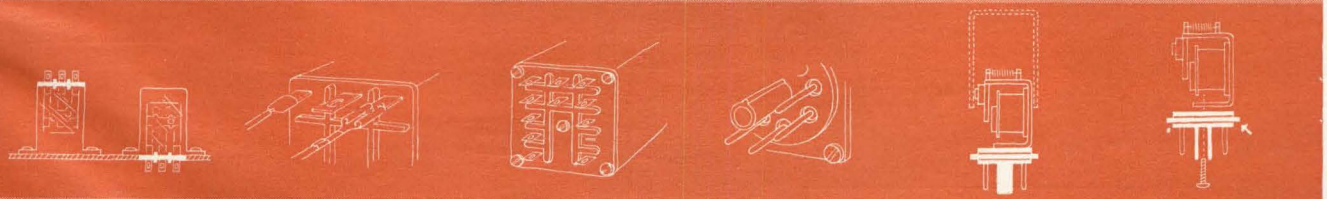
TERMINALS: Barrier type or octal plug.

LATCHING RELAYS: Enclosed with plug-in mounting; or unenclosed.

PLATE CIRCUIT RELAYS: Supplied in 2500, 5000 and 10,000-ohm coil resistances.

Write For New Relay Catalog 700

POPULAR "COST-SHAVING" FEATURES OF MODEL GPR RELAYS



CHOICE of below-chassis or above-chassis connecting in plastic enclosures.

MULTI-USE terminals allow soldering, insertion in printed circuit board, and use of AMP Style 110 push-on terminals.

ALL TERMINALS on *one* panel . . . permits insertion in printed circuit board.

OCTAL PLUG relays up to DPDT have recessed pin bases . . . meet UL spacing requirements to 150 V.

ALL ENCLOSED relays mount solidly on base . . . *not* on covers.

INTEGRAL plug-in base up to DPDT avoids wiring between contact terminals and pins.

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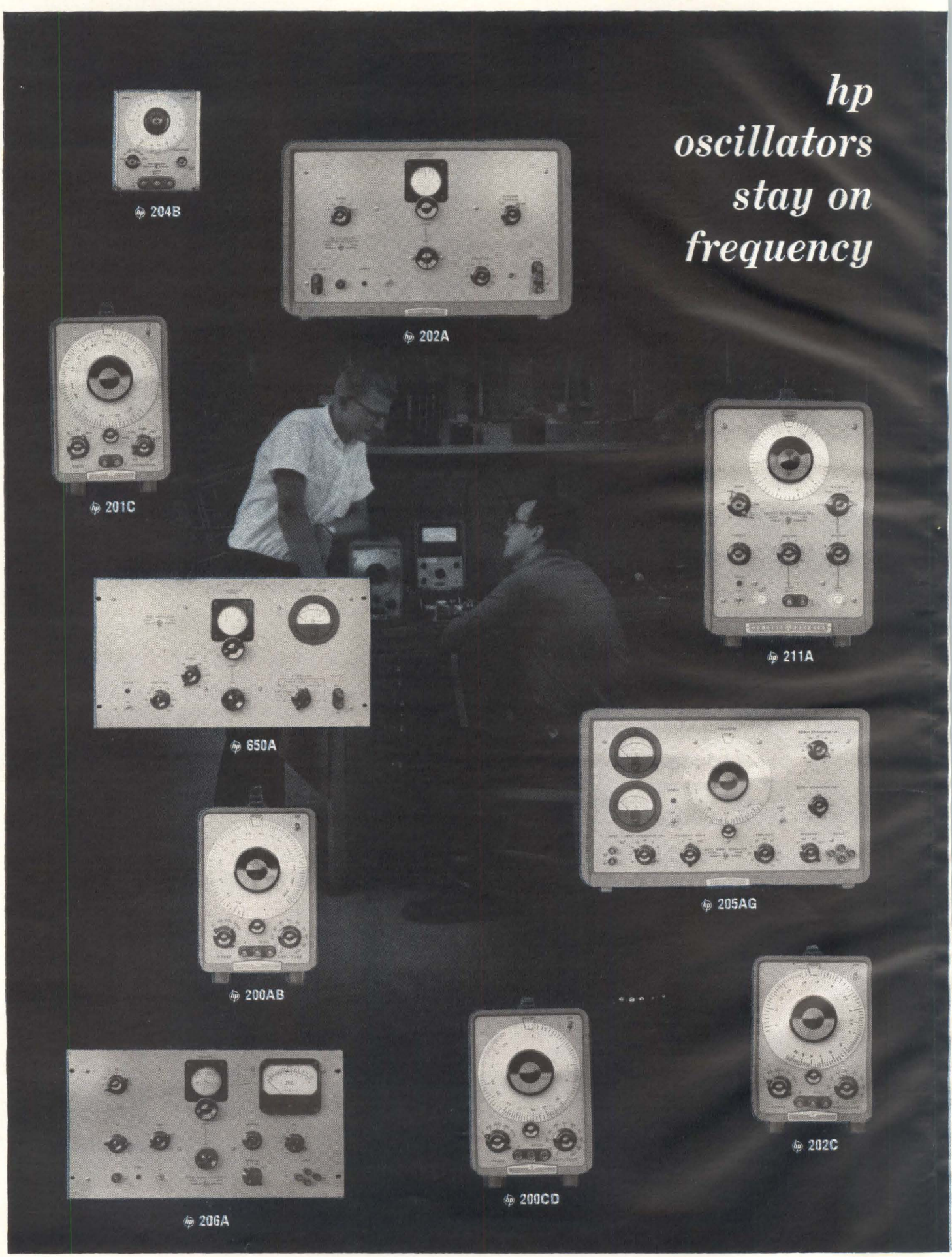
hp oscillators stay on frequency
hp 204B
hp 202A
hp 201C
hp 211A
hp 650A
hp 205AG
hp 200AB
hp 202C
hp 200CD
hp 206A

Accurate Test Signals 0.008 cps to 10MC

The resistance-capacity oscillator, pioneered and developed by Hewlett-Packard, provides simple operation with high stability and wide frequency range. Just select the signal you want on easy-to-read controls, and you get a dependable output without tedious resetting or adjustment. These oscillators give you low distortion, excellent frequency response and extreme amplitude stability. These instruments can make your test work easier, faster, successful, economical.

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Model	Frequency Range	Description, Features	Output	Price
200AB Audio Oscillator	20 cps to 40 KC, 4 ranges	Ideal for amplifier testing, modulating signal generators, testing transmitter modulator response.	1 watt (24.5 v/600 ohms)	$165.00*
200CD Wide Range Oscillator	5 cps to 600 KC, 5 ranges	Subsonic to radio frequencies, useful for testing servo and vibration systems, medical and geophysical equipment, audio amplifiers, video frequency circuits. Easy reading.	160 mw (10 v/600 ohms)	$195.00*
201C Audio Oscillator	20 cps to 20 KC, 3 ranges	High power, designed for testing amplifiers, speakers, crossover nets. ±1 db frequency response, entire range.	3 watts (42.5 v/600 ohms)	$250.00*
202A Function Generator	0.008 to 1,200 cps, 5 ranges	Source of continually variable, transient-free sine, square, triangular waves for electrically simulating mechanical, physical, medical phenomena. ±1% stability.	28 mw (30 v/4,000 ohms)	$550.00**
211A Square Wave Generator	1 cps to 1 MC, 1 range	Useful for audio, video testing. 0.02 μsec rise time. Full amplitude variation available on each of two outputs.	7 v p-p/75 ohms 55 v p-p/600 ohms	$350.00
202C Low Frequency Oscillator	1 cps to 100 KC, 5 ranges	Ideal for subsonic, audio, ultrasonic applications such as vibration, electro-cardiograph, electro-encephalograph. Low distortion and hum. Recovery time less than 0.5% above 5 cps.	160 mw (10 v/600 ohms)	$300.00*
204B Portable Oscillator	5 cps to 500 KC, 5 ranges	Solid state, portable, battery or optional ac operation. Output fully floating, will drive balanced and unbalanced loads referenced above or below ground. Highly stable. Distortion less than 1%.	10 mw (2.5 v/600 ohms)	$275.00***
205AG Audio Signal Generator	25 cps to 20 KC, 3 ranges	A single instrument for making high power audio tests, gain and frequency response measurements. Two VMs measure input and output of device under test.	5 watts adjustable/50, 200, 600, 5,000 ohms	$600.00**
206A Low Distortion Audio Signal Generator	20 cps to 20 KC, 3 ranges	Distortion less than 0.1%. Ideal for testing FM broadcasting units, high fidelity audio systems. Metered output, variable in 0.1 db steps.	+15 dbm/50, 150, 200 ohms	$900.00**
650A Test Oscillator	10 cps to 10 MC, 6 ranges	Ideal for measurements in audio, supersonic, video, rf ranges. Metered output flat within 1 db. Distortion less than 1%, 20 cps - 100 KC; less than 2%, 100 KC-1 MC; approx. 5% at 10 MC.	15 mw (3 v/600 ohms)	$550.00**

*Cabinet models; rack-mount models $5.00 additional. **Cabinet models; rack-mount models $15.00 less.
***AC operation optional, $25.00 extra. **Data subject to change without notice. Prices F.O.B. factory.**

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WASHINGTON OUTLOOK

IS THE SENATE SETTING UP COMPETITION FOR AT&T?

AN INCONSPICUOUS BILL perking along in the Senate could give Western Union Telegraph Co. a shove toward becoming a stronger international competitor of AT&T. The bill would let Western Union continue to operate internationally, by ending a long-standing order that Western Union sell its Atlantic cables. The firm has never found a buyer, and FCC has annually waived the order.

In little-noticed testimony in April to Sen. Estes Kefauver's Senate Antitrust Committee, a Western Union Executive, S. M. Barr, proposed that all the other international carriers merge, and then have this company link with Western Union's domestic facilities, forming a major company to compete with AT&T.

Last month, in Senate debate on the communications satellite bill, Kefauver unsuccessfully offered an amendment to end the Western Union divestiture order. But Sen. Warren G. Magnuson (D.-Wash.) introduced the measure, pushed it through Commerce Committee hearings and subcommittee approval. Barr's merger plans weren't discussed on the Senate floor, but his ideas seem to lie behind the sudden interest in letting Western Union pursue international business.

PROCUREMENT REGULATIONS ARE AMENDED

CONGRESS HAS PASSED the so-called Hebert bill amending the Armed Services Procurement Act. It calls for (1) more military purchasing through formal advertised bidding, (2) more detailed written justification when contracts are negotiated, (3) more competition in negotiated procurement, and 4) certification of cost estimates by firms with cost-plus contracts to bar inflated prices.

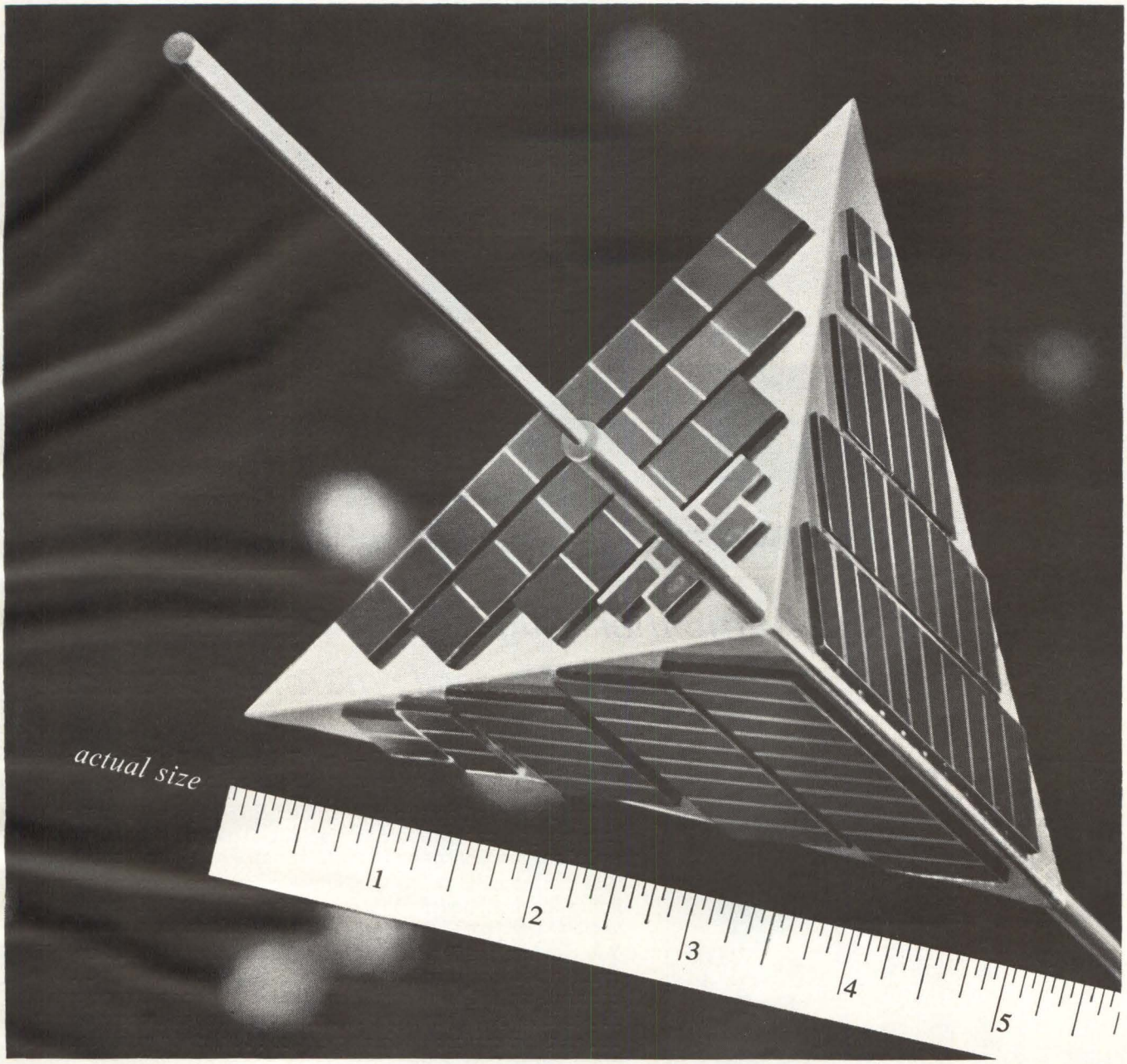
The final bill is milder than a version passed earlier by the House. A provision authorizing the General Accounting Office to review and invalidate negotiated contracts was dropped. The bill is not expected to have much impact on contracting procedures since its basic objectives are already covered by Defense Department regulations.

LABOR-SURPLUS AREAS GETTING MORE DEFENSE CONTRACTS

PENTAGON REPORTS a pick-up in the program to channel military contracts to companies in areas with high chronic unemployment. Total prime contracts awarded under a partial set-aside procedure during July, 1961, to March, 1962, were nearly double the dollar value for the entire fiscal 1961 and triple that in fiscal 1960.

In all, some $6.1 billion of procurement went to firms in labor areas in fiscal 1961, with $5.3 billion of that placed in the last six months of the year. In the first nine months of fiscal 1962, despite a decline in the number of areas designated as labor surplus communities, $5.8 billion in contracts were awarded to firms there.

But Sen. Hubert H. Humphrey (D.-Minn.), who presided over a recent Senate Small Business Committee hearing on the impact of defense spending on distressed areas, feels the Pentagon is not doing enough. He complains that Pentagon policies on contract awards and construction of new defense facilities have allowed "rich areas to get richer and poor areas to get poorer." He cites increasing concentration of new contracts and facilities in California and Florida and the continuing decline of defense business in the Midwest.



The world's smallest satellite has been developed by Space Technology Laboratories. Its shape will be different from all other satellites before it. STL engineers and scientists have used a tetrahedral configuration to bring about some remarkable characteristics in a space vehicle. There will be no need for batteries nor regulators in flight. The satellite will have no hot side, no cold side. It will require no attitude control devices. No matter how it tumbles in space it will always turn one side toward the sun to absorb energy, and three sides away from the sun to cool instrumentation and telemetry equipment inside. It can perform isolated experiments in conjunction with other projects. Or it can be put into orbit by a small rocket to make studies of its own, up to five or more separate experiments on each mission it makes.

STL is active on hardware projects such as this and as prime contractor for NASA's OGO and an entirely new series of classified spacecraft for Air Force – ARPA. We continue Systems Management for the Air Force's Atlas, Titan and Minuteman programs. These activities create immediate opportunities in: Space Physics, Radar Systems, Applied Mathematics, Space Communications, Antennas and Microwaves, Analog Computers, Computer Design, Digital Computers, Guidance and Navigation, Electromechanical Devices, Engineering Mechanics, Propulsion Systems, Materials Research. For So. California or Cape Canaveral opportunities, please write Dr. R. C. Potter, Dept. G, One Space Park, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

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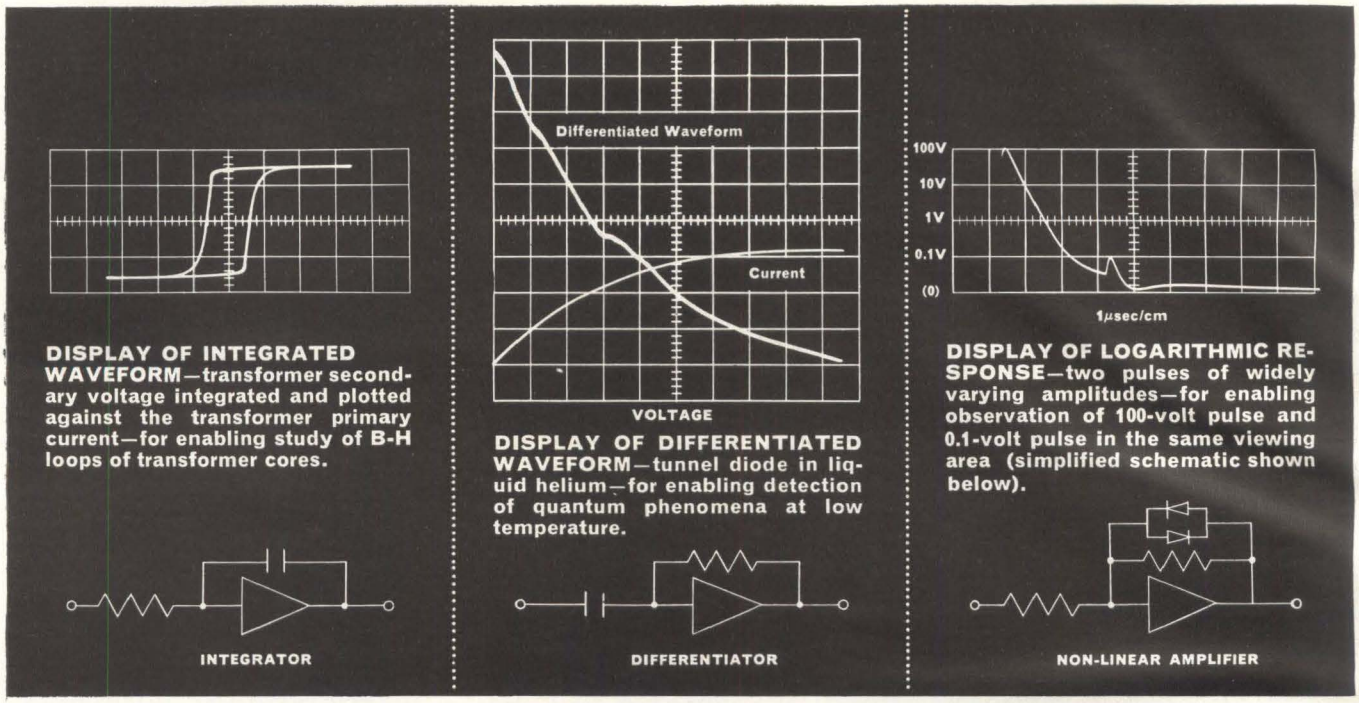
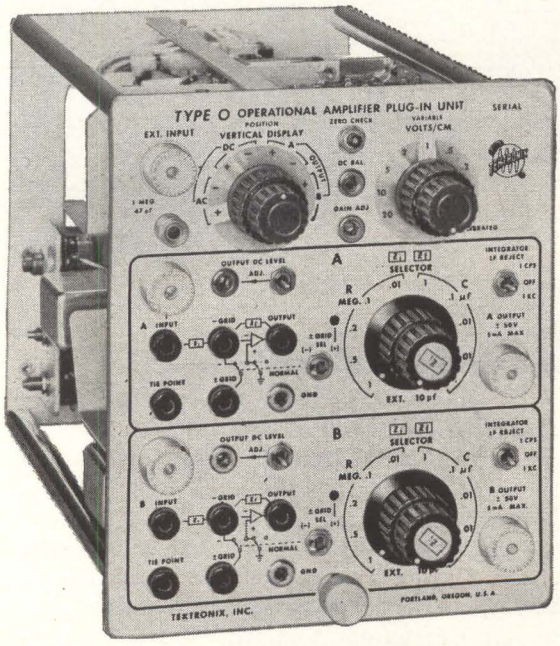


DISPLAY OF INTEGRATED WAVEFORM—transformer secondary voltage integrated and plotted against the transformer primary current—for enabling study of B-H loops of transformer cores.

DISPLAY OF DIFFERENTIATED WAVEFORM—tunnel diode in liquid helium—for enabling detection of quantum phenomena at low temperature.

DISPLAY OF LOGARITHMIC RESPONSE—two pulses of widely varying amplitudes—for enabling observation of 100-volt pulse and 0.1-volt pulse in the same viewing area (simplified schematic shown below).

New Operational Amplifier Plug-In Unit Permits Oscilloscope Measurements Under Dynamic Conditions



TYPE O UNIT U.S. Sales Price, f.o.b. Beaverton, Oregon $475

To arrange a demonstration of this highly-adaptable Operational Amplifier Unit in your Tektronix Oscilloscope, please call your Tektronix Field Engineer.

TYPE O UNIT—for Tektronix Oscilloscopes that accept letter-series plug-in units.

Using this new Operational Amplifier Unit in your Tektronix Oscilloscope, you can perform precise operations of integration, differentiation, function generation, linear and non-linear amplification.

You can accomplish many of these operations by simply manipulating the front-panel controls—for the Type O Unit features convenient *selection of precision input and feedback components.*

You can use the Type O Unit as a gated integrator . . . as a high-input-impedance amplifier . . . as a bandpass amplifier . . . as a constant-current-drive amplifier . . . as a peak-memory amplifier . . . as a function generator . . . as a capacitance-measuring device . . . as a low-current measuring device . . . and for many and varied other specialized operations—some performed *with* external circuitry and some *without.*

CHARACTERISTICS

The Type O Unit contains two complete operational amplifiers and one complete vertical preamplifier.

Each operational amplifier features 15 mc open-loop gain-bandwidth product, open-loop dc-gain of 2500, selectable input and feedback impedances, drift rejection for ac integration. The output of one operational amplifier can be applied to the input of the other for combined operations.

The vertical preamplifier can be used independently or to monitor the output of either operational amplifier. In a Tektronix Type 540-Series Oscilloscope, the passband is dc-to-25 mc, the risetime is 14 nsec, and the maximum calibrated sensitivity is 50 mv/cm.

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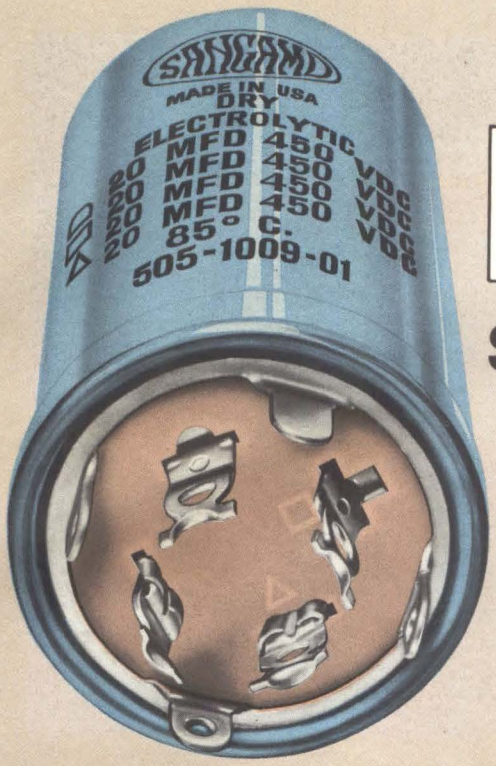
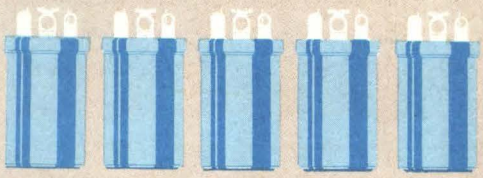


NOW



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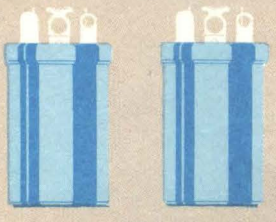
THAT SET NEW STANDARDS OF RELIABILITY!

Here's a "twist-tab" electrolytic capacitor designed specifically for the rigorous requirements of instrument manufacturers. Check this list of advantages over conventional "twist-tab" electrolytics.

- LONGER OPERATING LIFE (at 85°C)
- LONGER SHELF LIFE
- LOWER LEAKAGE
- LOWER POWER FACTOR
- LOWER ESR
- BETTER TEMPERATURE CHARACTERISTICS
- BETTER HIGH FREQUENCY CHARACTERISTICS
- BETTER END SEAL

The new blue-cased Sangamo Type 505 capacitor has everything the instrument manufacturer needs in a dry electrolytic and . . . no other capacitor can match this performance.

Write today for engineering test data . . . convincing proof that the new blue Sangamo Type 505 does establish new standards of quality and reliability.



In electronic instruments of tomorrow look for the Blue 505—symbol of quality.

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SANGAMO ELECTRIC COMPANY

SPRINGFIELD, ILLINOIS

LOW INDUCTANCE
FAST DISCHARGE

SANGAMO ENERGY DISCHARGE CAPACITORS

If you need large quantities of energy delivered rapidly, Sangamo energy discharge capacitors should be your first consideration. The capacitor shown, for example, has a capacitance rating of 2 microfarads and a remarkably low inductance rating of 0.015 microhenries. Rated for operation at 50 kilovolts, this capacitor is designed for maximum energy content per case size. The result: exceptionally high energy content (2500 joules) discharged in the order of nanoseconds . . . more rapidly than ever before possible.

In maser and laser research, magnetohydrodynamics, magnetic-forming operations, thermonuclear fusion research and many other projects, there is a growing demand for large quantities of rapidly delivered energy. Sangamo has been a pioneer in the development of energy sources for these applications and through advanced research will continue to develop energy discharge capacitors that set new standards for performance reliability.

IN STOCK FOR IMMEDIATE DELIVERY

Although designed for specific applications, certain energy discharge capacitor ratings have been found to serve a wide range of applications. These ratings, as shown below, are offered by Sangamo from stock for immediate delivery.

CAPACITANCE MF	VOLTAGE KV	SIZE INCHES
14	20	7¼ x 14 x 24⅝
60	10	7¼ x 14 x 24⅝
240	5	7¼ x 14 x 24⅝
8	20	7¼ x 14 x 15⅝
35	10	7¼ x 14 x 15⅝
140	5	7¼ x 14 x 15⅝

For more details on these and Sangamo's complete line of energy discharge capacitors, write for Bulletin TSC-208.

SANGAMO ELECTRONIC COMPONENTS

SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS

EC62-3

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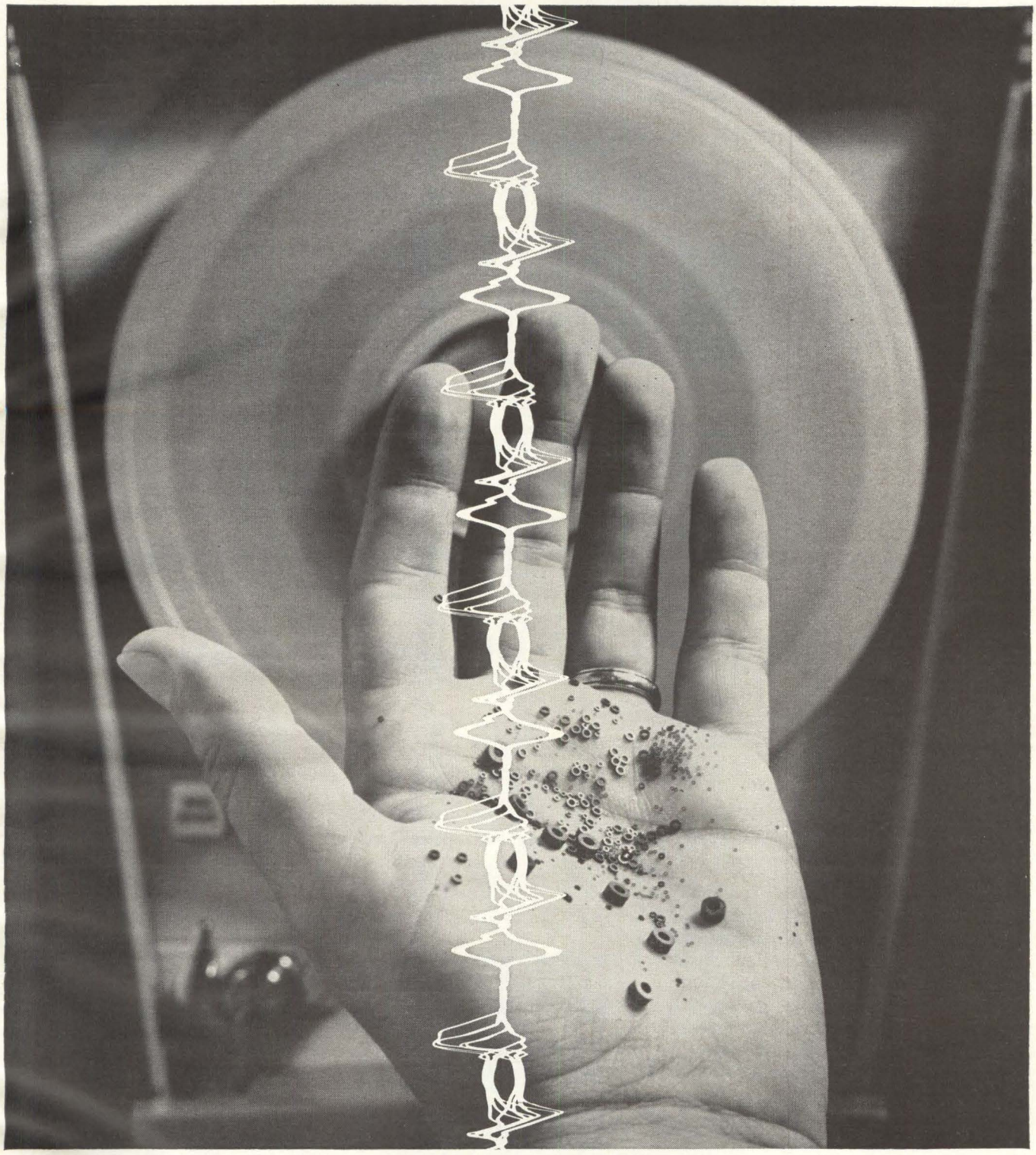


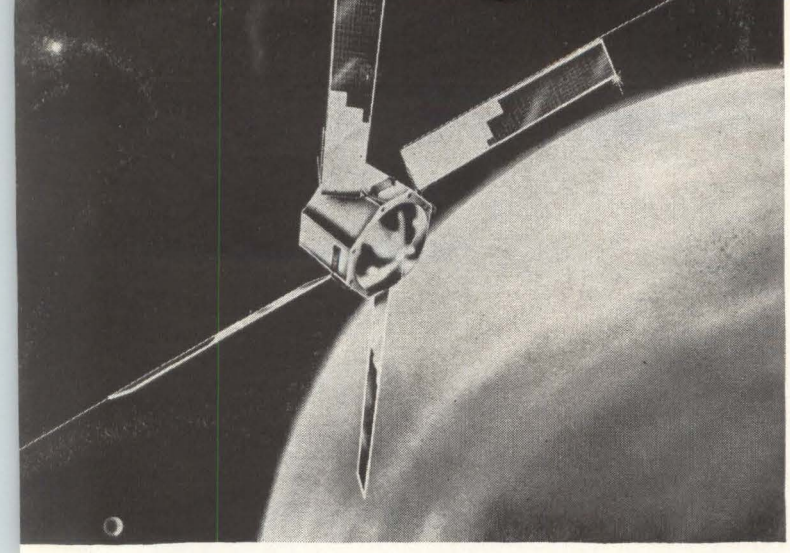
Who can hand you everything—from 30 mil cores to 60% of a computer? **AMPEX**

Want to string your own arrays? We can give you 7 sizes, 150 kinds of cores. Want arrays and stacks ready-made? Good. We can also supply every possible configuration and frame design—including word select and coincident current types. Don't want to fool around with do-it-yourself items? We can help you there, too. We've got the widest line of off-the-shelf core memories with random and sequential access operating modes. Plus the finest high and medium speed tape transports.

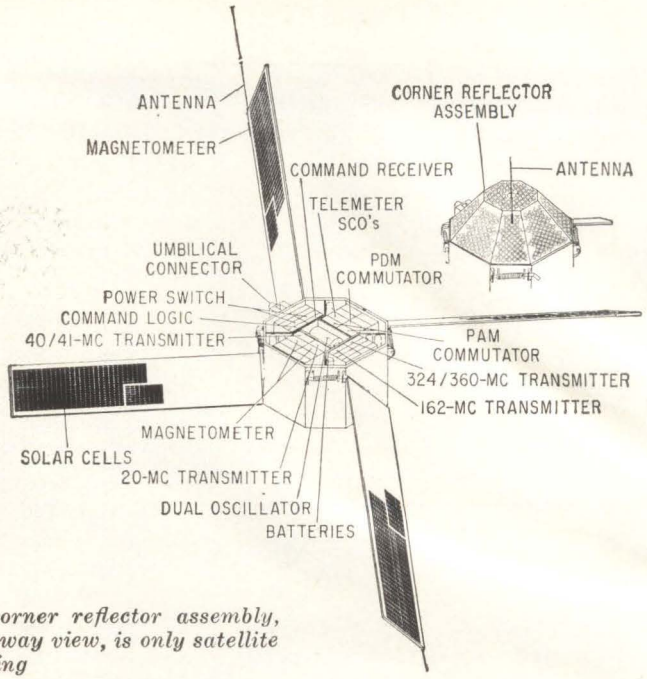
Plus computer tape. Plus the most extensive field engineering program today. In other words: when it comes to advanced, reliable computer components, Ampex has them. And the widest possible selection. Ampex Computer Products Co., Culver City, California. A division of the only company providing recorders, tape and memory devices for every application: Ampex Corporation, 934 Charter St., Redwood City, California. Sales and service engineers throughout the world. AMPEX

←CIRCLE 18 ON READER SERVICE CARD

CIRCLE 19 ON READER SERVICE CARD 19



ARTISTS CONCEPTION *of S-66 in orbit shows extended blades carrying solar cells*



LASER TRACKING *system corner reflector assembly, shown in this S-66 satellite cutaway view, is only satellite component necessary for tracking*

Ionosphere-Mapping Satellite To Try Laser-Bounce Ranging

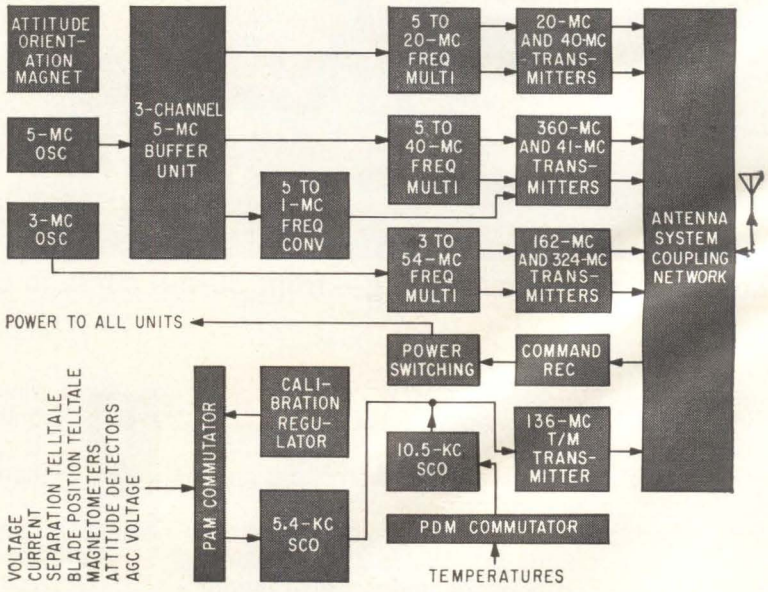
NASA is looking for answers to long-range communications problems

POLAR IONOSPHERE tracking satellite (NASA designation S-66), designed to make detailed studies of the ionosphere, will be launched from the Pacific Missile Range later this year. Fuller knowledge of the ionosphere gained through the satellite hopefully will aid in solving many long-range communications problems.

The satellite, planned as one of the Explorer series, will be launched in a polar orbit to provide total earth coverage and an opportunity for world-wide data acquisition. The satellite is one of eight projects planned as a part of a NASA ionospheric study. Two satellites, Explorer VIII and Ariel, have been launched. Three more will be launched in the future, in addition to S-66. A sounding rocket project and a probe project are also included.

A spokesman from NASA's Goddard Space Flight Center told ELECTRONICS that funding for the satellite is about $2 million.

TRACKING—The S-66 will also test a newly devised optical tracking system. A corner reflector will be carried by the satellite to reflect pulses from a ground-based laser. The laser will emit 1-μsec pulses with an energy output of about 1 watt-sec a pulse, and with beamwidth of 10^{-3} radian. Ground-based



DESIGN OF S-66 *systems will be modification of circuits proven in Transit satellites*

detectors will be precision tracking cameras and image orthicons used with telescopes. A range resolution of 30 meters (10^{-7} sec) is expected.

NASA's Minitrack network will provide daily tracking fixes to help the lasers acquire the satellite. A 136-Mc transmitter will be used as a Minitrack beacon, and for telemetering.

EXPERIMENTS—Basic objective of S-66 will be to describe the bulk behavior of the whole ionosphere. Electron distribution between the spacecraft and earth will be measured as a function of latitude, and seasonal and diurnal time. Solar radiation, responsible for producing the ionization, will be related to the behavior of the ionosphere.

Studies will also include the effects of solar flares, the geometry and number of irregularities in the ionosphere, and radio-wave propagation characteristics through the ionosphere at frequencies of 20 Mc to 360 Mc.

Four coherent transmitters, for the ionospheric measurements, will operate at 20 Mc, 40 Mc, 41 Mc and 360 Mc. They will be designed for maximum short-term amplitude and frequency stability and for minimum differential phase jitter. A crystal oscillator, operating at 5 Mc plus 250 ppm, will control the transmitters (see diagram).

OTHER SYSTEMS—Power for S-66 will be supplied by nickel-cadmium batteries, with a capacity of 2 amp-hours. Silicon solar cells of the blue-sensitive type, generating a total of 10 watts, recharge the batteries.

Attitude controls will be, for solar orientation, six solar cell devices, and for orientation with respect to the earth's magnetic field, a three-axis flux-gate magnetometer. A mechanical despin device will reduce the 200 rpm spin rate of the final stage of the Scout launch rocket down to 10 rpm.

MANAGEMENT—Goddard Space Flight Center has overall project management and will process data. A GSFC spokesman said that up to 150 international participants may aid in tracking and data collection. A final project report will be made available to all participants.

Spacecraft system design, fabrication and testing will be managed by the Applied Physics Laboratory of Johns Hopkins University. Design, begun last April, will be based extensively on Transit V-A. Langley Research Center will manage launch operations.

X-Ray Telescope to Probe Moon and Stars

SAN FRANCISCO—An x-ray telescope—a collimator that can collect and focus soft x-rays of galactic origin—was reported at the recent international symposium on x-ray optics and microanalysis at Stanford University. The device is expected to aid in x-ray astronomy and in analysis of the moon's composition by measuring the intensity of lunar-reflected radiation.

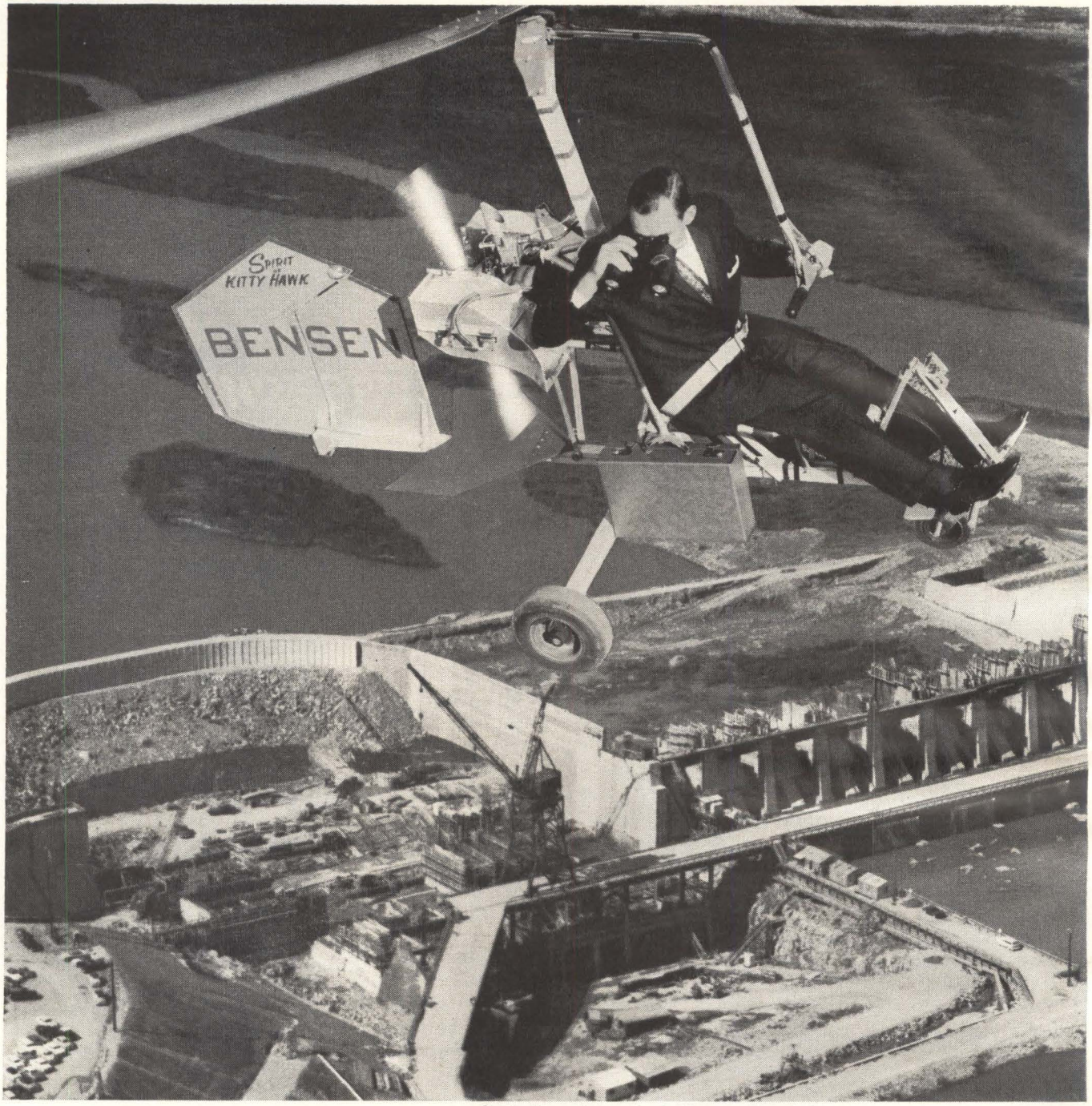
The collimator is a paraboloid cone of high-reflectivity material. It was developed by Riccardo Giacconi, of American Science and Engineering, Inc., working with Air Force Cambridge Research Lab, and Bruno Rossi, of MIT. Giacconi is also working on an image-forming version for photography.

Tests showed that the efficiency of x-ray collection was inversely proportional to the angle of incidence, so the Giacconi-Rossi collimator was designed to operate with x-rays reflecting at one or two degrees. It has a resolution of 1/10 the solar disc.

Soft x-ray analysis of the moon can tell the ratio of elements, but not specific composition. For example, it could determine the oxygen-silicon ratio, but not whether a compound was Si0 or Si_2O_4.

The first indication that x-ray astronomy in the night sky was possible, it was reported, was last June when a radiation-counter rocket probe discovered x-rays of much higher intensity than expected coming from the galactic center and around Casseopia-a. The probe was intended to detect x-ray reflections from the moon, hopefully leading to analyses, but the lunar reflections were obscured by the high-intensity sources.

White Sands scientists will try again to determine the properties and origins of soft x-rays with another Aerobee probe on Oct. 2, concentrating on the Taurus-a area, another suspected strong source.

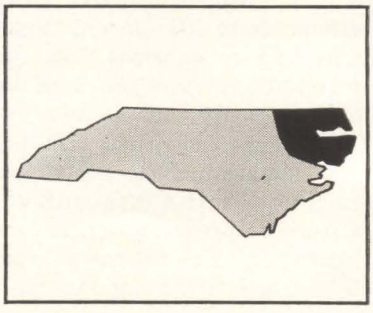


Single-Place Gyrocopter by Bensen Aircraft Corp.

Get a close-up of growing electric power in Northeastern NORTH CAROLINA

By the time you read this, a 34-mile lake will be almost ready to form behind VEPCO's new Gaston Dam. And, before your plant in Northeastern North Carolina is complete, Gaston's big turbines will be turning. They'll pour 200,000 kilowatts into VEPCO's modern, interconnected power network . . . helping to build its present capability of 2,049,000 kilowatts up to 3,019,000 by 1964.

Yes, you'll find dependable, economical electric power aplenty to work with this area's abundant, willing and trainable manpower.



North Carolina home-grows two workers for every one who retires or moves. And the state's Industrial Education Program trains them for your plant's needs. Want more facts, or site information? Write, wire or phone VEPCO in confidence, without cost or obligation.

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VIRGINIA ELECTRIC and POWER COMPANY

J. Randolph Perrow, Manager, Area Development
Electric Bldg., Richmond 9, Virginia • MIlton 9-1411
Serving the Top-of-the-South with 2,049,000 kilowatts
—due to reach 3,019,000 kilowatts by 1964.

CIRCLE 23 ON READER SERVICE CARD→

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New Design Principle. Con Avionics "Worst-Case" Analysis brings virtually failure-proof performance within the reach of everyone who uses power supplies. Here's why:

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Shown above is the AC-DC "Modular" Power Supply designed for easy incorporation in many electronic assemblies and systems. It features all solid state . . . unique heat sink construction . . . voltages from 2.0 to 305 VDC . . . adjustable output . . . power to 30 watts . . . regulation 0.1%.

Learn more about Con Avionics complete line of Transistorized Power Supplies. Call your local Con Avionics representative, or write to address below.

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New Low Cost General Purpose Supply available with regulated and unregulated outputs. 0-60 VDC/o-1.5 Amp.

New "Switching" Power Supply makes higher current capacities possible at low cost. 10-32 VDC/10, 20, 50 Amp.

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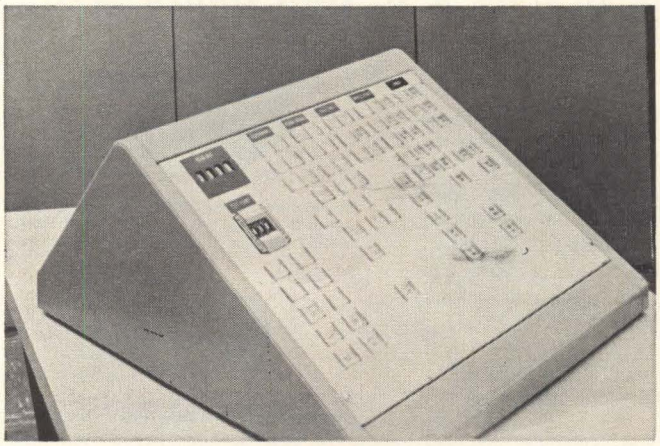
Increasing control efficiency... through digital conversion and telemetering

Unique advantages with usefulness in many applications are offered by The Peoples Natural Gas Company's data system that provides centralized, "fingertip" control of five remote regulating and measuring stations.

By TOM KURTZER
Regional Manager, Non-Linear Systems, Inc.
Chicago, Illinois

Automatic data acquisition and display gives true "fingertip" control to dispatcher J. H. Philips, enabling him to distribute peak day-loads up to 750 million cubic feet of gas to Peoples' 275,000 customers.



Dispatcher's console – through which he requests all data and remotely makes all valve position and controller set-point changes.

HOW THE Peoples Natural Gas Company, Pittsburgh, provided its highly-skilled dispatchers with fast, accurate data to economically meet complex situations may be of interest wherever remote, multi-station measuring and data acquisition are needed. The techniques, which center around digital conversion and telemetering, hold promise for such applications as electrical generation and distribution, pipeline networks, remote industrial processing, data collection from unattended meteorological stations, and similar operations.

Basic objective of the instrumentation system installed by Peoples to serve its 275,000 customers in western Pennsylvania is not unique:

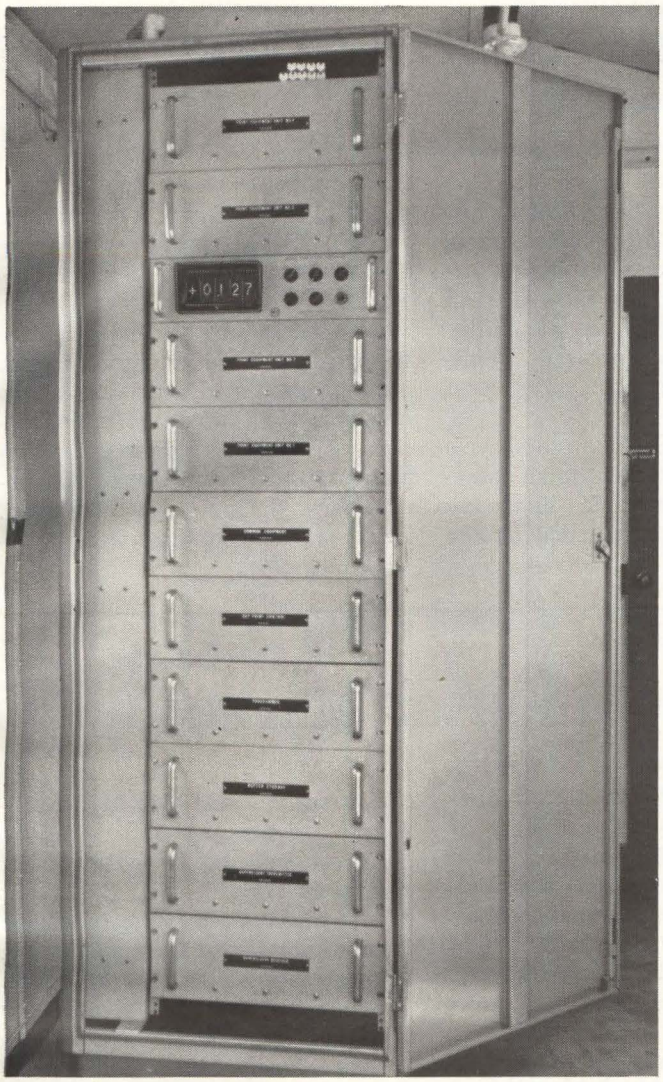
to provide highly accurate data from many sources quickly to enable skilled human beings to make intelligent decisions on complex problems.

In the case of Peoples Natural Gas, dispatchers must satisfy constantly changing customer gas volume demands, yet observe the gas purchasing contract requirements of several gas sources at the most economical rates at which gas must be withdrawn from each source.

Highlight of the system, in operation for more than a year, is digital telemetering between the dispatcher's office and the five remote stations. Analog measurements at the stations are converted to digital signals by four-digit digital voltmeters, manufactured by Non-Linear Systems, Inc., originator of the DVM. The data-acquisition, transmission and supervisory system was designed and built by the Westinghouse Electric Corporation. Measuring, recording, automatic controlling and alarm equipment was designed and built by The Bristol Company.

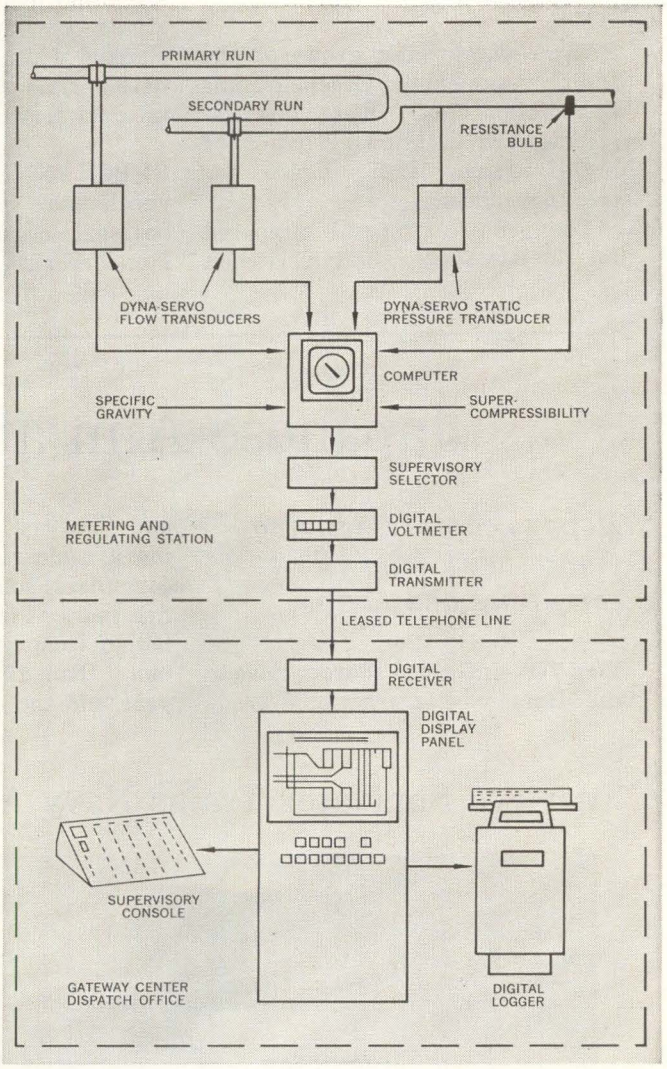
Why did Peoples use digital rather than analog telemetering which is so common in the gas industry? The company made its decision based upon these digital telemetering advantages.

- A digital signal suffers no loss of accuracy in transmission.
- In actual practice, it is difficult for a dispatcher to read an analog-type meter without close examination; thus human errors are likely. However, data in digital form, whether dis-



Basic instrumentation at each remote station. Note the easy-to-read display of the NLS digital voltmeter.

NLS V34A Digital Voltmeter. Five of these instruments are used in the Peoples system.



This diagram shows how two gas flows are totalized, corrected, converted to BCD code, transmitted, and displayed and recorded in the central dispatcher's office.

played visually or printed, is completely non-ambiguous.

Therefore, it allows dispatchers to make faster, more accurate decisions.

- Indicators for each function automatically retain their latest readings instead of reverting to zero as in analog setups.
- With a digital code, it is possible to provide almost absolute security against false signals or issuance of commands to the wrong equipment.

Here's how data is telemetered:

1. Data from pressure, flow, and temperature transducers are simultaneously corrected and converted to millivolts by a servo-driven slidewire.
2. This analog millivoltage is, in turn, converted to a digital form by an NLS V34A four-digit voltmeter.
3. The digital signal from the digital voltmeter is converted to the 7-4-2-1 binary code used in telemetering by Westinghouse relay equipment.
4. The information is then transmitted serially over lowest-cost telephone circuits in 5 bits, with the last bit used as a parity check.

Every code transmitted must have the correct number of long and short bits and the correct total number of bits. If it doesn't, it will be detected as false by the receiving equipment and rejected. Once again, this is an advantage made possible by the use of digital-type telemetering.

For more information on how digital voltmeters and other digital measuring instruments might be of assistance to you, please contact one of the 19 NLS factory offices or write to Non-Linear Systems, Inc., Del Mar, California.

non-linear systems, inc.
originator of the digital voltmeter

Oceanographers Seek Exclusive

They ask for six 3-Kc channels for data and other communications

PARIS—A working group of the Intergovernmental Oceanographic Commission (IOC) has taken a first step toward eventual allocation of high-frequency radio bands for oceanographers.

The group's proposal, prepared for the late-September IOC session in Paris, would give oceanographers exclusive 3-Kc channels in each of the six existing ITU mobile marine bands. The channels would have multiple use—telephone, facsimile, c-w and the like—at full channel width, with the possibility of 300-cycle subchannels for digital data transmission.

SUBCHANNELS—The 300-cycle subchannels correspond to an international oceanographic telemetry standard also recommended by the working group. The standard calls for nominal 300-bit capacity messages with maximum transmission rate of 100 bits per second and limits antenna input power to 100 watts.

Automatic buoys are restricted to call-up or interrogated types, clock-programmed transmission by buoys is prohibited. The idea behind this provision is to get maximum utilization of telemetry subchannels through time sharing. Later on, the standard will set re-

Japanese Aim at Computer Market

Hope to capture growing market with joint-effort companies and tariffs

TOKYO—Informed sources close to the Ministry of International Trade and Industry (MITI) are predicting a rapid rise in the number of computers sold in Japan. Within five years, it is estimated, the number of computers in Japan will be more than 10 times that of this year and the dollar value of those computers will climb to $472.2 million.

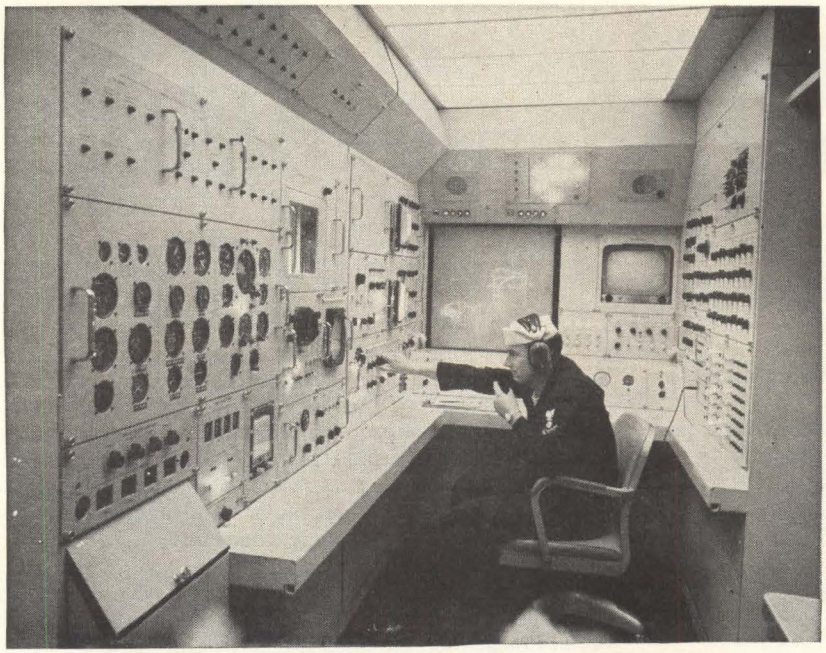
At present, Japan is importing computers from the U.S., but groups of Japanese companies have formed joint-effort companies in bids to capture the market here. Chances are they will be aided by tariffs on imported computers.

Larger computers can come into Japan free of tariffs until March 31, 1963, and punched-card systems until Sept. 30, 1962. About 90 percent of the trade with foreign nations is scheduled to be liberalized next month, but MITI has not come out with any definite plans to include electronic computers (except as mentioned above) on the free import item list.

The industry expects that the government will maintain a tariff rate of 15 percent on foreign electronic computers even after trade liberalization goes into effect.

NEW COMPANIES—One large joint-effort company, Japan Computer Co., was formed a year ago by seven companies: Toshiba, Hitachi, Nippon Electric (NEC), Fuji Communications, Oki Electric, Matshushita Electric Industries and Mitsubishi Electric. It started with a capitalization of $3 million, will double that this November. The company is headed by Naokai Murase, former deputy director of

Air-Sea Simulator Trains Navy ASW Crews



ANTISUBMARINE WARFARE *trainer built by ACF Electronics for the Navy simulates an S2F-3 aircraft, its electronic detection and countermeasures equipment and its armament. Some 32 computers are built into the system. Plotting board in control room, above, shows the instructor the path of the simulated aircraft and submarines*

Radio Channels in Marine Bands

quirements for trigger transmission so that automatic buoys can provide early warnings of hurricanes or typhoons.

Since obtaining international frequency allocation is a heel-dragging procedure, the communications working group will recommend that the forty member nations of IOC coordinate national frequency allocations as much as possible and at the same time move for formal ITU allocations, especially in the three mobile marine bands at 4.063 to 4.438 Mc, 6.200 to 6.525 Mc and 8.195 to 8.815 Mc.

POLAR CHANNEL—The working group also will propose that IOC member nations get together on a 3-Kc channel near the center of the 510 to 525-Kc band. This channel would be reserved for oceanographic purposes in polar regions, where auroral disturbances make higher frequencies useless. Russian oceanographers have already successfully experimented in the band. They reported that a 40-watt transmitter driving a top-loaded antenna 40 feet high had an effective range of 930 miles in the Arctic.

For the vhf and uhf bands, the working group will suggest that oceanographers try to obtain two channels from their national telecommunications authorities (like the FCC in the U. S.), a 20-Kc channel in the 40 to 60-Mc band and the lowest 10-Mc channel in either the vhf or uhf bands.

MITI during the Kishi government.

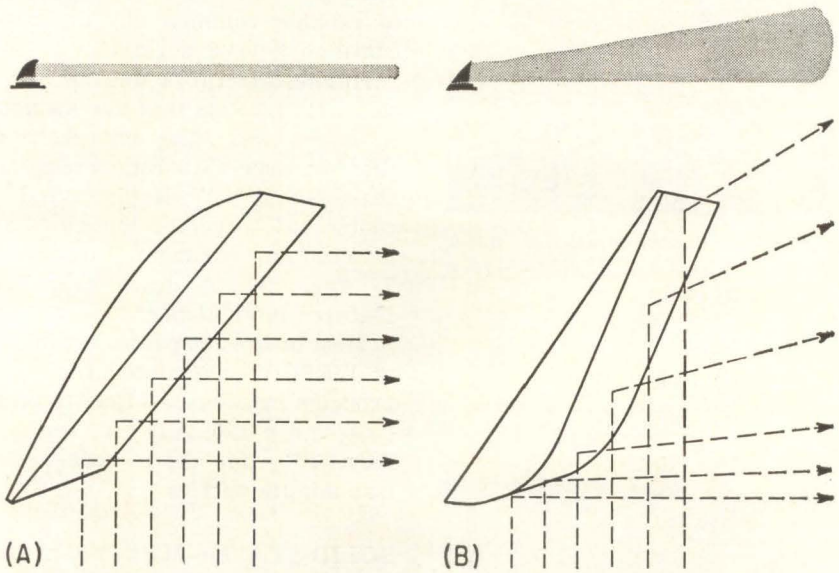
Japan Computer Co. was formed to rent domestic computers to companies that could not afford to buy them, to forestall imports of U. S. computers. The company began renting last October and had rented 27 domestic machines by March 31, 1962. Between April 1 and mid-August, 1962, it had 35 rentals, including eight computers still to be delivered.

The company's fees totaled $3 million during the 1961 fiscal year which ended March 31. During the 1962 fiscal year, it plans to do a $10-million to $12.5-million business.

Masanobu Kimura, business manager of the company, told McGraw-Hill World News that there are now about 300 electronic computers in operation in Japan, excluding punched card systems. About half of these are domestic makes and half foreign, with about 30 more foreign computers approved by the government but not yet delivered.

Last month, NEC, Fuji Electric Communication and Oki Electric formed another company to manufacture large computers (ELECTRONICS, p 7, Aug. 17).

(It was also announced, in New York, that Toshiba, the Japan Engineering Consultant Corp., Fuji Telecasting and Tosho Co. have organized another company, Japan Business Automation Co., to sell computers and lease computer time. The company will handle computers made by Toshiba.)



BEAM SHAPE *could be changed from pencil (A) to fan (B) by rotating two-sided mirror*

Mirror-Steered Radar Is Proposed

RADAR CONCEPT that would employ a bundle of radar beams reflected from a mirror to achieve extremely high total beam power has been developed by General Dynamics/Electronics. The company says it could be used to detect and track small cross-section targets at extreme ranges in space projects.

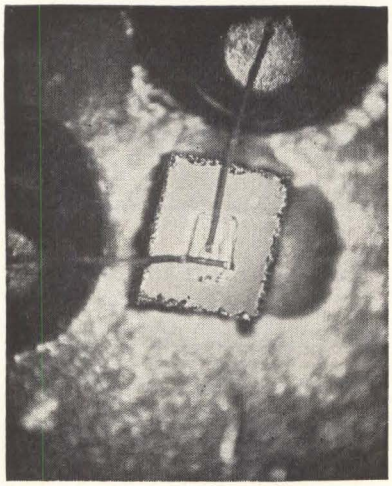
A fixed primary array could be installed below ground to provide a partially hardened radar site. The mirror would be above ground. The mirror would have two sides, one flat and one curved like a carnival mirror. As illustrated, the flat side would provide a pencil beam while the curved side would provide a fan-shaped beam.

GD/E says the concept would provide almost unlimited radiated power, eliminate electrical joint problems, make beam steering and shaping easier, be easier to maintain and more reliable than conventional systems.

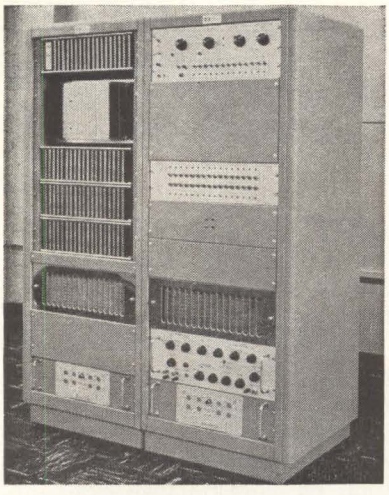
To feed the below-ground array, GD/E engineers propose multiple amplifier tubes in separate parallel transmission lines. A 1,000-element array, with each element radiating 1-Mw peak power for a total radiated beam of 1,000 Mw, is conceivable, it was stated.

WESCON Sets New Records

Show is judged the best yet, in technical interest and attendance



SILICON *planar epitaxial pnpn 3-terminal switch by Sylvania (see p 60, Aug. 10)*



HIGH SPEED *memory exerciser and 1-μsec memory consoles control unit having storage capacity of 4,096 56-bit words, introduced by Indiana General*

LOS ANGELES—As WESCON registration desks closed down last week, it was clear that the 1962 show was the largest yet. Attendance figures hit a new high of 46,184 and the general consensus was that the caliber of technical sessions and effectiveness of product display reached new peaks.

Two interesting trends were in evidence. Integrated circuits are being subjected to the same sort of price war that has plagued the semiconductor business over the past several months, and lasers are coming of age with the availability of reliable, commercially available, continuous-wave devices.

Hughes Aircraft's Malcolm Stitch told ELECTRONICS that the big news in lasers was "the emergence of the c-w laser as a commercial off-the-shelf item." Hughes and a couple of other companies announced new commercial models (p 7, Aug. 17). A dozen exhibitors featured laser displays.

Most of the companies exhibiting at WESCON announced their new products in advance (ELECTRONICS, p 30 and p 130, Aug. 10, and p 7, Aug. 17), but there were a few last minute entries.

SOLID-STATE—Motorola previewed a future line of off-the-shelf digital and linear integrated circuits by showing a 120-Mc transmitter-receiver developed under an Air Force contract and a 30-stage computer with a propagation delay reported as only 6 nsec per logic decision.

Motorola also displayed low-cost, germanium alloy-diffused *pnip* power transistors with breakdown voltage ratings up to 160 v. Improved characteristics are attributed to a relatively high-resistivity intrinsic region between the base and the collector. This region forms a voltage barrier contributing to breakdown voltage increases. A reduction in base width improved frequency response.

CORE MEMORIES—Two firms, Indiana General and Daystrom, introduced 1-μsec read/restore core memories. Daystrom's has a capacity of 4,096 56-bit words. A word-organized system, using partial-switching technique, it reportedly has an access time of 0.6 μsec, and is highly insensitive to stray noise.

IGC's unit has a capacity of 2,048 56-bit words, and features access times of 0.55 μsec for full-cycle operation and 0.50 μsec for half-cycle operation. High cycle speed is attributed to a more efficient terminal switching technique, in which pulse width is adjusted instead of pulse amplitude, and logic circuits using the NOR-logic technique exclusively.

FREQUENCY SYNTHESIZER—Another new product that attracted considerable attention was Hoffman Electronics' digital frequency synthesizer, capable of generating radio signals between 1.4 Mc and 35 Mc in increments as small as 10 cycles between 1.4 Mc and 7 Mc, and as small as 50 cycles between 7 Mc and 35 Mc.

The heart of the low-cost unit is a reference oscillator generating a comparator signal stable to one part in one billion per day. Output signal stability is one part in 100 million per day.

FIELD EFFECT—Four *p*-channel silicon planar diffused field-effect transistors were shown by Texas Instruments.

Parameters include input impedance greater than 5 megohms at 1 Kc, noise figure at 1 Kc from 1 db to 4 db, depending on which model transistor is used, operation in temperatures from −196 C to 200 C, and resistance to radiation effects up to 10^{15} neutrons/cm^2.

TI's new germanium alloy field-effect transistors have minimum input impedance of 1 megohm at 1 Kc and breakdown voltage of 60 volts at 100 μa. A grown-diffused tetrode audio transistor features minimum transconductance of 5,000 μohms with guaranteed minimum change of 20 db, higher gain control and a low maximum leakage of

80 na. A high-current solid-state d-c switch has a single gate element for both turn-on and turn-off.

TV DISPLAY—A character generator and display system, developed by A. B. Dick Co., permits alphanumeric data presentation on conventional off-the-shelf tv receivers. The system accepts data from punched cards, punched paper tape, magnetic tape and memories.

The input can be loaded at rates up to 250,000 characters a second. The output signal is a composite video signal: 0.5 v peak-to-peak into a 75-ohm impedance and a 4-Mc bandwidth. Display is in tabular form, with 64 characters.

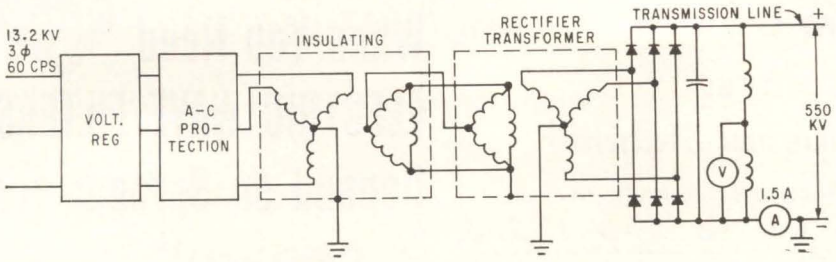
Voice-Analyzer Computer Aids Communications R&D

BOSTON—The speech research laboratory being completed at Air Force Cambridge Research Laboratories includes a computer, built by Melpar, that breaks down the human voice spectrum into 400 basic patterns.

The speech-analyzing computer is used in studies of complicated speech waveforms to help the labs' speech compression program. Objectives of the studies include determination of the minimum signal for transmission and reception of information.

Lunar Seismometer

SURVEYOR *moon probe, to be launched next year, will carry this lunar seismometer built by ITT Federal Labs and designed by Lamont Geological Observatory*



ONE-HALF OF A-C TO D-C *conversion circuit for d-c power line (1.1 Mv line to line, ±550 Kv to ground). Rectifier section will use about 13,560 silicon diodes*

Will D-C Power Cause Interference?

Answer is sought in tests with a 1.1-Mv power line in Oregon

POWER TRANSMISSION at 1.1 million volts d-c will be tested in a 5-mile section of the Bonneville Power Administration system in Oregon. A major objective of the tests will be the control of corona and radio noise.

The system will operate at ±550 Kv to ground, and radio noise must not exceed 250 microvolts when measured with a modified NEMA circuit. The system must also be essentially corona free at 900 Kv to ground. About 13,560 silicon diodes in a full-wave bridge will be used to convert the a-c to d-c (see diagram). Typically, an inverter circuit will be used to convert the d-c to a-c at the load.

For a given amount of copper and insulation, d-c lines can transmit about 40 percent more power with 29 percent less loss than a-c, but termination equipment is not as fully developed and is more expensive than for a-c. For overhead lines, d-c transmission is cheaper for distances greater than 300 miles; for land cables, d-c becomes cheaper at 30 miles, and for underwater cables at about 14 miles.

Equipment for the experimental line will be of American design and radio tests will be conducted with conventional equipment. Allis-Chalmers has received a $\$\frac{3}{4}$-million contract to supply equipment for the a-c to d-c conversion.

Japanese Firms Increase Electronic Output In '61

JAPANESE ELECTRONICS output increased 20 percent to a total of $1.4 billion in 1961, reports the U. S. Department of Commerce. Factory output in 1960 was $1.2 billion.

Television receivers, more than a third of the total 1961 output, rose 24 percent to 4.5 million units. Sound recorders and reproducing equipment increased 60 percent to $42.3 million and radio-phonographs increased 55 percent to $40 million.

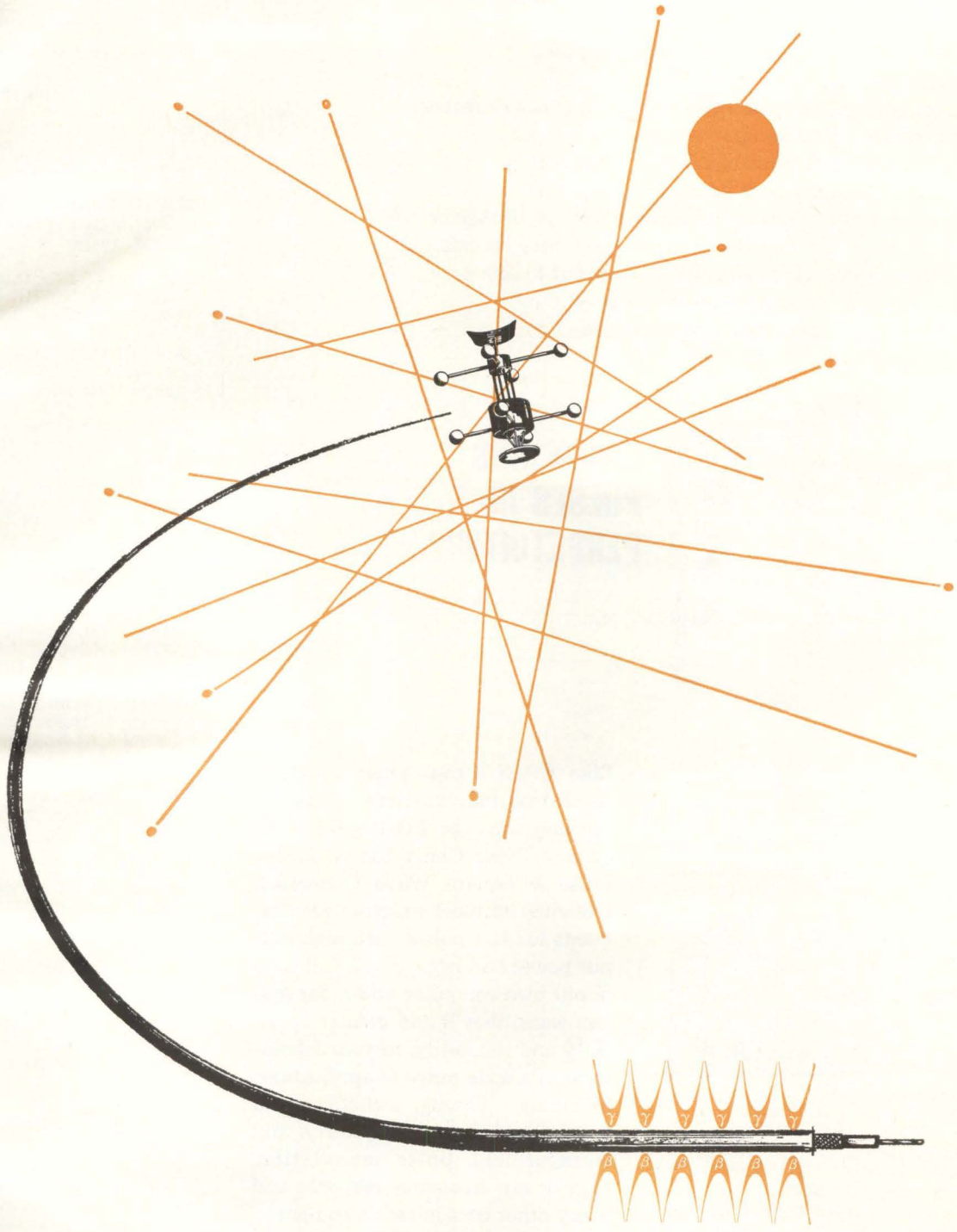
Output of radios with three or more transistors rose to 12.2 million units, with output of radios of one or two transistors estimated at 6 million units for 1961. Production of tube-type radios dropped 15 percent by volume and 26 percent by value from 1960 levels.

Other components showing an increase in unit production in 1961 include: transistors, up 29 percent; diodes, 40 percent; silicon rectifiers, 170 percent; resistors, 42 percent; capacitors, 35 percent, and transformers, 95 percent.

Japan Plans Satellite Broadcasts of Olympics

TOKYO—The Kokusai Denshin Denwa Co., Japan's overseas radio and cable system, is trying to rent from the Agricultural Ministry land in Juocho, near Tokyo. KDD wants the land to build a station for worldwide live broadcasts, by Telstar, during the 1964 Olympic Games in Tokyo. KDD announced plans and specifications for the station recently (p 22, March 23).

(It was also announced in New York that an IBM 1410 will be used to compute the results of events, transmitting them to scoreboards and to the teletypewriter facilities of news agencies.)



radiation resistance through irradiation

LEADER IN RADIATION CHEMISTRY FOR ELECTRONIC WIRE AND CABLE

RAYCHEM CORPORATION

MEETINGS AHEAD

EIA FALL CONFERENCE, Electronic Industry Association; Biltmore Hotel, New York City, **Sept. 11-13.**

ENGINEERING MANAGEMENT, IRE-PGEM, AIEE et al; Hotel Roosevelt, New Orleans, La., **Sept. 13-14.**

ENGINEERING WRITING AND SPEECH SYMPOSIUM, IRE-PGEWS; Mayflower Hotel, Wash., D.C., **Sept. 13-14.**

ELECTROCHEMICAL SOCIETY MEETING; Statler-Hilton Hotel, Boston, Mass., **Sept. 16-20.**

RECTIFIERS IN INDUSTRY MEETING, AIEE; Desher-Hilton Hotel, Columbus, Ohio, **Sept. 18-19.**

INDUSTRIAL ELECTRONICS ANNUAL SYMPOSIUM, IRE-PGIE, ISA; Sheraton-Chicago Hotel, Chicago, Ill., **Sept. 19-20.**

TUBE TECHNIQUES NATIONAL CONFERENCE, Advisory Group on Electron Devices in the Office of the Director of Defense Research and Engineering; Western Union Auditorium, N.Y.C., **Sept. 19-21.**

BROADCAST ANNUAL SYMPOSIUM, IRE-PGB; Willard Hotel, Washington, D. C., **Sept. 20-29.**

VALUE ENGINEERING & ANALYSIS CONFERENCE, EIA; Statler-Hilton Hotel, St. Louis, Mo., **Oct. 1-2.**

COMMUNICATIONS NATIONAL SYMPOSIUM, IRE-PGCS; Hotel Utica and Municipal Auditorium, Utica, N. Y., **Oct. 1-3.**

SPACE ELECTRONICS & TELEMETRY NATIONAL SYMPOSIUM, IRE; Fointainebleau Hotel, Miami Beach, Fla., **Oct. 2-4.**

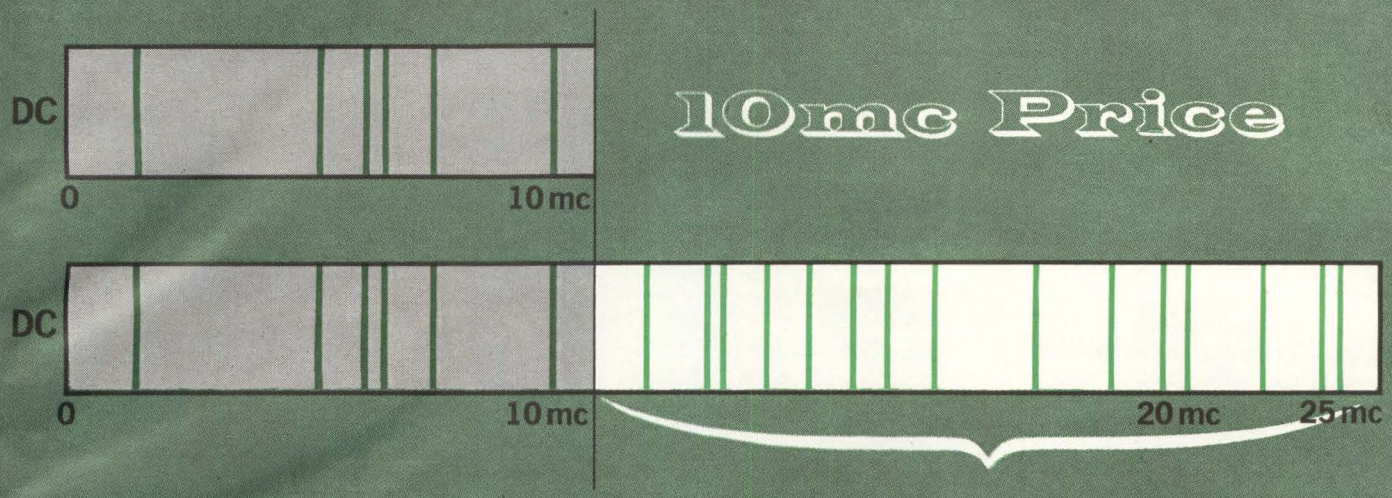
AEROSPACE SCIENCES NATIONAL MEETING, IAS; Dallas, Texas, **Oct. 4-5.**

ELECTRICAL ENGINEERS FALL GENERAL MEETING, AIEE; Pick-Congress Hotel, Chicago, **Oct. 7-12.**

NATIONAL ELECTRONICS CONFERENCE, IRE, AIEE, et al; Exposition Hall, Chicago, Ill., **Oct. 8-10.**

ADVANCE REPORT

SOLID-STATE CIRCUITS INTERNATIONAL CONFERENCE, IRE, AIEE, *U. of Pennsylvania; U. of Penn. and Sheraton Hotel, Philadelphia, Pa., Feb. 20-22, 1963. Nov. 1 is the deadline for submitting a 35-word abstract and a 300-500 word summary to: A. K. Rapp, Philco Scientific Laboratory, Blue Bell, Pa. Summary should highlight contribution to the art and include theoretical and experimental results when available. Fields of interest include: solid-state microwave amplification, oscillation; solid-state data storage and logic; circuit development providing improvement in bandwidth, gain, noise figure, stability, reliability; solid-state devices performing an integrated circuit function; micro-circuit techniques improving system performance and reliability; new devices and device characterization; solid-state techniques for adaptive systems; quantum electronics; cryogenics; optoelectronics.*



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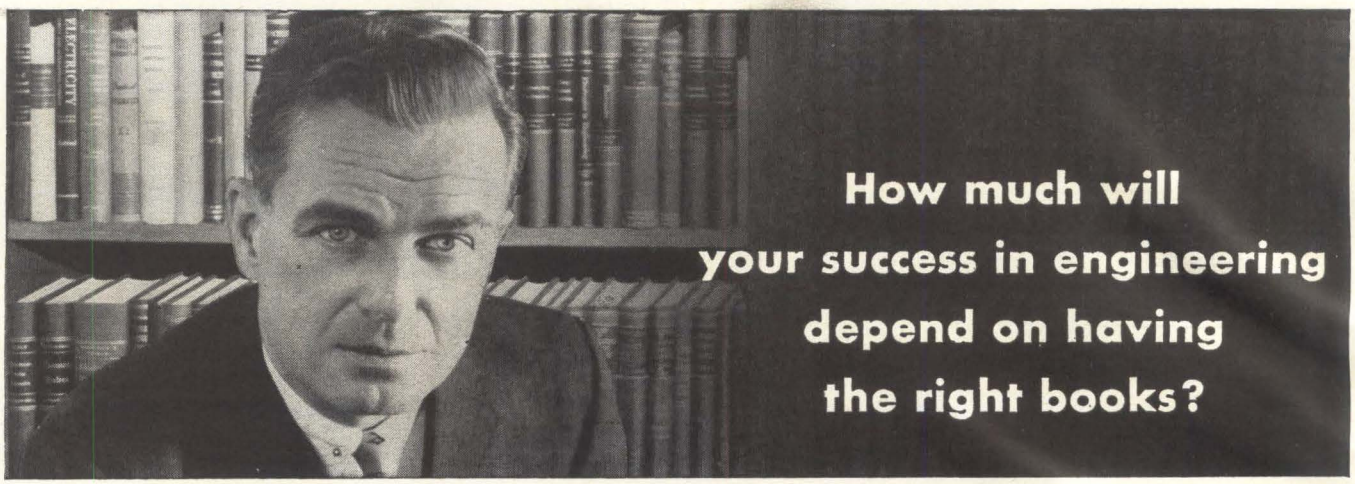

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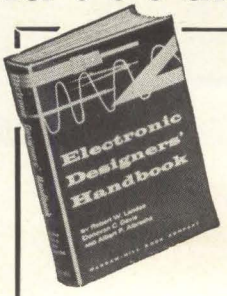

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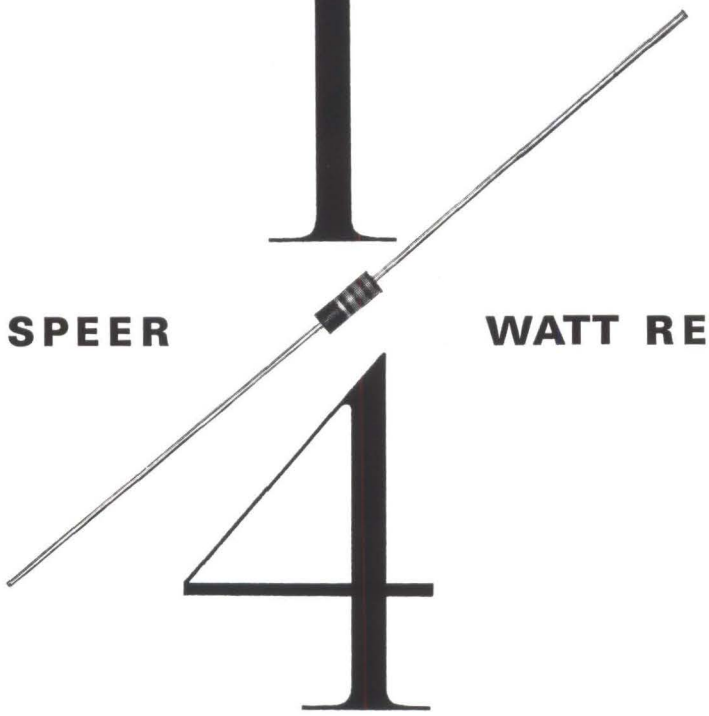

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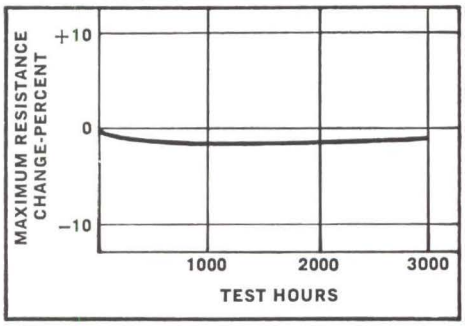

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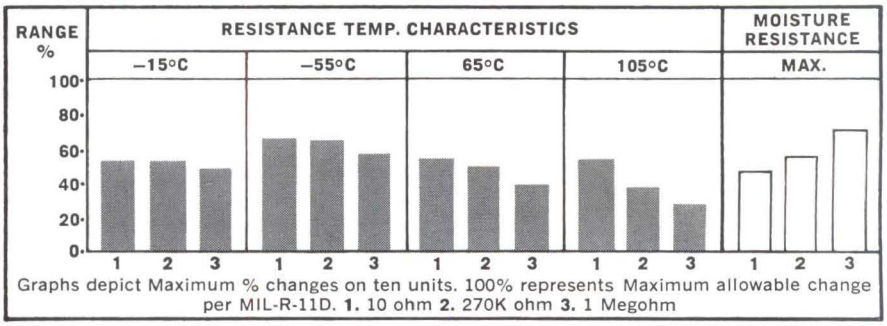

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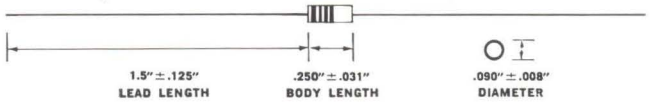

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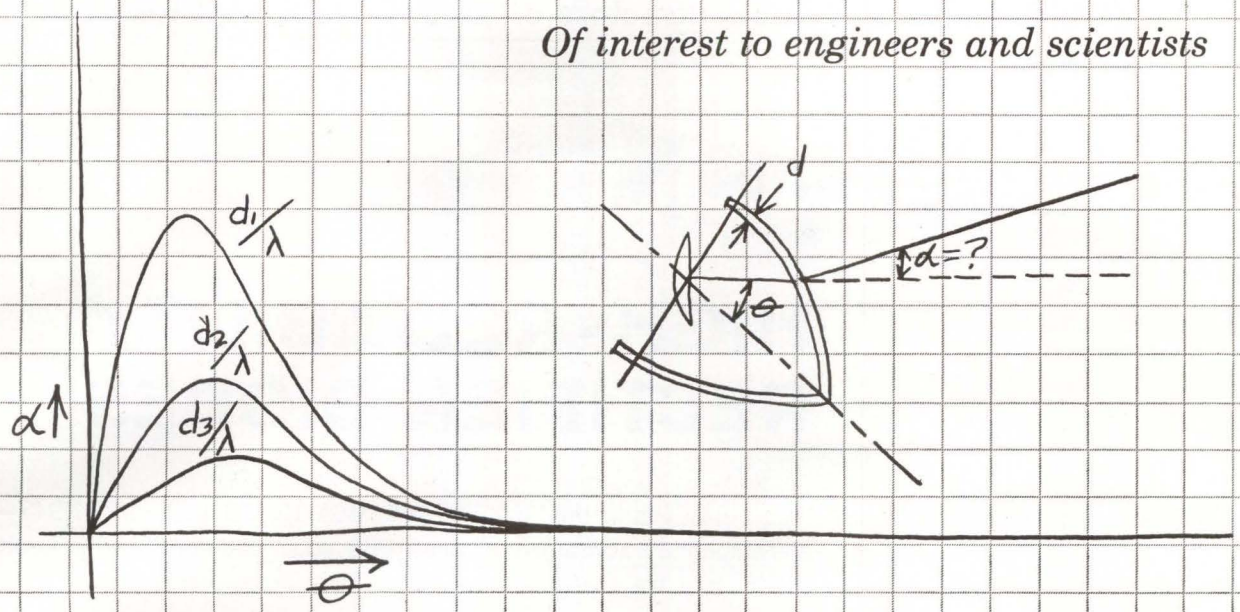

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USA 1N673	400	10	1.0	0.4	2.0	320	0.4	0.4	3.0
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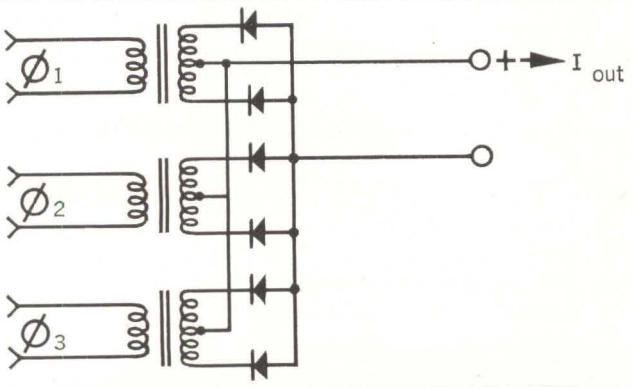

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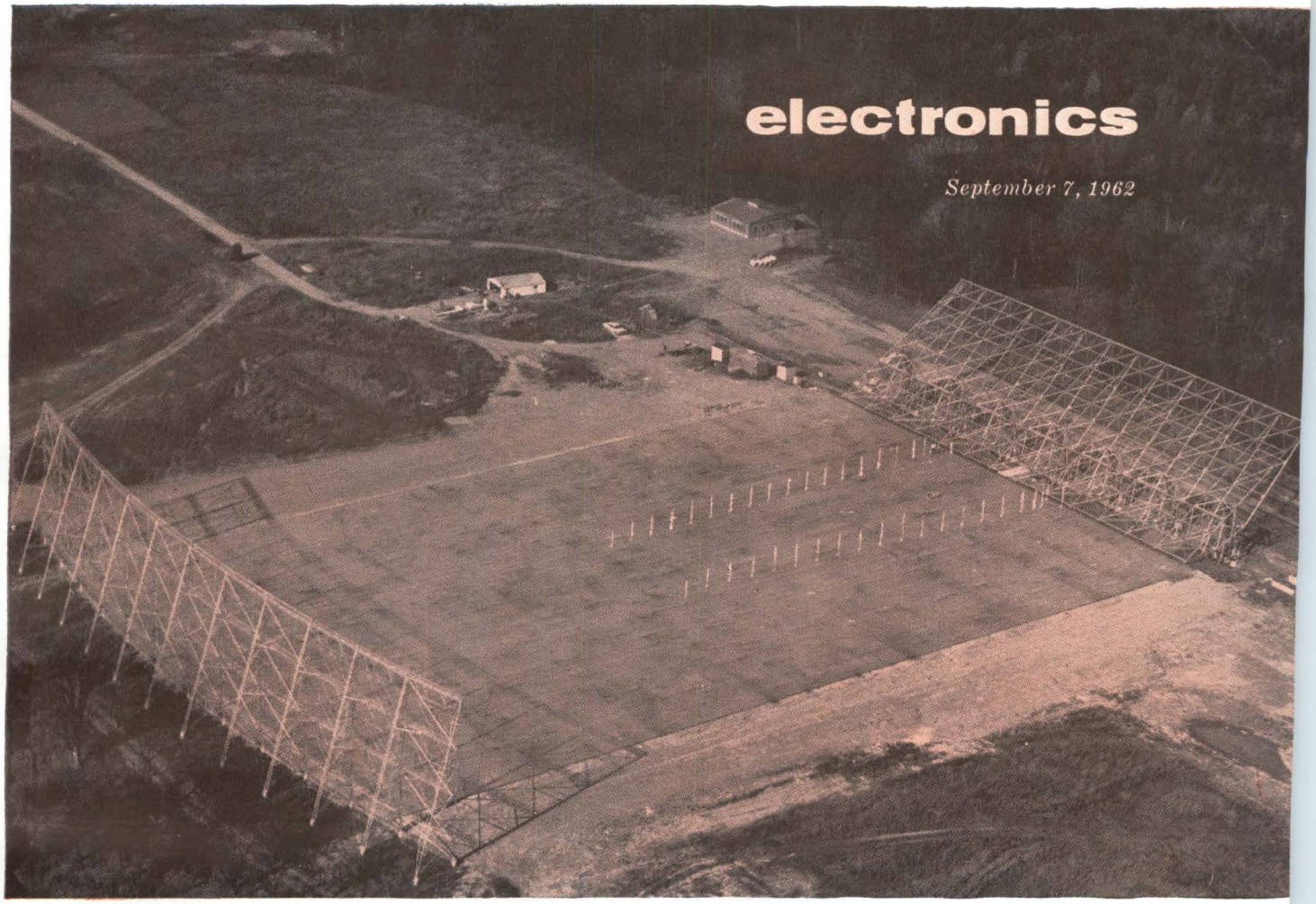


360-FOOT FIXED PARABOLOID *over ground plane, scanned by tilting flat plate at right, at the Ohio State University Radio Observatory, Delaware, Ohio—Fig. 1*

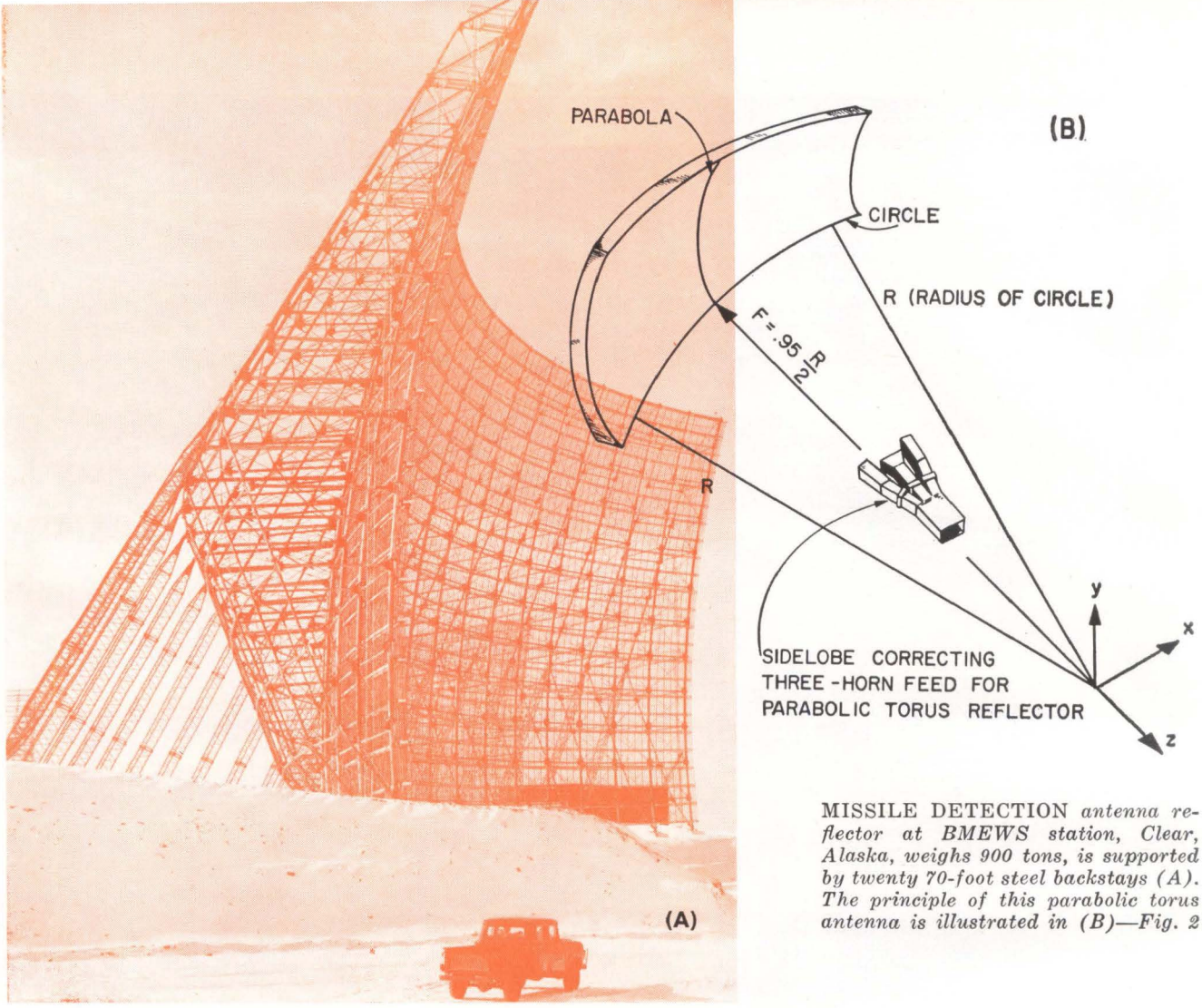
Modern Antennas in Space Communications

Space-vehicle tracking and communications require antennas with greater resolving power, higher gain and improved scanning capability; here is how some new designs measure up

By CARLYLE J. SLETTEN
Air Force Cambridge Research Labs.
L. G. Hanscom Field,
Bedford, Mass.

ANTENNAS with ever increasing range and resolving power are needed for locating and communicating with space vehicles. Strange, noisy signals emanating from cosmic processes in our solar system and in interstellar space are of interest to physicists and radio astronomers. Powerful radars capable of reflecting detectable signals from distant planets also require extremely large antennas. For all these purposes, the premium is on increased antenna aperture size.

Aperture size, frequency, and dimensional tolerance all affect antenna performance or capability to penetrate deeply into space.[1, 2] Antenna size cannot be increased without encountering severe engineering as well as economic constraints. A method for distributing radiation to or gathering radiation from large antenna



MISSILE DETECTION *antenna reflector at BMEWS station, Clear, Alaska, weighs 900 tons, is supported by twenty 70-foot steel backstays (A). The principle of this parabolic torus antenna is illustrated in (B)—Fig. 2*

apertures with low losses and coherent phase must be available. Below frequencies of about 500 Mc, transmission lines may be used efficiently to feed radiating elements directly; above these frequencies, shaped reflector surfaces fed through the air by techniques similar to optical reflectors are usually best. The physical position of most portions of the reflector surface must be held to within about $\lambda/8$ of the design dimensions to make effective use of such reflector antenna apertures.

Fortunately, space antennas do not require rapid beam steering capability, for objects in deep space cannot have large angular velocities relative to an earth observer. The principal scanning problem is to counteract the rotation of the earth. Such space antennas should have horizon-to-horizon scan in the east-west plane with modest scanning ability in north-south directions, since most of the scientific investigations will be done in the plane of the ecliptic. A more vexing problem is to measure the true bearing of the extremely narrow antenna beams and to search and map the vast heavens. The frequencies available for this space function are restricted by the losses, refraction and scintillation caused by the earth's atmosphere and ionosphere. The random fluctuations in these veiling gases may set an upper bound to antenna size much as seeing does for optical lenses. For the foreseeable future, however, the fundamental constraint is one of aperture cost.

THE UPWARD LOOK—Air-breathing vehicles must remain relatively near the surface of the earth. The elevation angles of interest for radar detection and communication with aircraft are therefore concentrated near the horizon. Communication with ground stations through the ionosphere requires antennas with beams concentrated along the horizon with, perhaps, provision for azimuth scanning. These conditions have led to development of antennas on high towers for azimuth scanning at low-angle elevation coverage, circular arrays or Wullenweber antennas for azimuth scanning, and $\csc^2\Theta$-shaped patterns on search radars looking along the earth's surface.

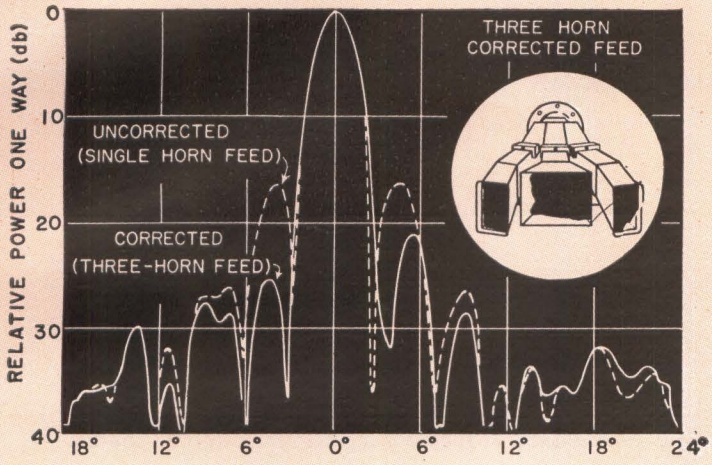
Ballistic missiles, satellites and space ships can be located at great distances from the antenna at high elevation angles as well as low. Hemispherical cover is now needed in addition to good horizon coverage. Missiles, satellites and space rockets in general have basically changed the antenna's physical attitude as well as enlarging the interesting regions of angular coverage. The demands of the space era require bigger antenna apertures in new configurations relative to the earth.

ANTENNAS FOR LOW-NOISE RECEIVERS—Although recent advances in rocketry and space technology

The Eyes and Ears of Modern Systems

ANTENNAS play a dominant role in the technological revolution sweeping the earth, because they are the eyes of the giant systems of search and communication man is using to augment his own biological senses. Most modern systems have no other sensory organs than the antennas, and, especially in space, intelligence can be conveyed only through antennas.

The forces pressing for better antennas are both scientific and economic. Economic pressure will inevitably steer us to simple, direct answers. "Ultimate Systems" with great versatility and high cost will usually be replaced by simpler antennas performing the diverse antenna functions more economically



SIDE-LOBE REDUCTION *due to corrected feed of antenna in Fig. 2—Fig. 3*

have profoundly affected radiating systems, one electronic discovery has had an important effect on antenna design. The maser or modern low-noise solid-state receiver has reduced the noise figure of the communicator or radar receiver below that of the antenna and its environs. Antenna surfaces are really cold in that they produce very little of the thermal noise entering the receiver. However, part of the antenna's job is to protect the receiver (antenna terminals) from thermal sources radiating from unwanted directions. It is common practice to measure antenna patterns on especially clean antenna ranges that approximate free space and then locate antennas near buildings, towers, or hills which cause serious spurious lobes and pattern distortion. The problem of thermal noise injection through the antenna cannot be so easily ignored as other aspects of antenna siting have been. The total spherical angular response of the antenna must be controlled to protect the maser from hot sources on the earth or in the sky. All lossy paths leading to the receiver must also be eliminated. In particular, the large-aperture antennas built from necessity on the earth suggest the attractive possibility of smoothing the nearby terrain so that it will act as a perfect reflector at the low angles seen from the antenna.

VARIABLE FOCUSING ANTENNAS—It is not generally appreciated that focused aperture antennas can transmit power with efficiencies of over 50 percent when located in the near field of each other. Remembering that near field regions are usually defined as

$$R = \frac{2D^2}{\lambda}$$

where R is the range within near field, D is the aperture size and λ is wavelength, there are antennas today that have near-field regions extending several hundred miles.

It might become practical to transmit electrical energy between points on earth or from earth to space by focused microwave antennas.

Another functional requirement is the need to resolve and identify missiles and other targets populating space and the atmosphere. An antenna focused on a target in the near zone (or Fresnel zone) can resolve the target's angular position much more accurately than when, as is usually the case, the antenna is focused at infinity.

INCREASED INFORMATION RATES—Compounding the difficulties confronting the antenna designer is the need to gather more information in a shorter time. The number of objects orbiting the earth is increasing rapidly. Faster missiles and aircraft accompanied by debris and decoys require more data capacity. Additional bandwidth is desirable to permit more channels per antenna for communication. Not only is frequency shifting necessary to keep pace with the daily vagaries of the ionosphere, but many military missions require the use and search of large chunks of the radio spectrum.

Other antenna design goals implicit in the quest for more information-gathering ability involve volume search of space suited to the functions being performed. One simple, favored solution is to make the antenna omnidirectional or as near to covering all directions in space as is theoretically possible. Obviously, it yields no angular position data on sources of radiation. From here on the game is played by systems designer and antenna engineer in trading off antenna beam shape, antenna gain, signal and antenna bandwidth, time on target, and multi-terminal or several antenna operations, against the functional needs or knowledge of source distribution.

Finally, not only technological and economic considerations influence antenna design, but also certain social and stylistic forces come into play. Each bureau, agency and company scientist likes to invent new antenna methods and designs. The tendency to build the ultimate antenna or system to solve a large class of problems usually leads to large contracts and disappointment in holding to schedules or performance specifications. Simplicity of antenna principle and structure usually leads to the greater satisfaction.

THE ROTATABLE PARABOLOIDAL DISHES—For both optical and radio wavelengths, the parabolic reflector has been developed to produce the greatest aperture gains and narrowest (or smallest) pattern beamwidths. The 200-inch Mt. Palomar optical telescope has a theoretical gain of 147 db and beamwidth of 5.7×10^{-6} degree at 5,000 A and the 50-ft K_A-band radio telescope at the Naval Research Laboratory has a gain of 72 db and beamwidth of $5{,}000 \times 10^{-6}$ degree (or 3 minutes). No design is simpler, for only a single reflector surface is needed which focuses perfectly to a point. For all wavelengths of interest the aperture size of the parab-

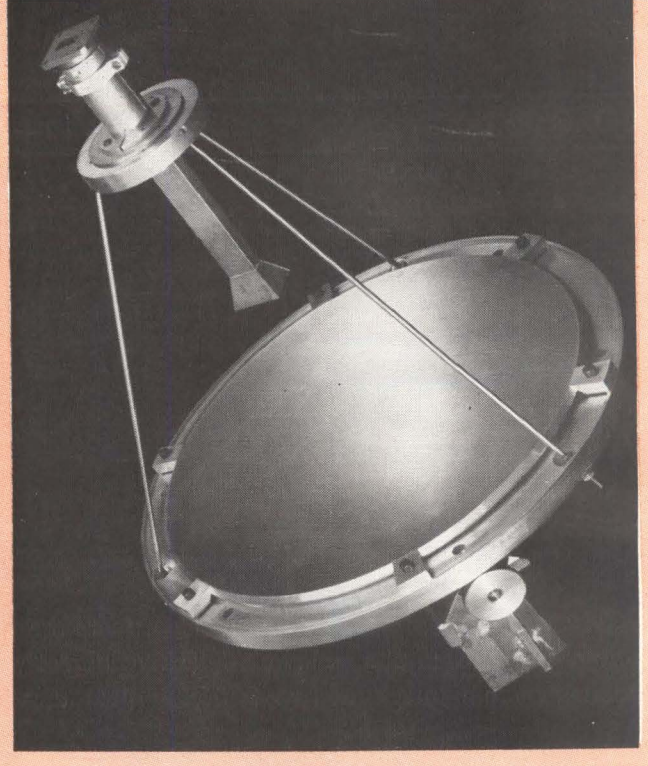
oloidal surface has been pushed to the limits of the materials used. The effective gain or electromagnetic-wave-gathering ability of the reflector depends on choosing shape and maintaining tolerances so that energy is collected in phase at the focus. The fact that materials bend when rotated in the earth's gravitational field is a fundamental obstacle to increasing the size of dishes relative to operating wavelengths beyond present sizes.[3]

The paraboloid has received a lot of design attention to increase its aperture size. One approach has been to compensate mechanically for the flexure deformation caused by weight.[4, 5]

A good method for achieving some scanning with a fixed paraboloid is shown in Figure 1. This design,[6] used by Kraus of Ohio State University, is scanned in the north-south direction by tilting a flat plate or mirror in front of a fixed paraboloid mounted over a ground plane on the earth. The antenna feed is also moved to get limited sean in the East--West plane.

WIDE ANGLE REFLECTORS—The surprising aspect of single-surface and paraboloidal reflector design is that more attention has not been given to enlarging the focal plane to permit scanning by feed motion only. One notable success in improving the wide-angle capability of reflector antennas is the parabolic torus antenna pioneered by Naval Research Laboratory.[7] This reflector surface (shown in Fig. 2A) is formed by rotating a parabolic curve about a point on the parabolic axis approximately 2 focal lengths from the vertex of the generating parabola. Figures 2B and 3 illustrate a method of side lobe reduction based on the successful application of the "transverse correction" technique which is strongly advocated below. This reflector has a wide focal region in one plane which makes it convenient for azimuthal scan or generation of elevation search pattern. This antenna has several interesting variants. The generating curve can be swung in a 360-deg arc forming a closed concave surface and when the reflector mesh is composed of rods inclined 45-deg with a plane through the focal region, 360-deg scan is possible for radiation polarized 45-deg from the vertical. An exterior parabolic torus produced by rotating a parabolic curve in a circle with the focus directed outward from the center of the circle is also a useful antenna requiring a phased line rather than a point source feed. Because these torus designs are not perfectly focused in the optical sense their usefulness as big antennas is limited.

CYLINDRICAL REFLECTORS—Another approach to big-dish design makes use of parabolic cylinders.[8] The designer reasons that he can afford to design one scanning line source to obtain beam steering in one plane with a singly curved reflector surface. One of the first big antennas using this principle was called VOLIR.[9] Here a wide-angle lens radiating from a line in the focus of a parabolic cylinder provides an attractive multilobe pattern. The success of such designs depends largely on the source design. Slotted waveguide arrays scanned by linear variation of phase velocity along the feeding guide is the usual approach at microwaves. An open structure like the trough guide[10] is attractive because phase velocity and radiation coupling can be independently adjusted with low ohmic losses and good impedance qualities as the beam is scanned through broadside. At uhf frequencies, moving dipoles coupled to a two-wire line[11] might be a logical scanning line source.

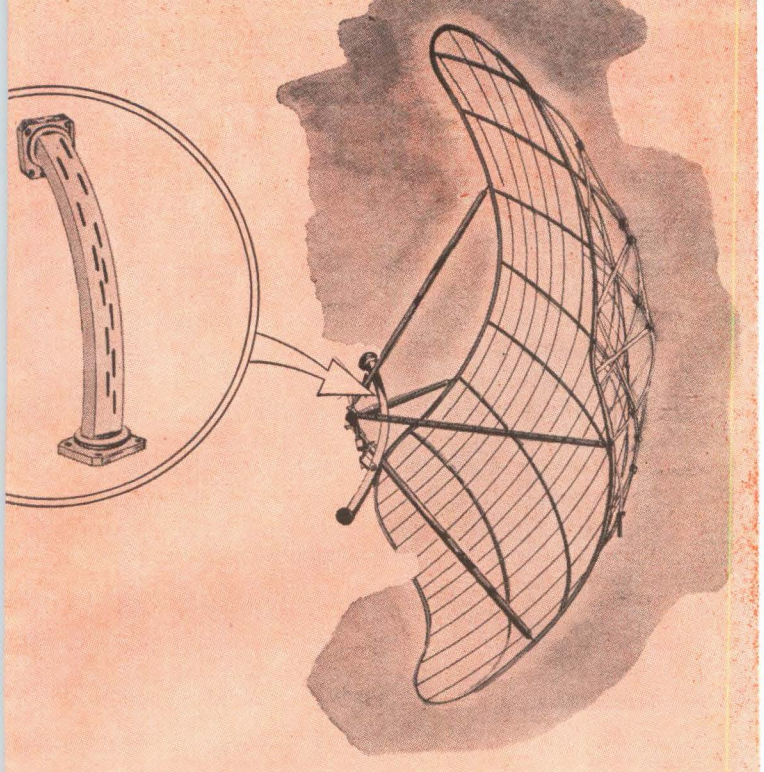


GREGORIAN CORRECTOR *for use with spherical reflector antenna to correct spherical aberrations—Fig. 4*

THE MULTIPLATE ANTENNA—The most recent reflector system and the one that appears likely to provide the biggest of all antenna apertures is the multiplate antenna.[12] This design involves building up a focusing reflector using many flat plates located on the ground along an arbitrary surface. Energy is collected in phase by proper rotation and translation of each reflector surface corresponding to pointing the beam in a desired direction. The cover shows a drawing of an antenna designed along these principles. The great advantage of this antenna for building colossal apertures is that the tolerance and motion problems are solved piecewise for flat elemental reflectors firmly fixed to the earth. Cost per unit area is low, instructions for positioning each reflector are simple and progress regularly across the aperture, and the inertia of each element is small so scanning can be done rapidly.

A large cone angle of the sky (half cone angle exceeding 45-deg) can be scanned with little loss of aperture efficiency. The antenna can be variably focused to improve angular discrimination in the near zone, which can easily extend out an earth radius or more. Fan-shaped beams can be produced by position instructions to the plates. Substantial amounts of r-f power can be fed to the antenna through multiple horns on a feeding tower. Difficulties exist in screening the radio receiver from the warm earth seen through the interstices between reflectors, and in preventing the regular stepped segments from building up far-outside lobes or grating lobes.

The multiplate antenna is related to several other designs which are also contenders for the big antenna class. A spherical mirror[13] can be corrected by stepping in $\lambda/2$ steps and making each radiating rim flat. Another diffraction type antenna based on the Fresnel zone plate is



CURVED-LINE *source feed for tricoordinate radar antenna, using phase-in-space principle—Fig. 5*

suited to making big apertures for millimeter wavelengths. A millimeter wave lens designed at ECI[14] gets good aperture efficiency by using $\lambda/2$ phase reversing steps.

SCANNING THE FIXED SPHERICAL REFLECTOR —The wide-angle or broad focusing capability of a concave spherical cap has excited the interest of optical designers for many years. To correct the spherical aberration of this mirror for operation at optical wavelengths, correcting dielectric lenses have been designed for use both in front of and behind the approximate or paraxial focus located one half radius from the surface. Perhaps the most successful corrector is the Schmidt lens[15] with the Mangin mirror[16] also receiving recent attention from microwave lens designers. Roy C. Spencer noted[17] in 1949 that the caustic or focal plane of a sphere has a degenerate line along the radius directed toward the main beam. He suggested that at microwave frequencies the phase and amplitude distribution along the radius could be controlled by antenna array techniques. When such arrays are fed near the paraxial focus, a phase velocity greater than the velocity of light is required. So various waveguide feeds with slot or dipole radiators and variable phase loading have been tried to achieve a one-dimensional or line source corrector for the spherical cap. A representative successful design[18] produced good quality patterns with 15 minutes of arc beamwidth. Phasing is achieved using a channel guide[19] with outboard feeds in the paraxial region to provide proper amplitude taper across the aperture. A circularly polarized feed was designed by Technical Research Group for the 1,000-ft antenna at Arecibo, Puerto Rico.[20, 21, 22] The literature contains further details on line source design.

The line source corrected fixed sphere can be scanned in a half cone of 20 to 45 deg with a small amount of aperture loss or sidelobe deterioration. The correction works perfectly in the optical sense as $\lambda \rightarrow 0$ so the beamwidth or gain limit depends on tolerances in the reflector screen an dthe ability to support and locate the feed with precision. Pattern bandwidth is restricted by most waveguide feeds which do not keep the phase along the feed according to Spencer's curve (a rigorous solution to the fields along a sphere radius has been achieved by A. C. Schell) for large departures from the design frequency. Because most feed designs are traveling-wave arrays with matched loads, the impedance bandwidths are good. By building in compensating line lengths to each of the radiation elements, Wiley[23] is producing a broadband solution for phased line sources.

Another approach to broadband feeding of a sphere makes use of a Gregorian or auxiliary reflector.[24] This correcting system is also perfect in the small wavelength (narrow beamwidth) limit and an example of such a corrector is Fig. 4. In fact a line source distribution of fairly arbitrary phase can be produced by a generating curve fed by a point source. When the feed position and reflector size are adjusted for minimum aperture blocking and compactness, the corrector tends to produce an inverse aperture taper on the large spherical mirror. This high sidelobe (-10 to -15 db down) pattern is near optimum[25] for radio astronomy purposes but not so good for radar scanning.

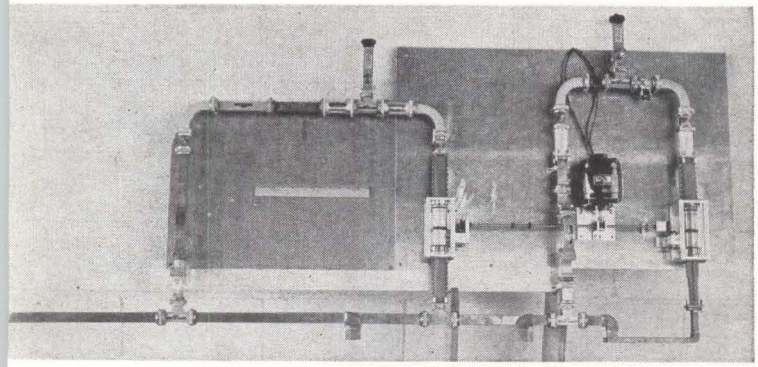
There are one-dimensional (line sources), two-dimensional (Gregorian corrector reflectors), and three-dimensional structures (Schmidt lenses for example) available for feeding and scanning large spheres. These provide a variety of correcting schemes. However, a method of transverse correction that lends itself to multiple feeds (multiport) use may eventually win out.

REFLECTORS WITH HIGH INFORMATION RATES —Focusing antennas can produce shaped beams by extending the feed source or sources in the focal plane. It is convenient to form a $\csc^2 \Theta$ pattern, where Θ is the elevation angle, by extending the feed source along a line of sharp azimuth focus. By using a portion of the paraboloid reflector surface above the vertex, an off-axis or no-aperture blocking solution can be obtained. It turns out that the proper location for such a feed is along a straight line passing through the focus parallel to a tangent to the midpoint of the paraboloidal section. Although positioning the line source below the focus results in low aperture blocking and improved impedance characteristics, extending the feed sources in a line in front of the reflector aperture gives better patterns from each source. In fact it can be shown that an off-axis section of a paraboloid has two focal points—a true focus and a zero astigmatism focus. Good antenna patterns over a 60-deg sector can be obtained using the proper focal region. Radiating elements such as slots on a waveguide should be phased with respect to each other to focus the array energy at the midpoint. Because of the rotational symmetry of the paraboloid, two or more beams can be rotated about the focus to form V-beams in space from a single reflector.[26]

These shaped beams are formed by feeding the appropriate power to elemental radiators in the focal region of a focusing lens or reflector. The image of this object distribution is formed at infinity or, practically speaking, in the far field of the antenna. In optical systems, the relative phase of sources in the focal region is usually not controllable on a point-to-point basis. The beam-shaping

on a paraboloid is best accomplished by focusing (phasing) the line source toward a central spot on the reflector. On certain wide-angle lenses and reflectors like the sphere or parabolic torus, this focusing or phasing relation between feeding radiators can be relaxed and good patterns are still produced. Under these conditions, relative phase between sources in the focal region can control the phase-in-space of the antenna patterns. This result can be achieved by connecting together a row (or any regular configuration) of point sources in the focal region by a traveling-wave feed line with terminals at either end. Now the signal received by a given point source, corresponding to a given beam direction, will arrive at different terminals of the feeding line with different phases. Thus the angular direction of an arriving plane wave received by a broad-shaped pattern can be measured with considerable accuracy. If the point-source radiators are progressively phased δ degrees apart, the change in phase between the two terminals will be 2δ degrees as the angle of plane-wave incidence changes from focusing one point source to an adjacent point source. Figure 5 shows such an antenna operating as a radar.

FLAT ARRAYS—All the big antennas discussed so far have the disadvantage that they require a feed structure remote from the reflector surface to achieve the optical illumination or feeding. Such feeding is cheap and requires only optics and air (free space) to distribute the power. However, a tower or feed suspension is usually needed to view the radiators or reflectors that can for convenience be arranged along the ground. Flat arrays fed by transmission line offer competitive solutions when the feeding transmission line is low loss and some form of variable phasing or feeding can be accomplished. Distributed power sources and receivers are considered under scanning. Below 500 Mc, two-wire transmission lines or coaxial cable can be used efficiently to distribute power and correctly phase dipole radiators. The really big antennas of the Mills cross[27] variety and billboard[28] type are constructed using feeders and power splitting (impedance transforming) junctions. Although a large variety of manual and solid-state phase shifters exist, the prospect of stationing and controlling one such device at each of the radiators in a large mattress-type array has discouraged most workers so far. Gain is proportional to the number of square wavelengths in the antenna aperture. To maintain and scan the antenna beam both on transmission and reception, elements must be about $\lambda/2$ apart. A flat array with n elements per row and m elements per column requires $m \times n$ phase shifters to scan in more than one plane. This means approximately 320,000 phase shifters and radiators for 60 db antenna gain.



DRANE-DAVENPORT *interferometer using nonlinear processing of received signals—Fig. 6*

One solution combines the phase shifter and radiator. Marston of Naval Research Laboratory[29] has shown that by rotating spiral antenna elements, flat arrays capable of beam scanning with circularly or linearly (variably) polarized patterns can be achieved, and that such arrays can be fed with a horn or point source, like a lens, as well as by transmission line techniques.

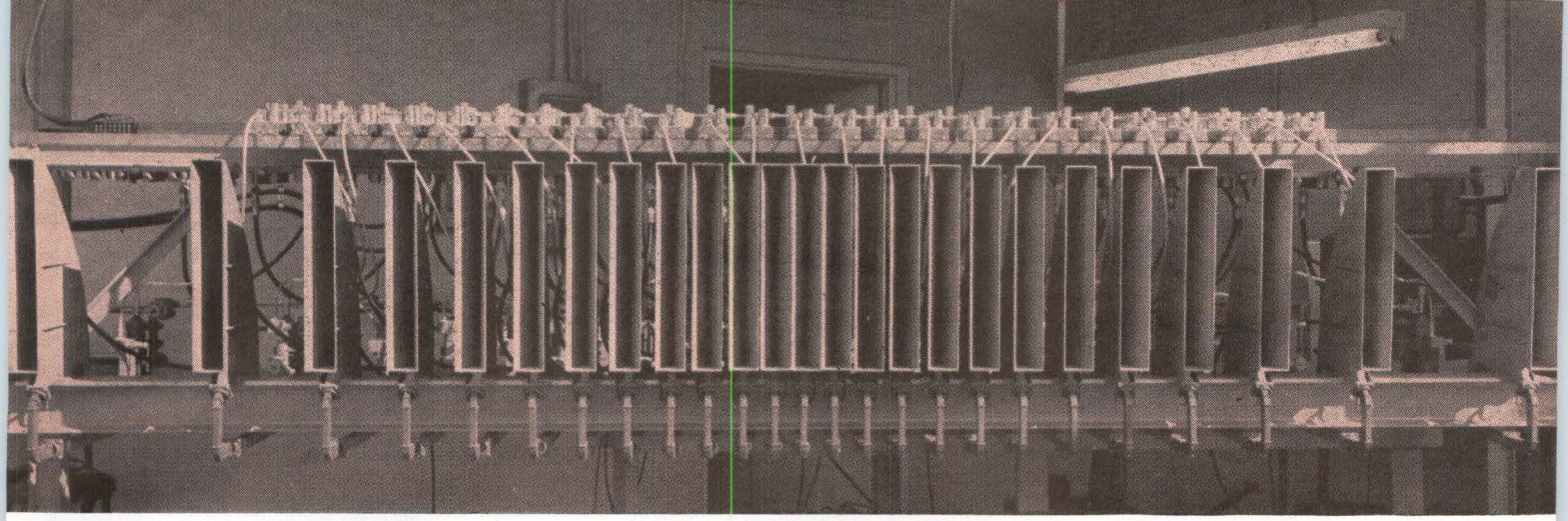
The problem of scanning a rectangular planar array is simplified (only n not $n \times m$ phase shifters are needed) if phase shifters are used only along columns. The El Campo, Texas solar radar uses this approach; its giant antenna is scanned in the east-west plane by phase shifters and in the north-south plane by manually changing the phase to each dipole radiator.

Dipoles can be excited by proximity-coupling to a two-wire line. This reduces the problem of controlled radiation to its essentials, for two-wire line, dipole rods and proper geometry are all that is required to build a linear array. Controlled radiation from a transmission line[30] only has been achieved with some success and eliminates the need for dipoles.

The proximity-coupled dipole can be scanned over 50 deg from the normal to the array by motion along the two-wire feeders.[11] If transmission and reception is accomplished by feeding from both ends of the array, a ± 50 scan angle can be achieved. Dual-terminal feeding[31] allows scanning of very large arrays using corporate structure phase shifters along the columns and by feed motion on the rows resulting in large sector of solid angle coverage. The most attractive means for achieving the motion of the dipoles appears to be either by relay-controlled trolleys or by mounting them on a rubber belt. Such antennas are contenders for the space era in that power handling, pattern quality and gain, bandwidth and scan rates are all acceptable for, say, satellite communication in the 50 — 500 Mc band. Cross or variable polarization is not possible, however.

INTERFEROMETERS—There is a class of antennas with large overall dimensions whose apertures are not completely filled with radiating elements. Usually the designer of such antennas is more interested in angular resolution than antenna gain. The gain of an antenna array is proportional to the number of radiating elements in the array assuming uniform distribution of power to the elements and the beamwidth is related to the overall dimension of the antenna in the plane in which the beamwidth is measured. To some extent the virtues of high-gain aperture antennas and high resolving interferometers can be achieved by separating two large aperture antennas a long distance apart and producing fine interferometer lobe structure within the broader beams of the aperture antenna. This technique is being used at Big Pine, California by California Tech. and near Great Malvern by the Royal Radar Establishment in England. Sometimes interferometers take the form of many moderately sized apertures regularly and widely spaced to produce many grating lobes. This approach is used by Stanford University[32] and the Mendon Observatory, France.[33]

A number of ingenious methods have been advanced for operating on the multilobe pattern characteristics of interferometers to produce a single unambiguous beam.



ADAPTIVE ANTENNA *array of unequally spaced horns covering 100 wavelength aperture, capable of automatically radiating the conjugate of a received wavefront to produce a focus at distant source. Developed at Research Division, Electronics Communications, Inc., under contract with USAF Rome Air Development Center—Fig. 7*

This goal can only be achieved on the receiving patterns and it usually involves some nonlinear operation on the signals. Walsh and Bond[34] achieved this result by multiplying together the two interference patterns produced by interlaced gratings of different spacings. The net result is an array of radiating elements much more widely spaced than $\lambda/2$, but with only one main beam. This pattern is electronically steerable in azimuth and the condition for nonambiguous pattern is maintained over a large bandwidth. The Drane-Davenport[35, 36] antenna, a further development of the Covington and Broten array, is also a linear array of nonuniformly spaced elements producing a single antenna beam (Fig. 6). This interferometer is made up of a continuous section of $\lambda/2$-spaced elements augmented by a regular progression of widely separated radiators. The signals received by these radiators are phase-modulated, correlated, and then multiplied together to produce a single beam. Another successful geometric arrangement was devised at Stanford Research Institute[37] to produce a single-beam widely-spaced interferometer. Workers at Hughes Aircraft[38] have succeeded, through time modulation and nonlinear processing, in getting beam scanning, multilobe generation and pattern control.

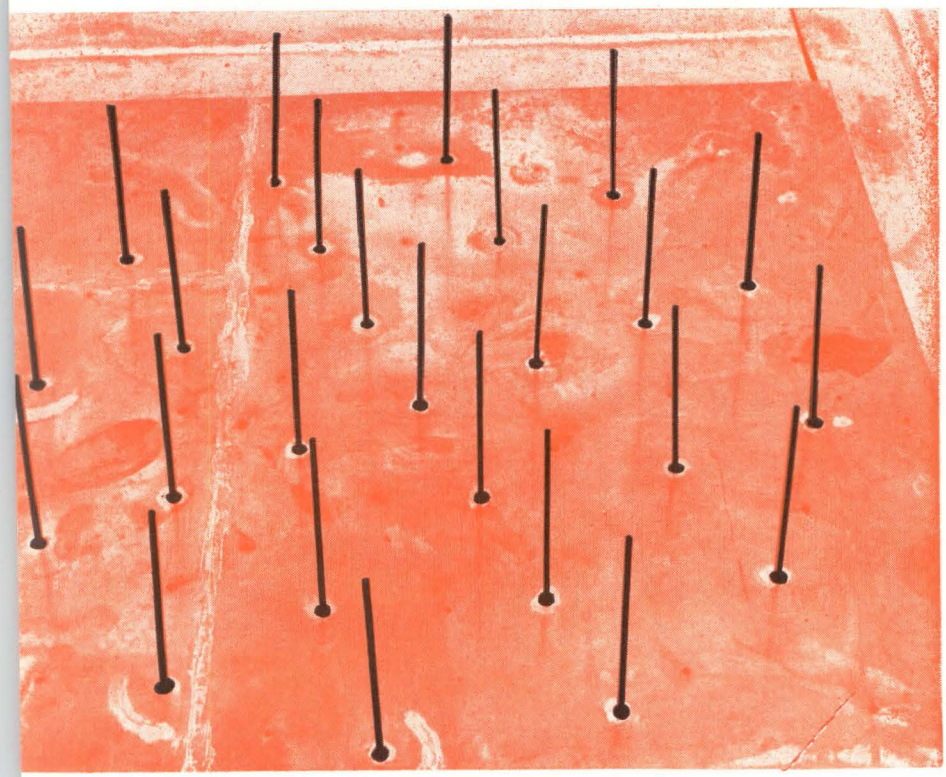
One of the better conceptual studies showing the relation between antenna pattern and bandwidth of signals received was accomplished at RADC[39] by N. J. Nilsson, et al. When the spectrum and modulation of the radiated signal can be controlled, as with a radar system, antenna patterns can be significantly controlled by interferometer configuration and signal modulation.

There is much active research going on in nonlinear antennas.[40] These antennas produce cross products which can distort the information or target image when several coherent or partially coherent signals are received. They often lack gain, and signal-to-noise levels are not always improved by the multiplication and correlation performed to produce the antenna patterns. When interferometer elements are spaced too far apart, random variations in the atmosphere or ionosphere may reduce the seeing as on large optical telescopes. This effect, of course, affects large aperture antennas also. Very little reliable data on medium effects at various frequencies exists, but for angles near the earth's horizon, there are probably existing antennas whose performance is degraded by lack of coherence across the large antenna dimension. The nature of the linear and nonlinear antenna performance under conditions of partial coherence is available through the work of Parrent, Skinner, Shore and Drane.[41, 42, 43]

VOLTAGE AND CURRENT CONTROLLED PHASE SHIFTERS—Replacing mechanical phase shifters in planar arrays by current or voltage controlled phase shifters offers the most obvious method for speeding up scanning. A great deal of effort to produce ferrite phase shifters has not resulted in completely reliable, temperature-insensitive, inexpensive components. Research on voltage-controlled ferroelectric devices has been less extensive and one of the first successful voltage-controlled scanning arrays[44] was reported in 1959. This antenna array used varactor diodes as voltage-controlled phase shifters. Research is continuing on materials for electronic phase control in the transmission lines or guides feeding antenna arrays. Perhaps some day it will be possible to scan a large array carrying high r-f power with low loss by simple voltage variation on the feed lines.

FREQUENCY SCANNING—Several methods of scanning depend on the fact that as the frequency is varied on a traveling-wave-type linear array, the phase between elements changes, causing the beam to squint or move slightly. This can be the basis for scanning the beam by intensifying the effect through design. The desired antenna performance is usually a liberal amount of beam swing for a small amount of frequency change. Such arrays and their feeding lines are called dispersive, for they separate different frequencies into different beam directions, much as a dispersive glass prism separates the colors in white light. In fact, frequency-scanned arrays can be designed using waveguide type prisms, but it is usually simpler to use another nuisance effect—the long line effect—to produce dispersion. By connecting long equal lengths of transmission line between adjacent radiating elements, very satisfactory beam scanning is achieved with tolerable transmission losses.

PHASED ARRAYS—The main disadvantage of fre-



AMPLITUDE SCANNED *circular array of concentric monopoles over a ground plane, University of Tennessee, Knoxville—Fig. 8*

REGION I

PASSIVE, LINEAR, FIXED-GEOMETRY OPERATIONS PERFORMED BY INTERCOUPLING NETWORKS CONNECTING ELEMENTAL FEEDS LOCATED ON BEST FOCAL SURFACE.

FUNCTIONS:

(1) RESTORATION OF PATTERN TO ON-FOCUS AXIS QUALITY
(2) APERTURE ILLUMINATION AND SPILL-OVER CONTROL

REGION II

PASSIVE, LINEAR ELECTRONIC SWITCHING OPERATIONS

FUNCTIONS:

(1) VARIABLE NETWORKS AND SWITCHES TO INTERCONNECT BEAMS FOR BEST SCANNING AND SEARCH PATTERNS
(2) PHASING CHANNELS TO PERMIT FOCUSING IN NEAR ZONE OF ANTENNA APERTURE

REGION III

ELECTRONIC NONLINEAR PROCESSES (MIXING AND AMPLIFICATION)

FUNCTIONS:

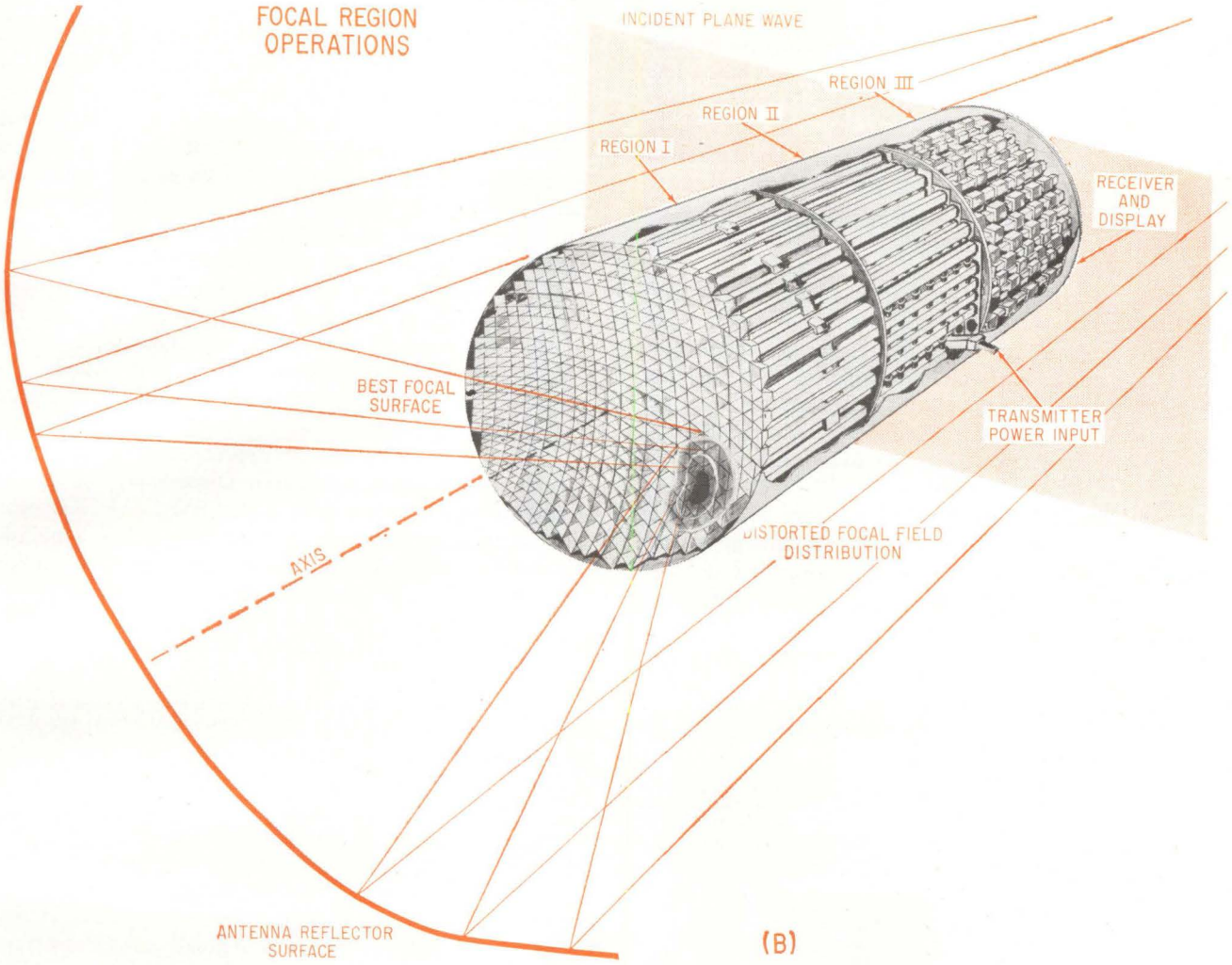
(1) PHASE COMPARISON FOR EXTRACTING ANGLE DATA OUT OF WIDE ANTENNA BEAMS
(2) MONOPULSE COMPARISON FOR ACCURATE TRACKING
(3) OPTIMIZE RECEIVED PATTERNS DEPENDING UPON TARGET CHARACTERISTICS
(4) AUTOMATIC CONTROL AND SELF-ADAPTING TECHNIQUES (A)

FOCAL-REGION PROCESSING *performs functions listed in (A); the operations are illustrated on antenna in (B) opposite page—Fig. 9*

quency scan is the need to transmit or receive a wide spectrum in order to scan the beam (or beams). This defect is corrected in the next scheme to be discussed which again makes use of dispersion in long lines to produce phase shifts. But, by two mixing operations, the proper increments of phase shift between radiators are generated without any change in radiated frequency external to the antenna.[45] As phase is preserved on mixing, it is possible to change the frequency of a control signal and run it through different lengths of dispersive line and then, by a further mixing operation, obtain the original transmitted frequency shifted in phase This is a successful way to scan electronically and has the advantage that good frequency stability accurately controls the beam position. These c-w control frequencies (sine waves) can be distributed around a large antenna system with good fidelity and in the presence of noise. However, now crystal mixers or other nonlinear elements are needed which add to the losses of the dispersive lines. The antenna is no longer reciprocal, so special accommodations must be made for scanning received and transmitted beams. This separation of the transmission and receiving function provides opportunity to generate high transmission power by assigning a power amplifier to each radiator element while simultaneously scanning the same receiving pattern or one different from the transmission pattern. The added versatility, including self-adapting capabilities and design flexibility (see Fig. 7) is obtained at a high cost per unit area of antenna aperture.

INCREMENTAL FREQUENCY SCANNING—A distinctly different kind of frequency scan was appreciated early by Roy C. Spencer at AFCRL, but has only recently been developed. Scanning a phased array means tilting a plane Huygens wave front from the antenna by linearly increasing or decreasing the phase along the array. When this is done at a uniform rate, the phase at each element changes uniformly. This is tantamount to a change in frequency at each element. Thus a phased array can be made to scan at a uniform rate by increasing the frequency at each progressive radiator by an amount Δf. Cottony at the Bureau of Standards has succeeded in producing the harmonics Δf, $2\Delta f$, $3\Delta f$, ... $N\Delta f$ (where f corresponds to the scan rate) and adding these to some higher r-f frequency. Of course f and its family of harmonics can be varied and the beam made to vary in sweep speed. Cottony[46] actually modulated the local oscillators on the receivers attached to Yagi antennas according to the $N\Delta f$ technique to provide a rapid beam sweep.

AMPLITUDE SCAN—Electronic scanning methods discussed so far for steering beams or patterns from a fixed array or aperture all depend on producing a variable phase at the radiating elements while keeping the amplitude or power at each radiator as constant as possible. Beam scanning can be produced by maintaining the phase fixed and varying the relative amplitude[47] from $+1$ to -1 to the radiators. It is convenient to vary the output of a balanced amplifier from $+1$ to -1 by changing grid voltages only. Such scanning methods can be adopted to circular arrays (r— θ geometry) where the equal phase elements easily developed by dispersive methods are not adequate. Electronic scanning of circular arrays by phasing methods can certainly be done. Mutual coupling effects can be included in scanning circular arrays (it is more difficult for linear or mattress arrays) and the University of Tennessee[48] has produced excellent sidelobes on



electronically amplitude-scanned circular arrays (see Fig. 8). Schell [49, 50] has also shown that concentric loops and corner reflectors can be scanned using amplitude scan principles. For disadvantages, more radiators are required than for phased arrays, and each amplifier is not used at full output at all times. It has been suggested that the output of each amplifier be combined in a junction to produce a variable phase output and thus eliminate ½ of the radiators. However, such a junction has intolerable reflection, or impedance, characteristics, and adding the amplifier outputs in space has a fundamental advantage. The second objection is not valid either because under rapid scan conditions, each tube can be used up to its full plate dissipation and the maximum rating from a common power supply can be utilized. Amplitude scan and the related synthesis method permit an alternate approach to scanning which has not been fully exploited.[51]

REFLECTOR ANTENNA AND FOCAL REGION—Most reflector antennas have an efficiency of about 50 percent. This represents a 3-db loss or an antenna gain of an ideal aperture one-half the size. This loss is due principally to spillover—that is, energy which never strikes the reflector in the optical method of feeding such reflectors. Such losses cannot be prevented by large directive feeds because severe amplitude tapering also causes loss in gain. In addition, spillover energy usually intercepts the warm lossy earth causing deterioration in the noise temperature of the antenna.

No one has found a cheaper and more satisfactory way to produce a large aperture antenna than by using a single metal reflector surface. As antennas get larger and their beams sharper, optical errors force operation closer to the focus. The total structures become harder to move and maintain in phase coherence while being moved. Although the gain and angular resolution become phenomenally good, the search or surveillance capability becomes poor. With the focal point and reflector in motion, it becomes uncertain where the beam is pointing when target acquisition is made.

What are the remedies? Both the optical telescope and the human eye give some hints. In antenna language, both photographic film and the retina of the eye are multilobe, high-information-rate antennas. The reflector telescope achieves its wide-angle capability by increasing the focal length (focal lengths are usually 3 to 5 times the aperture width for optical telescopes, whereas antennas usually have F/D of 1/4 to 1/2). It is believed that the eye achieves wide angle focusing by longitudinal receptors called rods and cones. The long focal length solution is impractical when extremely tall towers swinging over fixed reflectors are envisioned. However, the design used by Kraus[6] which has the focal axis on a metalized ground plane can make use of the magnification and improved wide angle performance of a long focal length. Using the analogy of the eye, Spencer[17] suggested a longitudinal corrector or line source for the spherical mirror.

Some effort to correct optical errors in the ubiquitous

paraboloidal antenna was undertaken by calculating position of high intensity ridge lines and placing phased line sources along these curved longitudinally extending surfaces.[52] Unlike the spherical reflector, the paraboloid caustic surface does not degenerate into lines, so that while such correcting line sources markedly improve patterns at wide angle from the axis direction, they do not eliminate all optical errors and each beam direction requires a different length of phased corrector.

Possibly the answer to getting an angular acuity and information rate capability comparable to the eye or optical telescope does not lie entirely in optical designs suitable for incoherent light. In radio, there is the possibility of operating on the phase, amplitude and polarization of the fields in the focal region down to detail areas about $(3/4\ \lambda)^2$ in size. Since the focal energy distribution is a Fourier transform of the incident (or desired) energy distribution on the reflector aperture, it is possible to selectively rephase and collect the focal energy to correspond to a desired in-phase, amplitude-tapered aperture distribution that in turn will give rise to the required far field patterns. The question is: can the energy spread and phase distortion in the transverse focal region be processed out to restore the antenna patterns for off-axis directions to their on-axis quality? The experimental answer to date is a qualified yes. Remarkable success in reducing objectionable side-lobe levels over both wide angles and good frequency bands has been achieved by inserting auxiliary feeds in the focal regions (see Fig. 3) based on the location of the field distributions.[53, 54]

This possibility of transverse correction—design of compensating feed structures transverse to the axis of the reflector or in the focal plane—is recommended as a high payoff research topic. Figures 9A and B indicate the sequence of processing operations and the beneficial results to be obtained.

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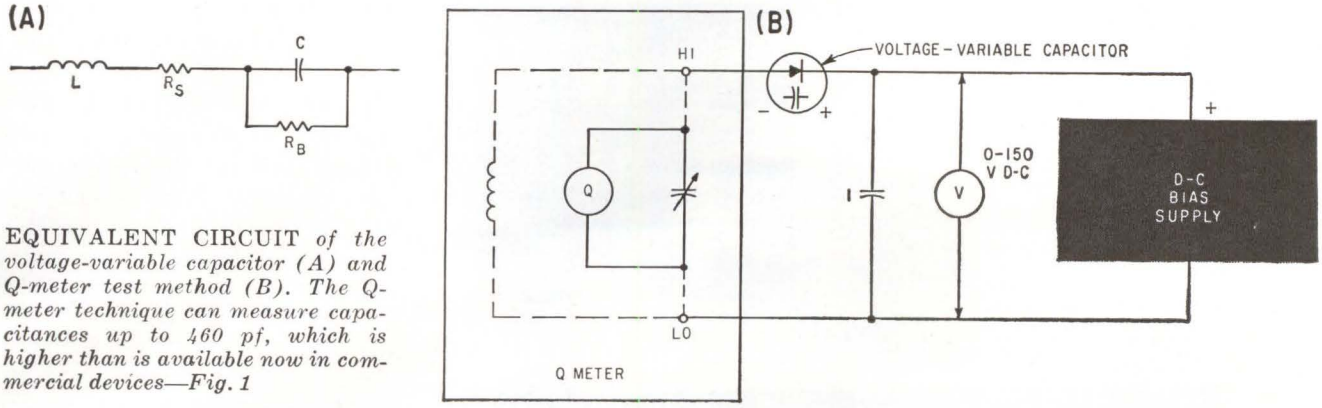

EQUIVALENT CIRCUIT *of the voltage-variable capacitor (A) and Q-meter test method (B). The Q-meter technique can measure capacitances up to 460 pf, which is higher than is available now in commercial devices—Fig. 1*

Three Ways to Measure VARACTORS OF THE FUTURE

Of three common techniques used to measure the parameters of voltage-variable capacitors, the Q-meter test is versatile and is accurate to ± 1 percent. The a-c bridge method is limited in frequency range but can provide somewhat higher accuracy. Maximum capacitance range with R-X meter method is 20 pf

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VOLTAGE-VARIABLE capacitors are formed in single-crystal silicon by the same techniques used to manufacture other semiconductor devices. With leakage currents of only a few millimicroamperes, the device acts like a perfect capacitor with a high shunting resistance; series resistance (due to semiconductor bulk resistance and lead connection resistance) is low. The low series resistance and high shunt resistance result in a Q high enough to fulfill the requirements of nearly all capacitor applications.

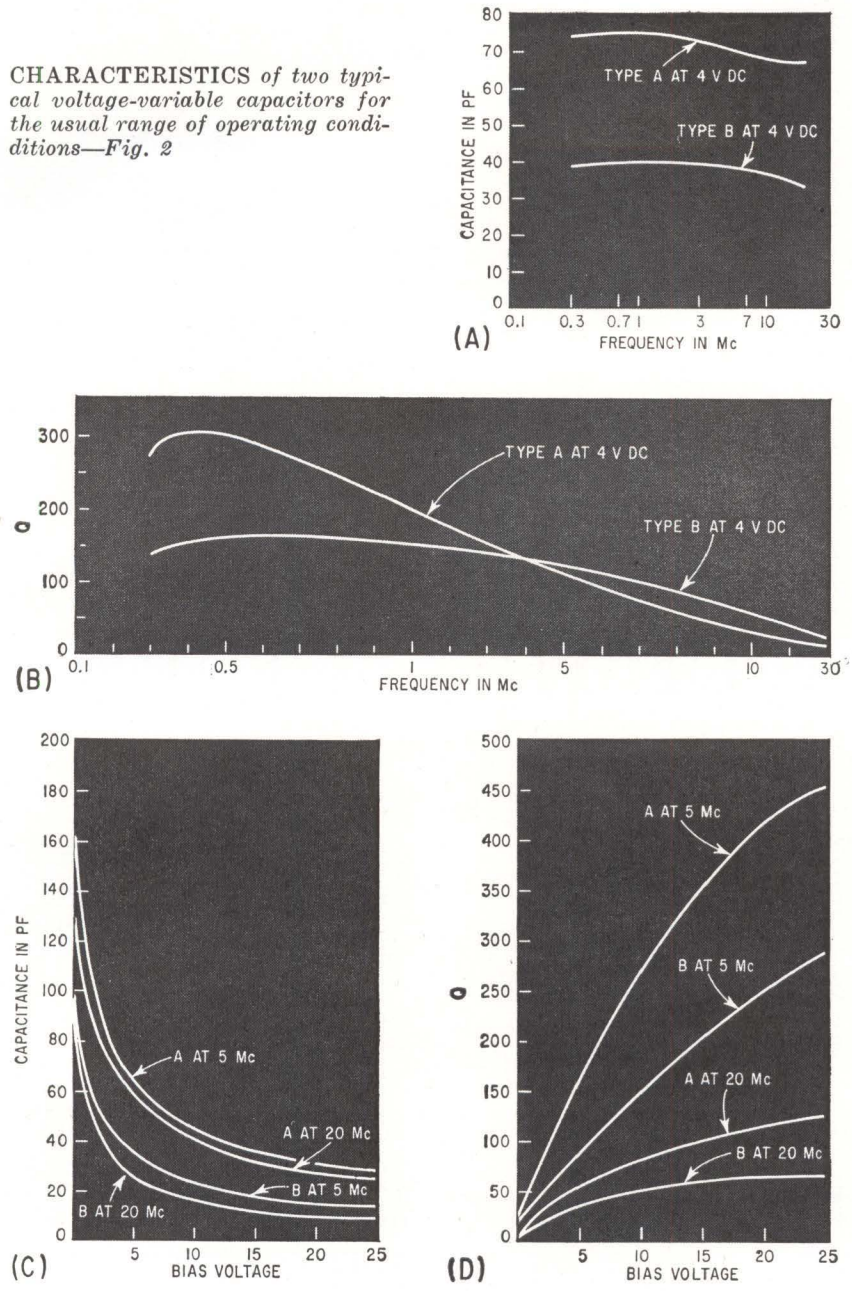
Figure 1A shows the equivalent circuit of the voltage-variable capacitor, where

C = junction capacitance, R_S = series resistance due to bulk resistivity of the semiconductor base and connecting leads, R_B = leakage resistance and is the dynamic inverse resistance of the junction, and L = series inductance.

Typical ranges of parameters are: C (at 4 volts), 7 to 100 pf; R_S, about 5 ohms; R_B, 100 megohms and higher; L, about 5 nanohenrys; Q at 50 Mc (4 volts), 10 to 20; maximum operating voltage, 15 to 130 volts d-c.

Major applications of voltage-variable capacitors are as control and tuning elements. As control devices they are generally placed in parallel with a conventional capacitor to control the total capacitance of systems such as automatic frequency controls, f-m modulators, and adjustable band-pass filters. As tuning devices they are used to supply all or nearly all the capacitance in receiver and transmitter tuning circuits, and in resonant-slope amplifiers.

Voltage-variable capacitors function over a wide range of frequencies. Parameter measurements are usually taken at the operating frequency of the application, typically from 1.5 to 20 Mc. Measurements using a Q-meter can be made from 50 Kc to 50 Mc. Since a d-c bias voltage cannot be applied directly to the terminals of the Q meter, the capacitor is placed in series with the meter as shown in Fig. 1B. The 1-microfarad capacitor bypasses the Q-meter signal from the power supply. Both the voltage-variable and the bypass capacitor are mounted on a $2 \times 2 \times \frac{1}{8}$ inch Plexiglass plate, and are connected to the Q-meter through banana plugs. The capacitor under test is placed in clips mounted on the Plexiglass plate, and bias voltage is applied directly across the bypass capacitor. With the fixture the capacitance of the voltage-variable capacitor can be measured over its rated voltage range at any desired test frequency. To date, all voltage-variable capacitors have a minimum voltage rating



CHARACTERISTICS *of two typical voltage-variable capacitors for the usual range of operating conditions—Fig. 2*

of 0.1 volt d-c and maximum ranging from 15 to 130 volts d-c.

PARAMETER MEASUREMENTS—Measurements are made as follows:

(1) Select the test frequency and connect the corresponding work coil to the coil terminals of the Q-meter. Apply power and make the initial adjustments of the Q-meter.

(2) Place the test capacitor in the test clips, observing the polarity shown in Fig. 1B. The voltage-variable capacitor normally blocks d-c current and isolates the Q-meter from the bias supply. If the unit is connected with opposite polarity, the Q-meter will not be isolated and it will not resonate during operation; also, its thermocouple may be damaged.

(3) Lift the negative lead of the capacitor under test and position it approximately one inch above the top of the test clip.

(4) Adjust the Q-meter to resonance and read the initial values of capacitance and Q: (C_1 and Q_1).

(5) Place the negative lead firmly in the test clip and apply the desired test voltage.

(6) Adjust the Q-meter to resonance again and read the final values of C and Q: (Q_2 and C_2).

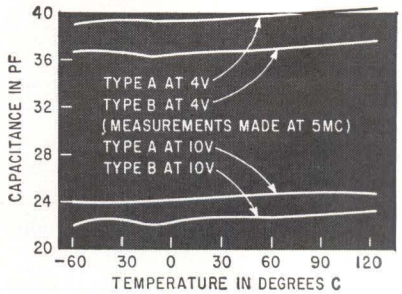
(7) The capacitance of the capacitor is $C = C_1 - C_2$ and the effective Q (Q_e) of the unit can be calculated from

$$Q_e = \frac{Q_1 Q_2 (C_1 - C_2)}{(Q_1 - Q_2) C_1}$$

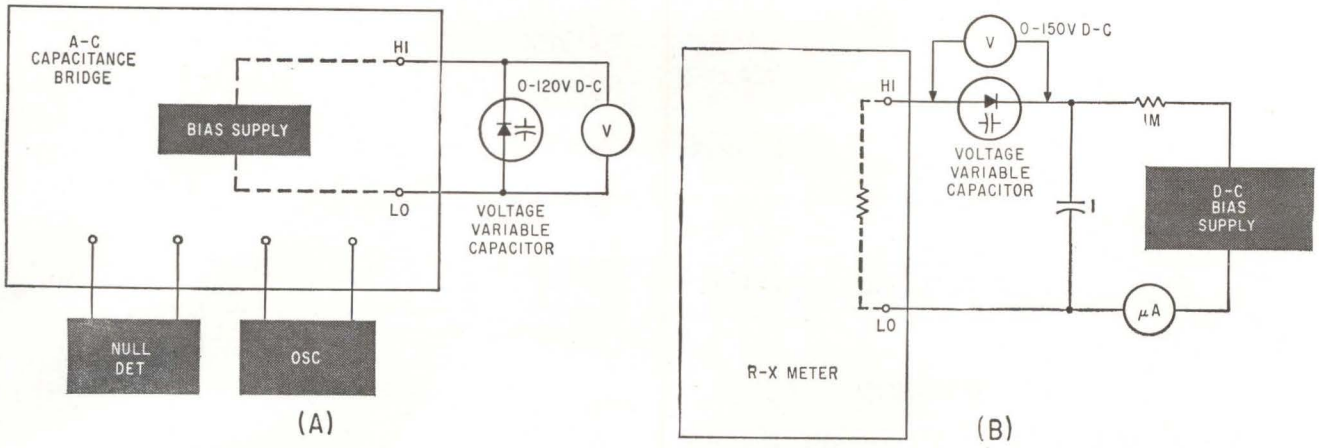
The Q-meter method cannot be used for measuring capacitances greater than 460 picofarads. However, since this value presently exceeds the maximum capacitance of commercial voltage-variable capacitors, the Q-meter technique has wide application. It can measure capacitance over the frequency range of 50 Kc to 50 Mc at any desired test voltage, and the corresponding change in Q can be calculated. Figures 2A and 2B show characteristics of some typical voltage-variable capacitors. All measurements were performed on the Q-meter at a test voltage of 4 volts d-c. Figure 2C is a plot of capacitance as a function of voltage at 5 Mc and 20 Mc. Figure 2D is a plot of Q as a function of bias voltage at the same frequencies.

Little change in capacitance occurs over the temperature range of −55 to +125 C., as Fig. 3 shows. The curves represent capacitance at 4 volts and 10 volts d-c, and at a test frequency of 5 Mc.

AUXILIARY COILS—Since capacitances are determined from the difference between C_1 and C_2, the value of C_1 obtained must be at least equal to the sum of the maximum expected capacitance of the variable capacitor, under test conditions, and the minimum scale reading on the Q-meter. Under some conditions, the work coils supplied with the meter may not permit readings high enough. To overcome this, the two auxiliary work coils described in the table can be constructed and used in place of the coils supplied with the meter. Both



TEMPERATURE VARIATIONS *do not affect capacitance significantly—Fig. 3*



FREQUENCY RANGE *of a-c bridge measurement technique (A) is extended by external oscillator and null detector. Range of R-X meter technique (B) is up to 20 pf—Fig. 4*

coils are made of 14-gage, tinned, soft copper wire, are mounted on Plexiglass sheets, or any similar, high-dielectric-constant material, and are housed in 2 × 2 × 4 inch aluminum boxes to shield them from stray fields. They are terminated with banana plugs, spaced to fit the meter.

AC-BRIDGE METHOD—To measure capacitance by the a-c bridge method, a capacitance bridge capable of measuring from 1 to 1,000 pf, and with provision for measurement at d-c test voltages is required. An external oscillator and null detector may be used, as shown in Fig. 4A, to take measurements down to 100 Kc.

The a-c bridge test is performed as follows:

(1) Select the desired capacitance range and zero-balance the bridge.

(2) Connect the voltage-variable capacitor to the insulated terminals, observing the polarity.

(3) Apply the bias voltage.

(4) Balance the bridge using the capacitance and conductance dials.

(5) The capacitance may be read directly from the capacitance dial; Q is calculated using

$$Q = \frac{2\pi fC}{G}$$

where C = capacitance in picofarads, G = conductance in micromhos, and f = frequency in Mc.

This technique works well only over the frequency range 100 Kc to 1 Mc. Bias voltages of −5 to +120 volts d-c are available.

Accuracy of measurement is from ±0.25 to ±0.75 percent, depending upon the capacitance range used during measurement.

AUXILIARY WORK COILS

Length of Wire	Test Frequency	Expected Value of C_1
11 inches (Two 1.25 inch i-d loops)	20 Mc	395 pf
5 inches (Looped around terminals)	30 Mc	335 pf

R-X METER METHOD—The R-X meter measuring method is similar to the Q-meter method in that it employs the same test fixture, but with a 1-megohm resistor added to isolate the a-c supply from the R-X meter, as shown in Fig. 4B.

The test circuit of Fig. 4B can be used whenever the d-c biasing current is less than 50 milliamperes, and can be used on all commercial voltage-variable capacitors available so far. (The d-c leakage currents are less than 1 microampere.) The procedure for measurement is:

(1) Select the test frequency and adjust the R-X meter.

(2) Connect the circuit and adjust the meter and the bias supply to obtain the test voltage across the capacitor.

(3) Since the impedance of the voltage-variable capacitor is capacitive-reactive, adjust the C_P control for the initial minimum null; then adjust the R_P and C_P controls alternately to obtain final balance.

(4) The capacitance is read directly from the C_P dial; the Q can be calculated using

$$Q = \frac{R_P}{X_P}$$

where R_P is read directly from the dial and X_P is calculated from

$$X_P = \frac{1}{2\pi fC_P}$$

or, combining the two equations

$$Q = 2\pi fR_PC_P$$

This method of measurement can be used from 0.5 to 250 Mc and will measure voltage-variable capacitors with up to 20 picofarads at the bias voltage of interest.

The accuracy of measurement varies with frequency and ranges from ±0.5 to ±1 percent over the range from 0.5 to 50 Mc.

Of the three measuring methods, the Q-meter method is the most versatile. Capacitance can be measured at both varying frequency and varying bias voltage. Measurement accuracy is ±1 percent and is independent of frequency.

The a-c bridge method is limited to capacitance measurements over a narrow band of frequencies (100 Kc to 1 Mc), and no voltages in excess of 120 volts d-c can be used during measurement. This method does, however, offer the greatest measurement accuracy; depending upon the capacitance, the accuracy is from ±0.25 to ±0.75 percent.

The R-X meter method offers the advantage of measuring capacitance at varying frequency and at varying bias voltage, but is limited to a maximum capacitance of 20 picofarads. This method is similar to the Q-meter method, and offers the same measurement accuracy,

Simplified LOW-PASS FILTER DESIGN

New method for exact design of low-pass filters having maximally flat amplitude in the passband allows the point of infinite rejection to be directly chosen

By WILLIAM J. KERWIN, 1555 Mary Avenue, Sunnyvale, California

DESIGN of a Tchebysheff type II filter by conventional methods requires a considerable knowledge of network theory as well as the determination of the complex roots of a 6th degree polynomial. This is not only difficult and time-consuming, but the point of infinite rejection is not determined until after some preliminary work has been completed. If this result is unsatisfactory, another trial must be made.

This method not only simplifies the work but allows the point of infinite rejection to be directly chosen. This is useful in the design of a filter for use with a demodulator in which a specific ripple frequency due to the carrier must be filtered out. It is also valuable in obtaining a wider passband and better rejection of the unwanted frequency components than could be obtained by the usual Butterworth filter which has no rejection frequency.

Figure 1A shows the basic π-section filter to be considered. The addition of a capacitor (C_2 in Fig. 1B) is all that is needed to obtain an infinite rejection point at any specified frequency. Addition of this capacitor produces the improvement in filter performance.

FILTER FORM—The filter shown has no insertion loss and can be designed for flat response in the passband. The shape of the resultant filter curve is shown in Fig. 1C. The cut-off frequency is normalized to $\omega = 1.0(-3\text{db})$ and the frequency of infinite rejection is indicated as ω_x. The frequency of minimum attenuation beyond ω_x is designated ω_{max} and the amplitude at that point as A_{max}. An increased slope of cutoff is produced by reducing the value of ω_x and results in an increase in A_{max}.

An analysis of the circuit shown in Fig. 1B results in ($p = j\omega$)

$$\frac{E_{out}}{E_{in}} = \frac{L\,C_2\,P^2 + 1}{\begin{matrix} L\,(C_1\,C_2 + C_1\,C_3 + C_2\,C_3)\,P^3 + \\ L(C_2 + C_3)\,P^2 + (C_1 + C_3)\,P + 1 \end{matrix}} \quad (1)$$

Simplify this by letting

$$\frac{E_{out}}{E_{in}} \overset{\Delta}{=} \frac{\alpha p^2 + 1}{ap^3 + bp^2 + cp + 1} = \frac{1 - \alpha\omega^2}{1 - b\omega^2 + j(c\omega - a\omega^3)}\Bigg]_{p = j\omega} \quad (2)$$

and the square of the magnitude is

$$\left|\frac{E_{out}}{E_{in}}\right|^2 = \frac{(1 - \alpha\omega^2)^2}{(1 - b\omega^2)^2 + (c\omega - a\omega^3)^2} \qquad \frac{1 - 2\alpha\omega^2 + \alpha^2\,\omega^4}{\begin{matrix} 1 + (c^2 - 2b)\,\omega^2 \\ + (b^2 - 2ac)\,\omega^4 + a^2\,\omega^6 \end{matrix}} \quad (3)$$

The necessary condition for flat response is that each term in the numerator be equal to the corresponding term in the denominator. Thus

$$c^2 - 2b = -2\alpha \quad (4)$$

$$b^2 - 2ac = \alpha^2 \quad (5)$$

In addition, to set cutoff (0.707 amplitude) at $\omega = 1.0$ rps

$$\left|\frac{E_{out}}{E_{in}}\right|^2 = (0.707)^2 = \tfrac{1}{2} \text{ at } \omega = 1.0 \text{ rps} \quad (6)$$

Setting $\omega = 1.0$ in Eq. 3 results in

$$\left|\frac{E_{out}}{E_{in}}\right|^2 = \frac{1 - 2\alpha + \alpha^2}{1 + c^2 - 2b + b^2 - 2ac + a^2} = \tfrac{1}{2} \quad (7)$$

Using Eq. 4 and 5 obtain from Eq. 7

$$a^2 = 1 - 2\alpha + \alpha^2; \quad a = 1 - \alpha \quad (8)$$

Note that the position of ω_x is determined by the value of ω at which the numerator of Eq. 2 is equal to zero. That is $1 - a\omega^2 = 0$ at $\omega = \omega_x$. Therefore

$$\alpha = 1/\omega_\infty{}^2 \quad (9)$$

These are the necessary conditions to determine the coefficients of Eq. 2 for any desired ω_x.

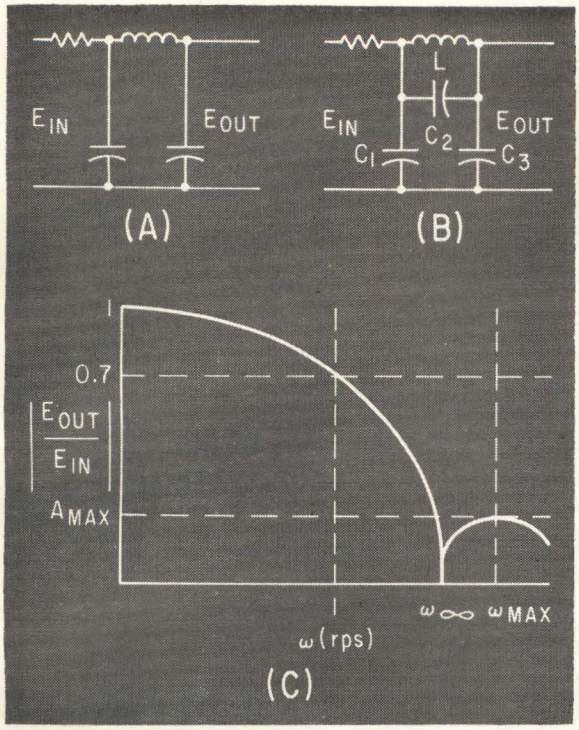
Step 1: Choose ω_∞ and find $\alpha = 1/\omega_\infty{}^2$.

Step 2: Solve for $a = 1 - \alpha$.

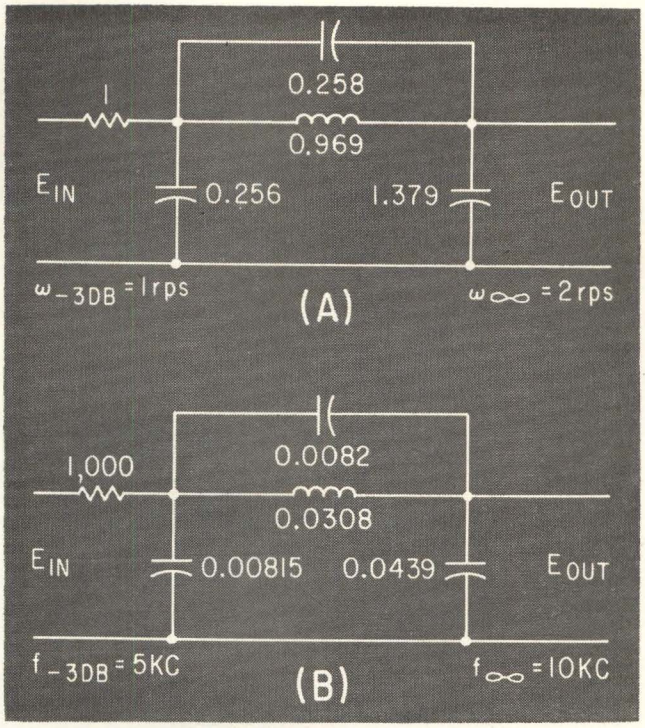
Step 3: Substitute the value of α from Step 1 and solve for c. (Choose + real root) $c^3 + 4\alpha c + 8(\alpha - 1) = 0$. This equation is a result of combining Eqs. 4, 5 and 8.

Step 4: Solve for $b = (c^2 + 2\alpha)/2$. (From Eq. 4.)

Having a,b,c and a, return to Eq.



BASIC *π-section filter (A), improved filter (B) and resultant filter curve (C)—Fig. 1*



RESULTANT FILTER *with normalized values (A) and final design result (B)—Fig. 2*

1 and compare it to Eq. 2

$$LC_2 = \alpha \quad (10)$$

$$L\,(C_1\,C_2 + C_1\,C_3 + C_2\,C_3) = a \quad (11)$$

$$L\,(C_2 + C_3) = b \quad (12)$$

$$C_1 + C_3 = c \quad (13)$$

Simultaneous solution of Eqs. 10 through 13 results in

Step 5: $C_1 = (a - \alpha c)/(b - \alpha)$

Solving Eq. 13 for C_3

Step 6: $C_3 = (cb - a)/(b - \alpha)$

From the above and a combination of Eqs. 10 and 12

Step 7: $L = (b - \alpha)^2/(cb - a)$

From the above and Eq. 10

Step 8: $C_2 = \alpha\,(cb - a)/(b - \alpha)^2$

As an example, assume the frequency of infinite rejection is to be at twice the cut-off frequency ($\omega = 1.0$ rps in the normalized filter—that is $\omega_\infty = 2.0$ rps.

Step 1: $\alpha = 1/\omega_\infty{}^2 = 0.250$
Step 2: $a = 1 - \alpha = 0.750$
Step 3: $c^3 + 4\alpha c + 8\,(\alpha - 1) = 0$
$c^3 + c - 6 = 0$
$c = 1.635$
Step 4: $b = (c^2 + 2\alpha)/2 = 1.585$
Step 5: $C_1 = (a - \alpha c)/(b - \alpha) = 0.256$ f
Step 6: $C_3 = (cb - \alpha)/(b - \alpha) = 1.379$ f
Step 7: $L = (b - \alpha)^2/(cb - a) = 0.969$ h
Step 8: $C_2 = [\alpha\,(cb - a)]/(b - \alpha)^2 = 0.258$ f

The resultant filter with element values in normalized form is shown in Fig. 2A.

Assuming that a 5,000-cps cutoff frequency and an input resistance of 1,000 ohms are desired, these relations are needed

$$R = R_N Z \quad (14)$$

$$L = L_N Z/\omega \quad (15)$$

$$C = C_N/Z\omega \quad (16)$$

The subscript N denotes the normalized element values, Z the increase in input resistance, and ω the increase in cutoff frequency from their normalized values of $R = 1.0$ ohm and $\omega = 1.0$ rps. For these conditions $f_{-3db} = 5{,}000$ cps (that is $\omega_{-3db} = 2\pi\ 5{,}000$) and R = 1,000 ohms: $\omega = 2\pi\ 5{,}000$ and $Z = 1{,}000$.

Thus

$R = (1.0\text{ ohm})\,Z = 1{,}000$ ohms
$C_1 = 0.256\,f/\omega Z = 0.00815\ \mu$f
$C_2 = 0.258\,f/\omega Z = 0.00821\ \mu$f
$C_3 = 1.379\,f/\omega Z = 0.0439\ \mu$f
$L = 0.969\,(Z)/\omega = 0.0308$ h

The final filter design is shown in Fig. 2B.

ATTENUATION — To determine the minimum attenuation in the cutoff region, determine ω_{max}. Substituting into Eq. 3, Eqs. 4, 5 and 8

$$\left|\frac{E_{out}}{E_{in}}\right|^2 = \frac{1 - 2\alpha\omega^2 + \alpha^2\,\omega^4}{1 - 2\alpha\omega^2 + \alpha^2\omega^4 + (1-\alpha)^2\omega^6} \quad (17)$$

Differentiating and equating to zero

$$\omega_{max} = \sqrt{3/\alpha} \quad (18)$$

Substituting Eq. 18 into Eq. 17

$$\left|\frac{E_{out}}{E_{in}}\right|^2_{\omega_{max}} = \frac{1}{1 + 6.75\,(1-\alpha)^2/\alpha^3} \quad (19)$$

as the squared amplitude at ω_{max}. In the previous example $\alpha = 0.25$ so $\omega_{max} = 3.46$ and

$$\left|\frac{E_{out}}{E_{in}}\right|^2_{\omega_{max}} = \frac{1}{244}$$

Thus, the attenuation is 23.9 db or greater for all values of ω greater than ω_x. When the attenuation in the cutoff band is the critical design factor, α can be determined directly from Eq. 19 for any given attenuation minimum in the cutoff band, and the design continued with Step 2 of the design procedure. The low-pass filters designed by these methods can be converted to equivalent high-pass, bandpass or band-rejection filters by conventional methods.

It should be noted that a minimum value of 1.52 exists for ω_x. An attempt to choose a lower value will result in C_1 becoming negative.

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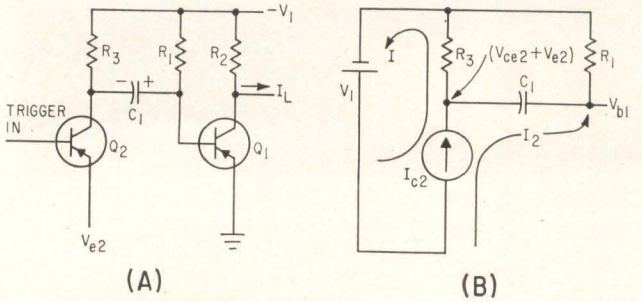
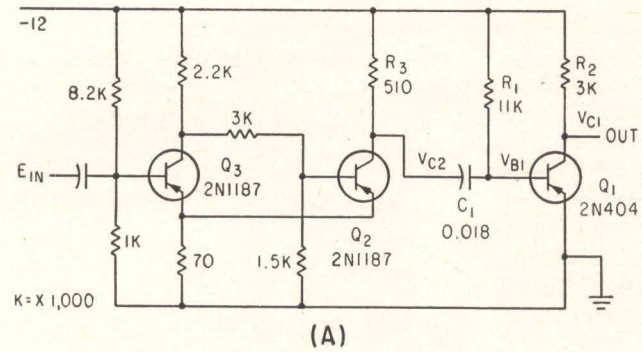
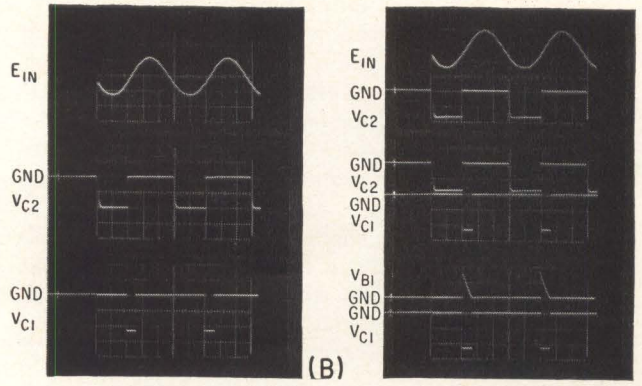
Eliminating the First Stage of a

How to economize on components by using the output stage of a circuit driving a monostable multivibrator as the first stage of the monostable multivibrator. Example illustrates use of design equations



BASIC *pulse-forming circuit (A) uses output stage (Q_2) of a driver as the input section of a monostable multivibrator (Q_2-Q_1). Partial equivalent circuit is shown in (B)—Fig. 1*





CIRCUIT DESIGNATIONS *of this pulse former (A) correspond to those shown in Fig. 1. Typical circuit waveshapes (B) have time scale of 200 μsec/cm and vertical scale of 5 v/cm—Fig. 2*

CONTROL or computing circuits often require a pulse of fixed duration at the output of a Schmitt trigger or other digital circuit. This requirement is most often met by a monostable multivibrator. The monostable configuration can be simplified with a saving in components by considering the output stage as part of the monostable circuit.

Consider Fig. 1A. In the quiescent state, transistor Q_1 is held in saturation by the current in R_1 while Q_2, the output stage of a Schmitt trigger, is off due to biasing. If $V_1 >> V_{be1}$, capacitor C_1 is charged to V_1 volts with the indicated polarity. When Q_2 is turned on, a positive voltage is applied to the base of Q_1, turning it off. If the instant that Q_2 turns on is $t = t(0)$, circuit timing is governed by

$$V_c(t) = (V_{e2} + V_{ce2} - V_1) + (2V_1 - V_{e2} - V_{ce2})e^{-t/T}$$

Where $T = R_1 C_1$.

$$V_{b1}(t) = -(V_{e2} + V_{ce2}) + V_c(t)$$
$$= -V_1 + (2V_1 - V_{e2} - V_{ce2})e^{-t/T} \quad (1)$$

Transistor Q_1 will remain off until its base voltage reaches zero volts. From Eq. 1

$$0 = -V_1 + (2V_1 - V_{e2} - V_{ce2})\, e^{-t/T}$$

From which

$$t = -R_1 C_1 \ln [2 - (V_{e2} + V_{ce2})/V_1] \quad (2)$$

DESIGN CONSIDERATIONS—Since the assumption was made that $V_c(0)$ was equal to V_1, this condition must be provided for in the design of the circuit. This can be accomplished by restricting the recovery time R_2C_1 to be small compared to the minimum off time of Q_2. Capacitor C_1 can be assumed to be completely charged if the product $5R_2C_1$ is made equal to the minimum off time of Q_2 thus satisfying one requirement (Requirement 1). The off time of Q_2 depends on the firing points of the Schmitt trigger.

The accuracy and the repeatability of the pulse width are affected by leakage currents and the change of emitter voltage of Q_2 due to capacitor surge currents. Ignoring leakage for the moment, derive an expression for the collector current of Q_2 from the equivalent circuit of Fig. 1B.

$$I_1 = [V_1 - (V_{ce2} + V_{e2})]/R_3$$
$$I_2(t) = [V_1 - (V_{ce2} + V_{e2}) + V_c(t)]/R_1$$
$$= (2V_1 - V_{ce2} - V_{e2})e^{-t/T}/R_1$$

However, $I_{c2}(t) = I_1 + I_2(t)$

$$= \frac{V_1 - (V_{ce2} + V_{e2})}{R_3} + \frac{(2V_1 - V_{ce2} - V_{e2})e^{-t/T}}{R_1}$$

$$I_{c2}(0) = \frac{V_1 - (V_{ce2} + V_{e2})}{R_3} + \frac{2V_1 - (V_{ce2} + V_{e2})}{R_1} \quad (3)$$

Equation 3 shows that the forward base drive of Q_2 supports more than the d-c collector current when transistor Q_2 turns on. If this is not designed into the circuit the output pulse width may differ from the calculated value (Requirement 2).

The effect on V_{e2} and V_{ce2} of this surge current can

Monostable Multivibrator

By RUSSELL L. PAUL and ALLAN S. OTTENSTEIN
Seaboard Electronic Corp., New York, N. Y.

be minimized by making the collector current of Q_2 large with respect to the expected capacitor surge current (Requirement 3).

Transistor leakage currents affect the pulse width by producing an effective voltage change at the base of Q_1 due to I_{CO1} and at the collector of Q_2 due to I_{CO2}. By choice of current values in the elements, the error produced by leakage can be reduced to within the error due to normal component tolerances (Requirement 4).

DESIGN PROCEDURE—The first step in the design of a circuit is to choose the maximum value of collector current in transistor Q_1 for a load current I_L. Hence

$$I_{c1} = (V_1 - V_{ce1})/R_2 + I_L \quad (4)$$

For Q_1 to be saturated, R_1 must supply a minimum base drive current I_{bf}

$$I_{bf} = I_{c1}/h_{FE\,min} \quad (5)$$

To reduce the effect of I_{CO1} on pulse width, make $I_{bf} \geqq 10\ I_{CO1\,max}$. Then, choosing $I \geqq I_{bf}$, or $I \geqq 10\ I_{CO1\,max}$, whichever is greater

$$R_1 \leqq (V_1 - V_{be1})/I \quad (6)$$

This satisfies Requirement 4.

The emitter voltage of output stage Q_2 is determined primarily by the circuit. In the Schmitt trigger of Fig. 2A, the value of V_{e2} is determined by the desired threshold voltage and input impedance of the trigger circuit. If, on the other hand, the driving circuit is a flip-flop or inverter, the emitter voltage may be zero, or set at some other level as required by the application.

Obtaining the value of V_{ce2} from the manufacturer's data sheet, and given the pulse width, the value of C_1 is determined from Eq. 2. To insure that Eq. 2 is valid, make

$$R_3 \leqq 5\ (\text{minimum off time of } Q_2)/C_1 \quad (7)$$

This satisfies Requirement 1.

The effect of I_{CO2} on the pulse width is minimized when

$$R_3 \leqq V_1 - (V_{ce2} + V_{e2})/10\,I_{CO2} \quad (8)$$

This satisfies Requirement 4.

To prevent the capacitor surge current from affecting the emitter voltage of Q_2, make

$$R_3 \leqq R_1\,[V_1 - (V_{ce2} + V_{e2})]/10\,[2V_1 - (V_{ce2} + V_{e2})] \quad (9)$$

This satisfies Requirement 3. The choice of R_3 is governed by the smallest value resulting from the solution of Eq. 7, 8 and 9.

If V_{e2} equals zero, Eq. 9 need not be considered unless a transistor having a high saturation resistance is employed. A zener diode can be used if it is desired to keep this value constant.

To insure that transistor Q_2 is saturated and that enough base drive is provided to support the initial surge of collector current, see that for Q_2

$$I_{bf2}\,h_{FE\,min} \geqq (V_1 - V_{ce2} - V_{e2})/R_3 + [2V_1 - (V_{e2} + V_{ce2})]/R_1 \quad (10)$$

This satisfies Requirement 2.

In solving Eq. 7, 8 and 9 in the design example, the results of the first two equations appear to have little effect on the value of R_3. This is not always true. Equation 7 will dominate where long pulse widths are required as compared with the period of the operating frequency; Eq. 8 may be dominant if high-temperature operation is involved. All three equations may have considerable effect on the pulse width and all effects must be taken into consideration.

DESIGN EXAMPLE FOR FIG. 2A

TRANSISTOR DATA

For Q_1, a 2N404	For Q_2, a 2N1187
$h_{FE\,min} = 15$ at $I_c = 8$ ma	$h_{FE\,min} = 45$ at $I_c = 20$ ma
$I_{CO\,max} = 0.1$ ma	$I_{CO\,max} = 0.1$ ma
$V_{be1} = 0.15$ v	$V_{be2} = 0.47$ v
$V_{ce1} = 0.1$ v	$V_{ce2} = 0.175$ v

CIRCUIT REQUIREMENTS

Pulse width	125 μsec
Voltage V_{e1}	−12 v
Voltage V_{e2}	−1.5 v
Minimum off time of Q_2	200 μsec
Load Current	4 ma

CALCULATIONS

From Eq. 4

$R_2 = (12 - 0.1)/(8 \times 10^{-3} - 4 \times 10^{-3}) = 2.97$ kilohms

Let $R_2 = 3$ kilohms

From Eq. 5

$I_{bf1} = 8 \times 10^{-3}/15 = 0.53$ ma

Choose $I = 10\ (I_{CO1}) = 10\ (0.1\text{ ma}) = 1$ ma

From Eq. 6

$R_1 \leqq (12 - 0.15)/10^{-3} = 11.85$ kilohms

Let $R_1 = 11$ kilohms

From Eq. 2

$125 \times 10^{-6} = 11 \times 10^3\,C_1 \ln [2 - 1.675/12]$

Let $C_1 = 0.018$ microfarad

From Eq. 7

$R_3 \leqq 5\ (200 \times 10^{-6})/0.018 \times 10^{-6} = 55.5$ kilohms

From Eq. 8

$R_3 \leqq [12 - (0.175 + 1.5)]/1 \times 10^{-3} = 10.325$ kilohms

From Eq. 9

$$R_3 \leqq \frac{11 \times 10^3\,[12 - (0.175 + 1.5)]}{10\,[24 - (0.175 + 1.5)]} = 0.51 \text{ kilohms}$$

Let $R_3 = 510$ ohms

Checking Eq. 10 with a minimum h_{FE2} of 45

$$I_{bf2} \geqq \frac{12 - 1.675}{5.1 \times 10^2} + \frac{24 - (1.675)}{11 \times 10^3} \geqq 0.495 \text{ ma}$$

This condition must be met in the design of the initial circuit

Quick Way to Find Radar Range

Nomograph determines new range of radar set when a transmitter or antenna parameter has been changed, if old range is known

By E. T. MESERVE*
Vitro Laboratories,
Eglin AFB, Florida

THIS NOMOGRAPH gives a quick solution to the radar range equation when the old range and an absolute db value are known. The unit of range is immaterial, provided the old and new range have the same units. The radar equation gives the range R as

$$R^4 = \frac{P_t G_a^2 \lambda^2 A_t}{4\pi^3 (BW)(NF) L (S/N) K T_0}$$

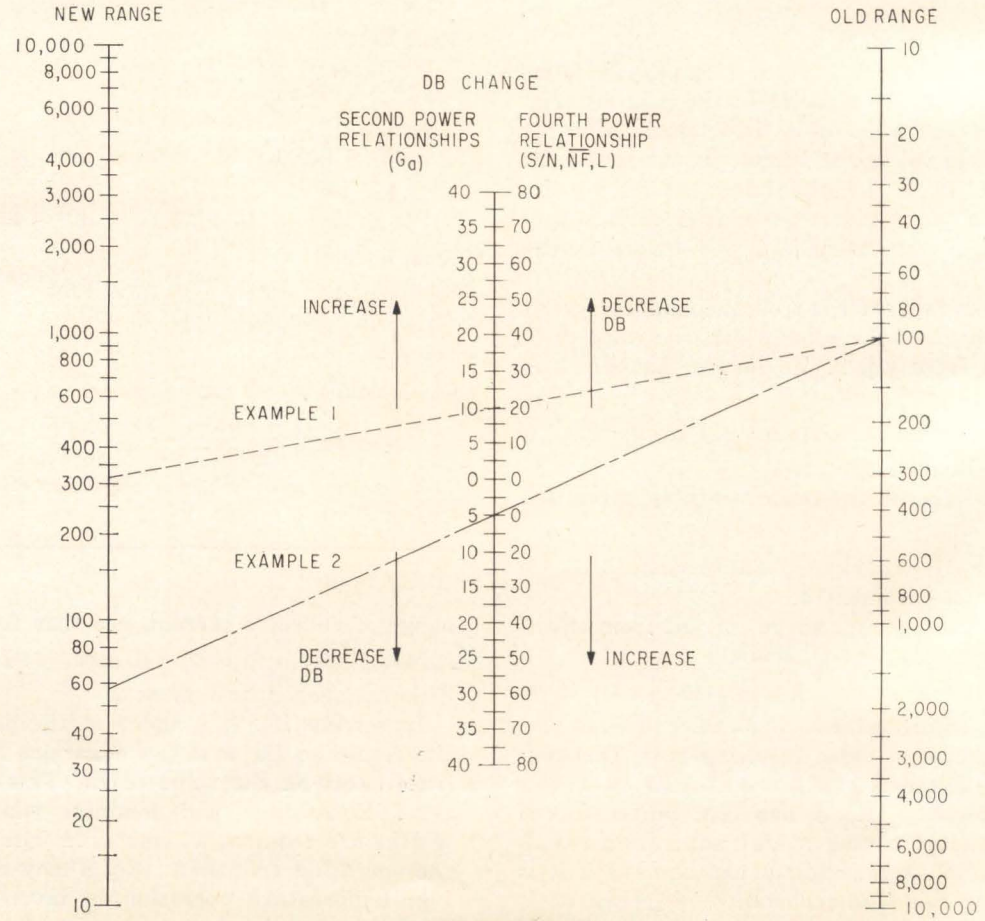
where P_t is peak transmitted power, G_a antenna gain, λ wavelength, A_t area of target, BW bandwidth, NF noise figure, L plumbing loss, S/N signal-to-noise ratio, and K and T_0 constants.

It can be seen that NF, L and S/N have a fourth-power relationship with range, and that G_a is a second-power function.

EXAMPLE 1 — Find the new range, when the old range is 100 nautical miles and the absolute increase in antenna gain is 10 db. Draw a line from the 10-db point above the 0-db mark (since an increase in absolute db is being considered) to 100 on the old range scale. An extension of the line intersects the new range scale at 320, giving the new range as 320 nautical miles.

EXAMPLE 2 — Find the new range when the old range is 100,000 yards and the absolute increase in noise figure is 10 db. Draw a straight line from the 10-db point below the 0-db mark (since a decrease in absolute db is being considered) to the 100 point on the old range scale. An extension of this line intersects the new range scale at 66, giving the new range as 66,000 yards.

* Now with Douglas Aircraft Co., Eglin Air Force Base, Fla.



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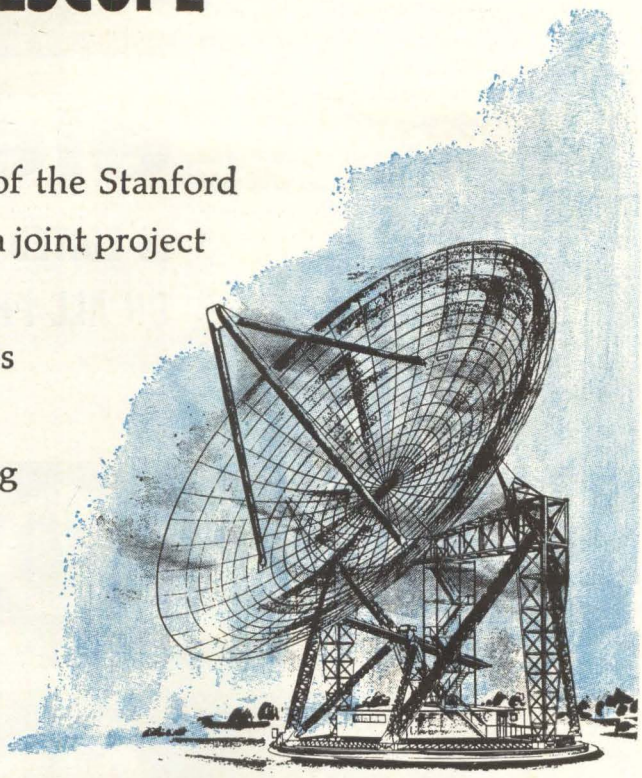

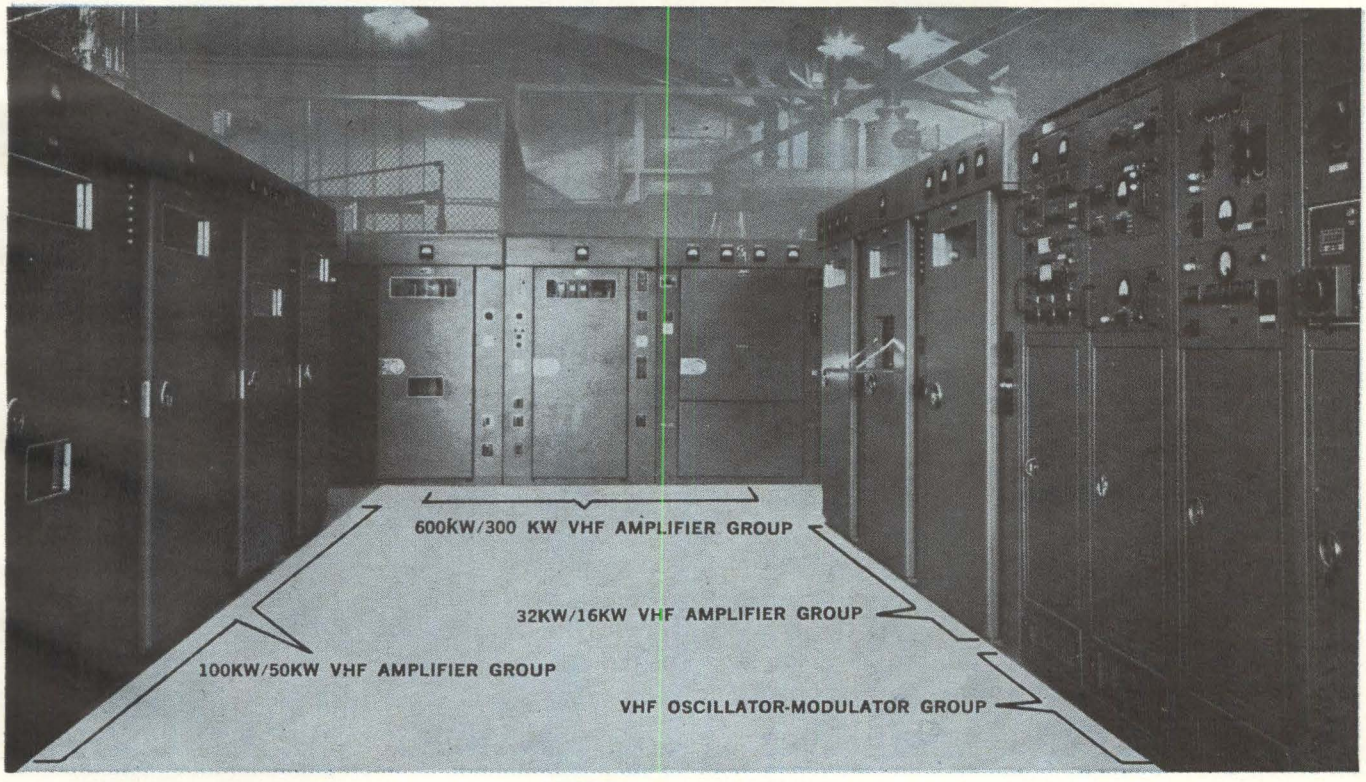

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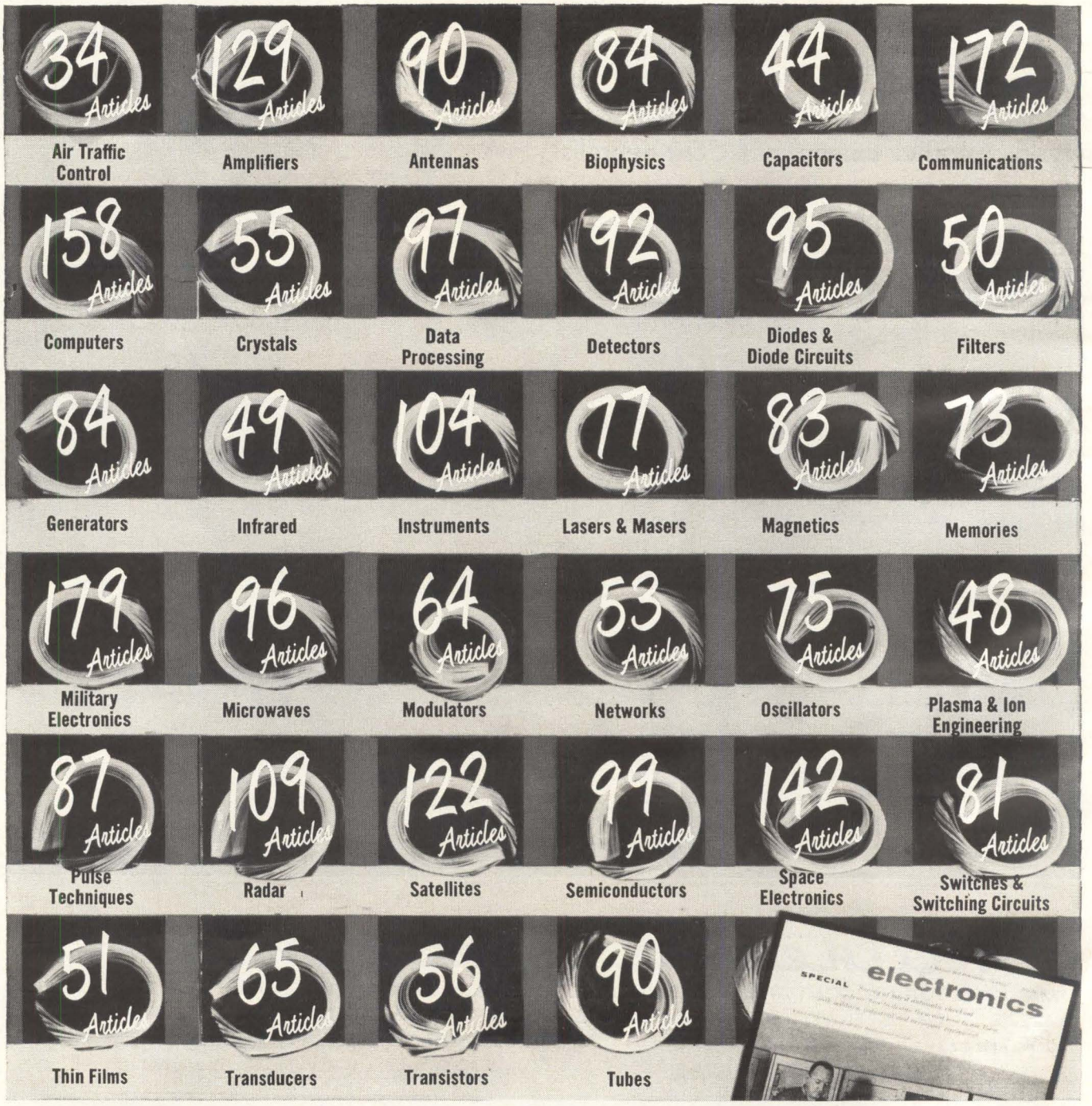

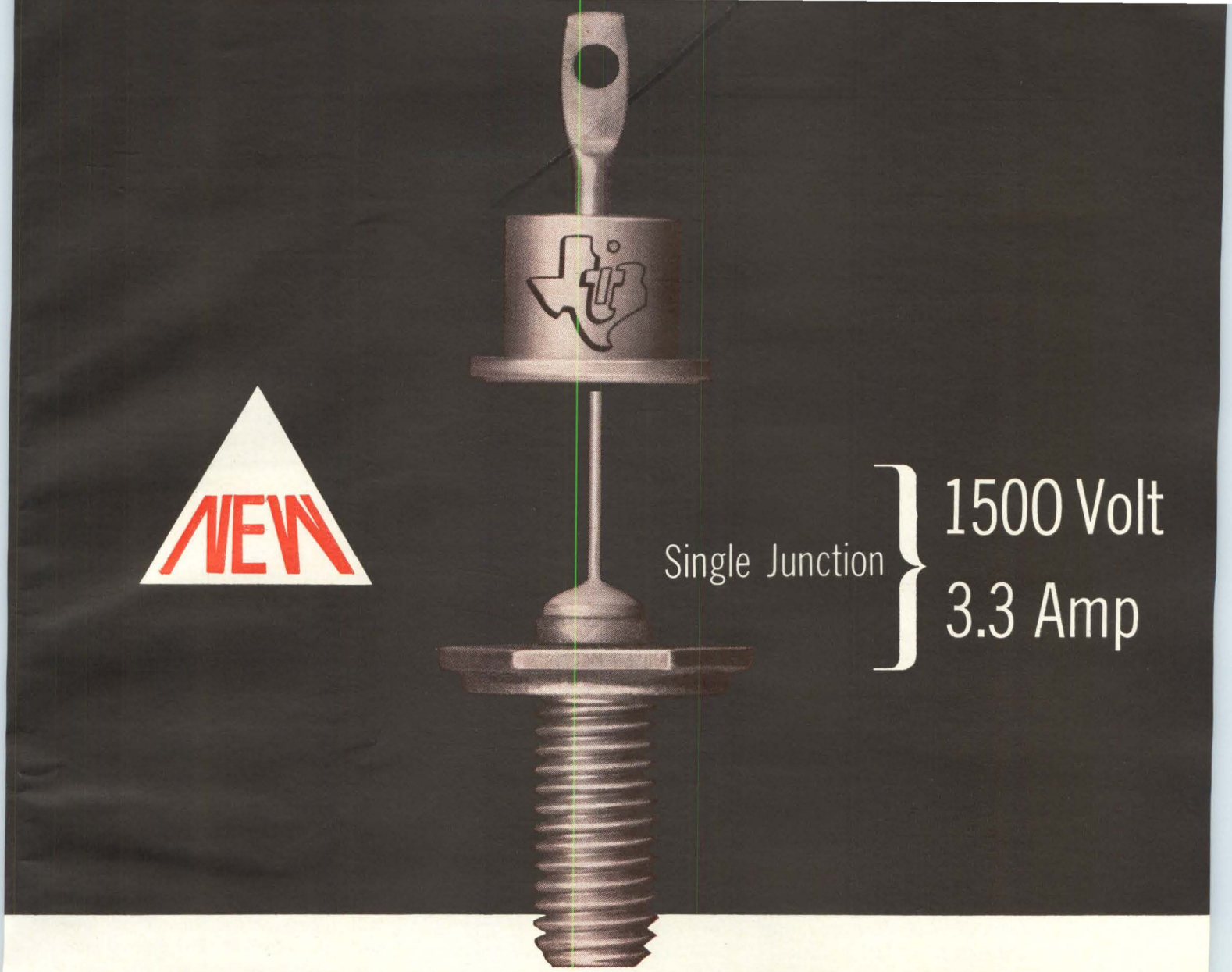

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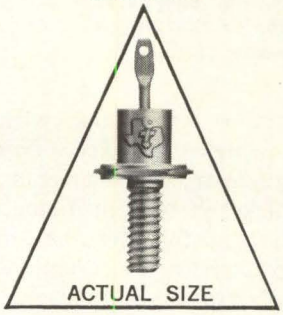

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BV_R	Minimum Breakdown Voltage	I_R = 100 μa	2000 v
V_F	Maximum Forward Voltage Drop	I_F = 2.0 amp	1.5 v
I_R	Reverse Current	V_R = 1500 v at 25°C	5 μa

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New Transformers May Bring Transistor Tv

Combined magnetostrictive-piezoelectric devices give high step-up ratios

By FREDERICK W. KANTOR

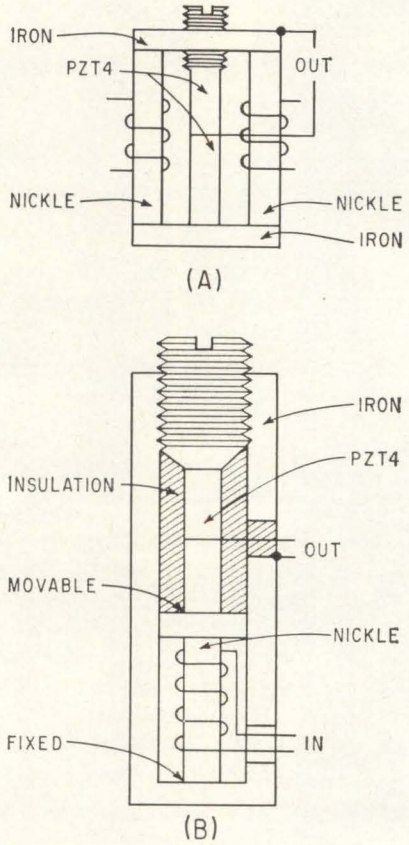
Integrated Research and Technology, Inc., Bellerose, N. Y.

MAGNETOSTRICTIVE element driving piezoelectric material can produce voltage multiplication ratios of several thousand. Such magnetostrictive-piezoelectric transformers might be used to make practical electrostatic-deflection transistor tv receivers. The devices are suitable for a variety of other high-voltage low-current uses.

Small step-up transformers that will produce large voltage multiplication ratios and have low-frequency cutoff of a few cycles per second are difficult to make using conventional methods. However, recent advances in piezoelectric materials combined with continuing progress in magnetostriction provide a practical means for providing high voltage multiplication ratios.

Output of conventional transformers is proportional to the time rate of change of flux through the output coil, making it very difficult to obtain good low-frequency response from small units. However, the output force of a magnetostrictive transducer is proportional to current flowing through the coil around it. Also, voltage of a piezoelectric element is proportional to the applied force. Thus combining the two results in a transformer having an output proportional to input, rather than to its first derivative with respect to time. As a result, good low-frequency response is relatively easy to obtain.

CONSTRUCTION—The piezoelectric material selected was Clevite PZT 4, which was fabricated in rods $\frac{3}{8}$ inch in diameter and $\frac{1}{4}$ inch long. Two rods were placed end to end as at A in the figure to reduce the voltage losses due to stray capacitance associated with single mounting. A modified 0 frame, with magnetostrictive elements of type A nickel $\frac{1}{16}$ inch in diameter by $\frac{31}{32}$ inch long forming the sides, was used to stress the ceramic elements. A setscrew takes up slack.



PIEZOELECTRIC *rods (A) are mounted in 0 frame with magnetostrictive elements forming sides. Tubular construction (B) provides greater rigidity*

Each nickel rod was wound with 45 turns of #22 wire, and coil resistance was less than 0.005 ohm. With 50 millivolts input, an output of 150 volts was obtained and used to operate an NE-2 neon bulb.

Another test model was designed to match the mechanical impedance of the magnetostrictive elements more closely to that of the piezoelectric material. Nickel rods $4\frac{1}{2}$ inches long were used because of the low magnetostrictive coefficient of nickel. Using the same piezoelectric elements, a shimmed W frame was made, which resulted in an output of over 400 volts.

PERFORMANCE—It has not been possible because of the high output impedance and low efficiency of the $\frac{1}{8}$-inch diameter piezoelectric rods to make reproducible measurements of transformer efficiency. However, overall efficiency is less than 20 percent, probably considerably less. Also, when working into a pure voltage load, such as crt deflection plates, low-frequency response is limited only by R-C decay resulting from leakage resistance. With ceramics and glass, this leakage is low enough to permit a low-frequency cutoff of about 1 cps. There is a mechanical resonance peak associated with each of the elements used and an overall peak caused by coupled mechanical oscillation. The separate peak would be eliminated in a production model by tighter mechanical bonding.

In constructing the transformers, the frame must be as rigid as possible so that the displacement will appear across the ceramic piezoelectric element. For this reason, one possible design is a tube, as at B in the figure. The magnetostrictive element is inserted from one end and bonded. The piezoelectric element is inserted from the other end and held in place by an adjustment screw. Because of the great rigidity possible with this design, the coefficients of thermal expansion of the various parts must be closely matched to reduce thermal d-c drift. For mechanical impedance matching, it may be desirable to use a magnetostrictive ferrite.

APPLICATIONS—Since substantially lower deflection power is required, the magnetostrictive-piezoelectric transformer might be used to make practical transistorized tv sets using electrostatic crt deflection. Suitable transformers would be about $\frac{1}{4}$ inch in diameter and about $1\frac{1}{2}$ inches long. Magnetostrictive-piezoelectric transformers could also be used to provide the

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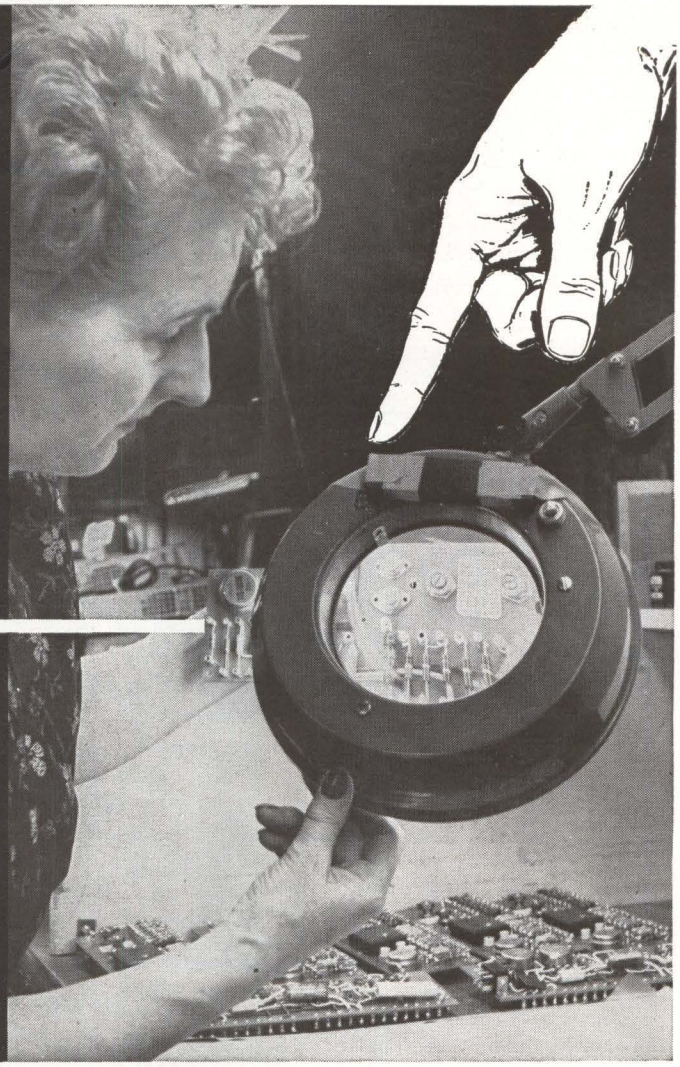

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high voltage required by Kerr cell shutters.

It might also be possible to couple the transformers with thermoelectric power-generating diodes to produce compact power supplies for low-drain devices. Such supplies would be ½ to 1½ cubic inches and could be used for multiplier phototubes, image intensifiers, geiger counters and infrared image converters.

The magnetostrictive-piezoelectric transformer might be combined with a fresnel lens. By mounting the assembly on a spinning satellite, high-voltage for low-current apparatus could be provided.

Shaft Resetter Reduces Loading

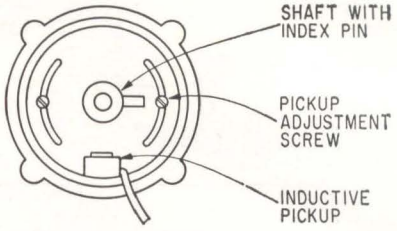
By FRED W. KEAR
Lytle Corp., Albuquerque, N. M.

SHAFT-POSITIONING device has been developed for applications in which available input torque is limited or in which shaft position is used as a precise analog representation of a measured quantity. The device resets a randomly positioned shaft to a predetermined reference position.

By avoiding brush-commutator arrangements in the design, mechanical loading of the shaft is limited. This approach also avoids brush noise, which can be damaging to transistor circuits unless it is controlled at added expense, size and complexity.

The general appearance of the shaft with its index pin and inductive pickup is shown in Fig. 1. One important consideration in fabrication of the inductive pickup and index pin is to keep the period of pulse generation to as small a portion of shaft rotation as possible. In this case, the most useful combination for position sensing proved to be an index pin of nonmagnetic material with 0.015-inch sheet magnetic material laminated in a slot at the tip of the pin. The core of the inductive pickup is constructed similarly. The pickup consists of a thin permanent magnet laminated between supporting layers of nonmagnetic material.

A substantial number of turns of insulated wire forms the coil around the permanent magnet to generate a voltage pulse each time the index pin passes the pickup. A large number of turns is necessary to provide optimum sensitivity without increasing size of the magnetic core. Magnetic flux must also be limited to prevent unnecessary torque loading of the shaft.



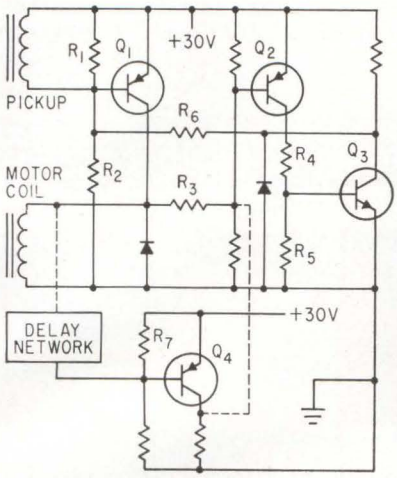
INDEX PIN *alignment with inductive pickup causes generation of voltage pulse—Fig. 1*

CIRCUIT OPERATION—The circuit at the top of Fig. 2 as activated by application of a +30-volt d-c command signal to the positive bus. Transistor Q_1 is forward biased by resistors R_1 and R_2, energizing the motor coil. The motor armature is mounted on the shaft being monitored so that motor torque rotates the shaft. As the shaft rotates, the index pin moves toward the magnetic core of the pickup. As alignment is reached, the inductive pickup generates a voltage pulse.

The output pulse from the pickup applies a reverse bias to the base of Q_1, de-energizing the motor coil. The motor should produce little torque so that overshoot is prevented, since one of the original requirements is for a device that will result in little mechanical damping or loading.

When the motor coil has been de-energized, a negative voltage is applied to the base of Q_2 through R_3, forward biasing the transistor. When collector voltage of Q_2 reaches about 30 volts, biasing resistors R_4 and R_5 forward bias Q_3. The voltage produced at the collector of Q_3 is fed through R_6 to maintain the reverse bias on Q_1.

As long as the command signal is applied to the 30-volt bus, the motor coil remains de-energized unless the locking voltage is removed from R_6. This locking voltage can easily



MOTOR COIL *is energized when command signal is applied and de-energized by pickup pulse. Auxiliary circuit delays shaft resetting —Fig. 2*

be removed by connecting the base of Q_2 to the +30-volt bus directly with a switch or remotely with a relay.

DELAYED RESETTING — The lower circuit in Fig. 2 is used for automatic shaft positioning after a preset time, determined by the time-delay network. This circuit causes the circuit above it to reposition the shaft index pin with the inductive pickup at the end of the time-delay period, which starts when the command signal is applied to the 30-volt bus. The negative pulse is taken from the emitter of Q_1, applied to the delay network and used to overcome the bias established by R_7 and R_8. Thus Q_4 is forward biased, connecting the base of Q_2 to the 30-volt bus and allowing the motor to be energized again.

A typical application of the shaft positioning device is in orienting equipment in a vertical position. The inductive pickup is attached to a vertical-sensing device, and the equipment to be oriented vertically is attached to the shaft. A polarity-sensing relay is also attached to the shaft and is used to reverse motor current when the index pin passes through the reference established by the inductive pickup. The polarity-sensing relay makes it unnecessary for the motor to rotate more than 180 degrees to orient the shaft to the vertical position.

The polarity-sensing relay is also a low-torque device, producing negligible loading of the shaft.

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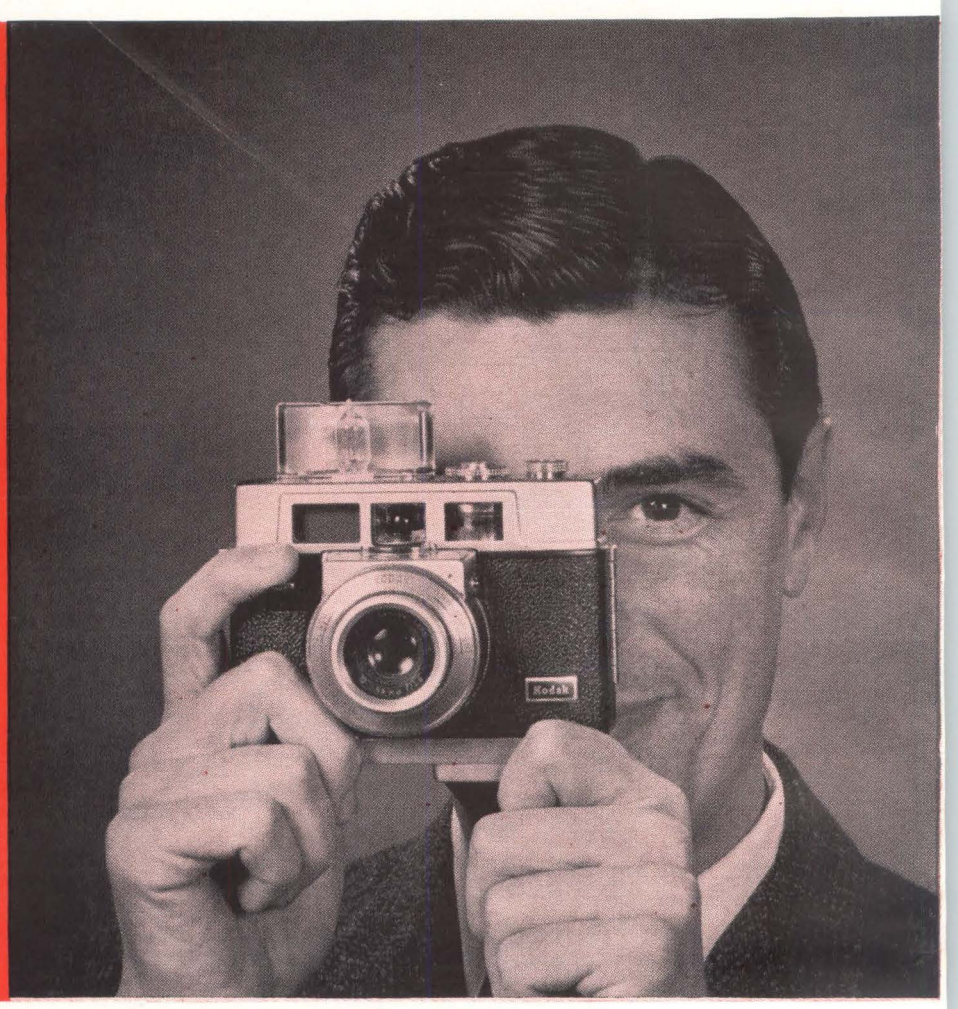

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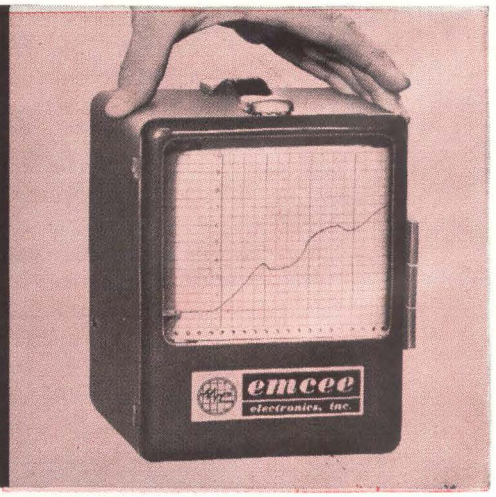

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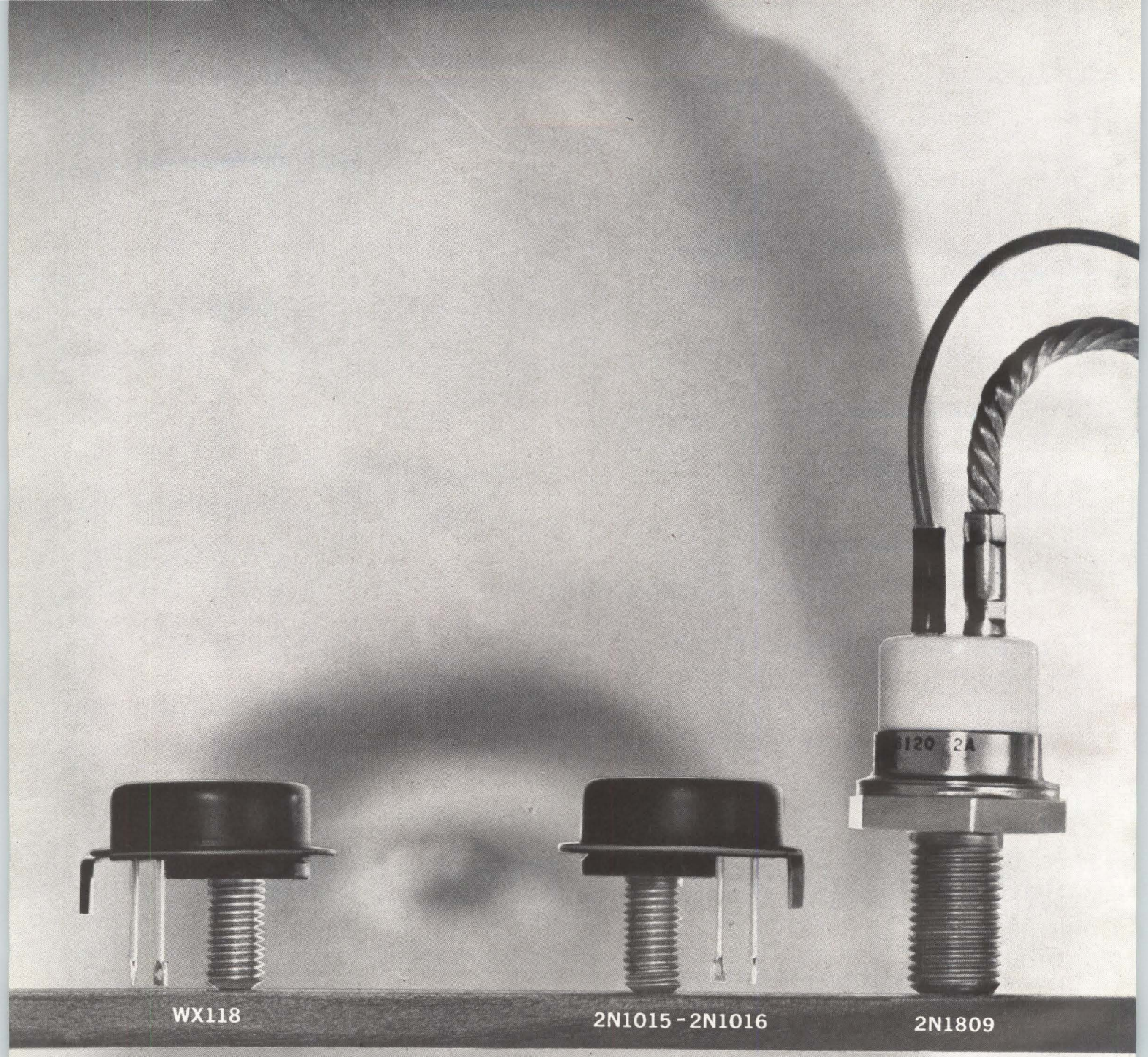
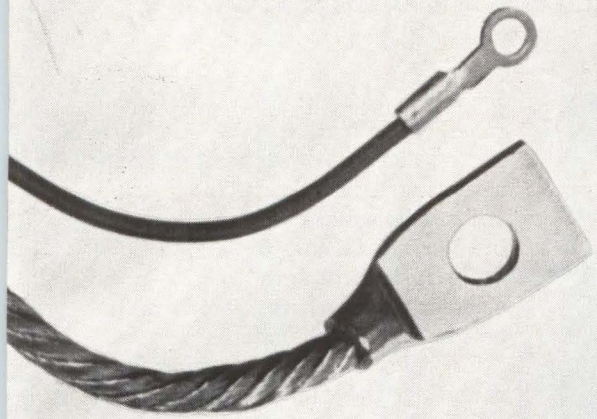
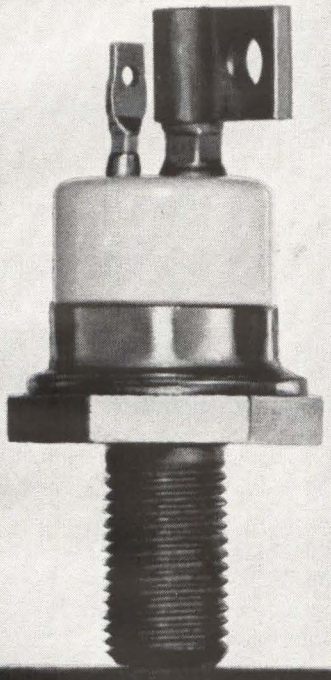

WX118
2N1015 - 2N1016
2N1809

Look to Westinghouse for Silicon Power Transistors with lowest saturation resistance





2N2109

LSR*=.037 Lowest saturation resistance ratings in the industry enable design engineers to obtain three-fold increases in power-handling capability. Now—with these higher performance specifications you can replace germanium units and gain the silicon power transistor advantages of reduced heat sink size . . . higher allowable ambient . . . improved control range . . . and upgraded reliability in almost all circuits.

	I_C	V_{CE}	Typical R_{CE} (SAT)
2N1809-2N2109 series	30 A	50-200V	.037
2N1015-2N1016 series	7.5 A	30-200V	.25
WX118 series	10 A	50-150V	.22

*Lowest Saturation Resistance

2N1809-2N2109 series. New 30-amp "Rock-Top" transistors . . . world's most powerful! With 30-amp, 200-volt, 250-watt ratings these newest Westinghouse series 2N1809 and 2N2109 transistors are designed to meet the most exacting high power applications. Germanium-level saturation resistance (.037 ohms), and freedom from secondary breakdown mean highest efficiency and operating reliability.

WX118 series. World's highest gain power transistors provide current gain of 400 at 10 amps! New Westinghouse Type WX118 high-gain silicon transistors simplify circuitry, increase reliability, reduce cost of assembly. They're ideal for application in high power, high efficiency regulators, inverters and switching circuits. Saturation resistance is only 0.22 ohms.

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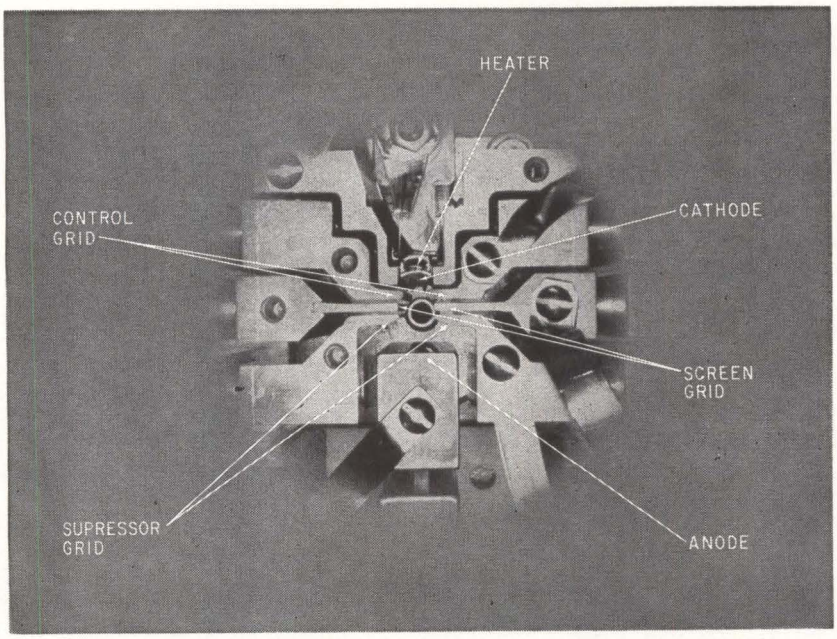
Movable Electrodes Help Tube Designers



ELEMENTS *of movable-electrode analog are coupled to knobs which can move each grid independently, either closer to the electron beam, or away from the beam*

Tube elements can be manipulated to appraise space charge in vacuum

By STERLING McNEES

Manager, Advanced Power Grid Laboratory, Eitel-McCullough, Inc. San Carlos, California

A FLEXIBLE vacuum tube, that is, one in which distances between cathode, anode and grid elements may be varied during operation, now enables an investigator to change the position of all elements to determine optimum interelement configuration.

Formerly, designers of grid-type electron tubes have had to evolve designs with data gathered from crude electromechanical analogs, empirical formulation and hindsight.

The movable-electrode analog for power grid-type vacuum tube design, developed by Eimac's Advanced Power Grid group, is shown in the photo. Elements represent the cathode with its internal heater, the anode, and the grids which are actually vertical sections of two adjacent grid wires of each grid.

Eimac's present power-grid research is on the feasibility of half megawatt and one megawatt tubes. While the analog could be used in the development of nearly any grid-type tube, it is being used to determine what direction might be best taken toward half-megawatt and one-megawatt development.

DIALING THE CHARGE—Elements are mounted on blocks, which are coupled by rods to adjustment knobs. Knobs are equipped with micrometer dials and, when turned counterclockwise, push against vacuum-tight diaphragms. This moves the blocks and the associated elements closer to the center of the electron beam. When the knobs are rotated clockwise, springs in the back push the elements back out of the beam. The two elements for each grid can be moved independently.

Knobs can move the tube elements as little as one mil. After the ideal position has been determined for each element in a particular tube configuration, the elements can be moved to new positions representing manufacturing tolerances. The effect of these tolerances is then measured.

Operating voltages are fed to the elements through insulators in the bottom of the chamber.

In operation, the chamber surrounding the analog is evacuated and voltage is applied to the heater to cause a chemical change in the cathode coating. Then voltage is applied to the other elements and the tube is pulse modulated. The duty cycle of the pulse modulation enables the investigators to operate the analog at higher power levels than it would tolerate in continuous operation. Typical operating voltages are 10 Kv on the plate and 3.5 Kv on the screen. Grid and anode currents are observed on an oscilloscope and photographed.

Because the elements can be removed from the mounting blocks, various shapes can be inserted and operated to establish their relative merits.

The window in the top of the chamber enables the investigator to verify the position of the elements with a measuring microscope. Although micrometer dials are quite accurate, they do not indicate element movement caused by thermal expansion. The window also permits visual examination of the model in operation.

SPACE CHARGE—Because electrons have a negative charge, they repel each other when tightly bunched. And bunching, or density modulation, is the operating principle of a grid-type tube. In other words, it's possible to staurate the electron beam and reach a point where additional modulation is not possible.

A tube may be space-charge limited, or its performance can be seriously modified, before its cathode emission limit is reached, or before anode dissipation limits appear. A small modification of the tube's in-

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INTEGRATED CIRCUIT APPLICATIONS

SCIENTISTS AND ENGINEERS: Today Motorola is pacing a scientific revolution in electronics with a disciplined approach to integrated circuit applications. Under the personal leadership of Dr. Daniel E. Noble, the men of the Military Electronics Division are synthesizing the process technology and device design capabilities of Motorola's Semiconductor Products and Solid State Systems Divisions with military and space requirements. This coordinated effort, unique in the electronics industry, is yielding a new breed of reliable integrated circuit devices resulting from Motorola's broad range of jointly funded contracts with each of the three services, JPL/NASA and other government agencies. To implement programs such as these, marrying the frontier processing techniques of diffusion, epitaxial growth, electronic ceramics and thin films to practical electronic hardware applications, we can offer immediate opportunities to both systems and equipment design engineers experienced in the following areas.

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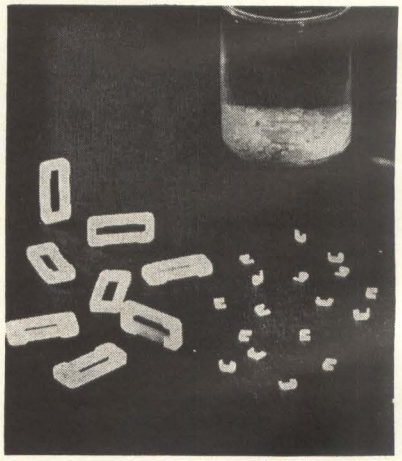
ternal structure can often overcome some of the effects of space charge; thus appears the importance of being able to move the tube elements while the tube is in operation.

Use of the movable-electrode analog can reduce substantially the time and cost required for the design of large power tubes. Previously, several prototypes had to be built before the designer could find a close approximation to optimum element shape and position. Data for prototypes came from measurements of potential distribution in a larger-than-scale model submerged in water, from the behavior of steel balls as they rolled over a contoured rubber diaphragm, or the distribution of voltage over resistance paper on which a drawing of the tube had been made with conducting ink. All these analogs were designed to determine electron flow, yet none of them could produce good information on the space-charge effect, which is so important in tube design.

Getters Adsorb Organic Contaminants



MOISTURE *getters cut relay failures, remove contaminants*

USE OF a unique glass that adsorbs moisture and contaminants doubles the reliability factor of miniature and subminiature relays used in missiles, aircraft and space satellites. The dessicant helps assure hundreds of thousands of miss-free operations in critical switching circuits under conditions of launch, reentry, ballistic flight or orbital flight.

Babcock Relays Division of Babcock Electronics Corporation of

Costa Mesa, Calif., said the dessicant is an activated getter made in molded form by Corning Glass Works. The material is Corning's Vycor brand porous glass—Code 7930.

With the glass getters, relays as small as 0.048 cubic inch and as light as 0.1 ounce exhibit relatively long life, high contact rating and high temperature capability, according to Babcock's Carl L. Martin. He said the porous Vycor getters were chosen for the high-reliability relays because of adsorption property in a relatively small matrix. They can be molded to close tolerances, space inside the relays can be utilized to the maximum. Martin said that forces of more than 100 G's have been withstood successfully by the relays without getter flaking or cracking.

THIRSTY GLASS—The getter is a porous, high silica material formed by leaching the fluxes from a special borosilicate composition. Average pore diameter is four millimicrons and void space is 28 percent of volume. Internal surface area is 150 to 200 square meters per gram. The apparent specific gravity of the glass, when dry, is 1.5.

Approximate chemical composition of dry Vycor thirsty glass is 96 percent SiO_2, three percent B_2O_3, less than one percent R_2O_3, and a trace of alkali.

Organic material contaminates glass exposed to air, so getters are shipped in glass containers of deionized water.

The getters are installed in relays by Babcock in a white room. The assemblies are subjected to a bake cycle at a temperature above 200 C and a vacuum below five microns of mercury for about one hour. The cycle, which is the second received by the relays, removes about 90 percent of the contaminants in the devices.

During operation, Martin said, the activated getters prevent relay contacts from being fouled by contaminants emitted at elevated temperatures. This contamination is the major cause of erratic performance and eventual failure of hermetically sealed relays. Up to 99 percent of organic contaminants remaining after production degas-

sing are adsorbed by the dessicant.

Getter activation is a drying process performed under controlled temperatures, time periods and moisture ambient. Properly done, it removes water from the getters while maintaining their porosity and gettering effect.

Company began using activated getters as an outgrowth of an orderly investigation into the causes of relay failures. Started more than two years ago, the studies comprised what may have been the relay industry's first reliability program. Each test sample was subjected to hundreds of thousands of operations at loads varying from one micro-amp to 10 amps, temperatures from minus 65 to plus 125 C, vibration of five G's to 3000 cycles per second, and shock beyond 1,000 G's.

High-reliability relays are now made available with glass moisture getters. Various types are used in airborne, spaceborne, undersea and ground system applications, including the Polaris missile and a military satellite.

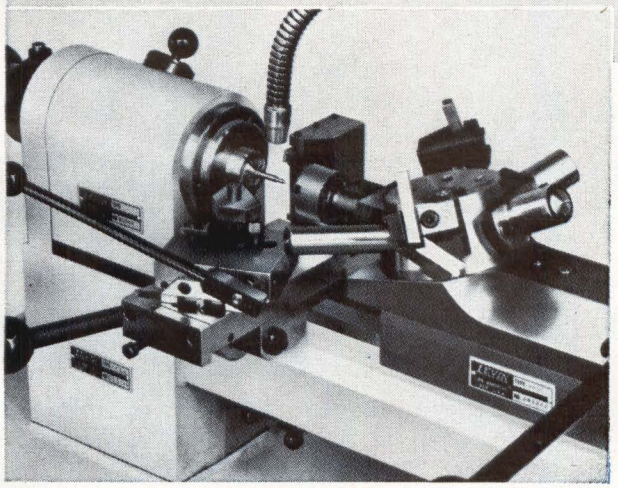
Delay Lines Utilize New Glass Medium

DIGITAL DELAY lines, because they are small, light, stable and reliable, have applications in missile and satellite guidance computers, in high-speed circuits requiring wide bandwidths and stability, in computer circuits requiring storage of high-speed video pulses, and in commercial devices where inexpensive but reliable lines are necessary in large volume.

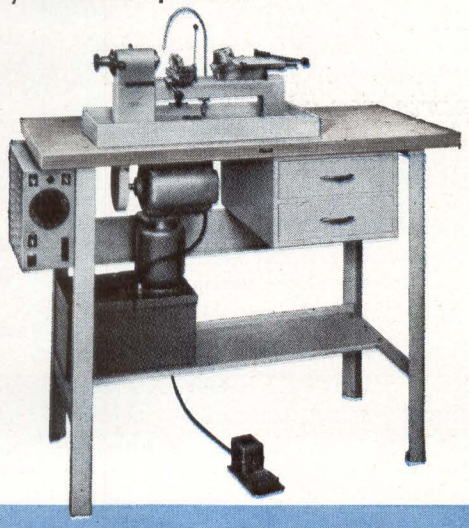
A new glass, developed by Corning, provides storage capacity for delay lines used as buffers and memories in digital computers and processing equipment. Storage capacity of the improved glass is between 3,500 and 4,000 bits, temperature coefficient is zero ±1 ppm per deg C at room temperature. Variation of the temperature coefficient of time delay with temperature is 0.11 ppm per deg C.

Bit capacity is the product of frequency and delay time. New glass can be operated at frequencies from one megacycle to higher than 50 Mc, with delay times ranging from approximately 500 μsec to about one μsec.

SMALL PART PROBLEMS ?



LEVIN Heavy duty instrument lathes offer the best solution to small part lathe operations. 29 standard models for first and second operation work in 3/16", 5/16", and 1/2" collet capacities.



Shown above, an ACAF turret lathe set up to produce the small needle valve, illustrated, with a 0.0118" bleed hole. The self indexing turret is extremely sensitive for fine work. Speed regulation is continuously variable from 0 to 4000 r.p.m. with IR drop compensation.

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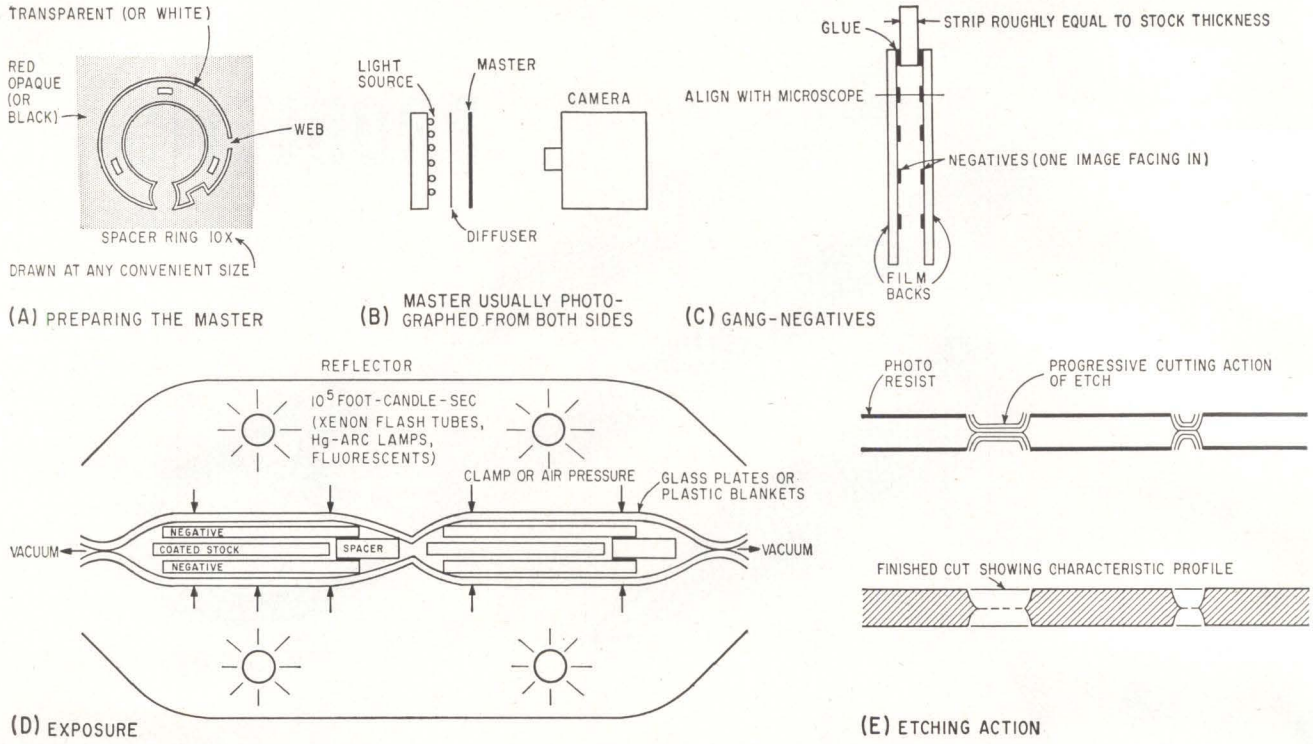

NOTE SHARPENING *of corners in master drawing (A) and web to keep part from falling into bottom of etch bath. High contrast film is used to make the negatives (B); a vacuum film holder should be used for highly accurate work. Gang negatives (C) are useful for volume production. After the coated metal is exposed (D), it is soaked in developer, rinsed, then oven dried. After etching, the part is cleaned of resist in a hot stripper. Complex parts are stored in sheet form to prevent tangling; the holding web is cut through when the part is used*

Photofabrication Makes Intricate Parts Quickly

High volume output for production or one only parts for R & D

By NICHOLAS REINHARDT
RAYMOND FLUKE
HARRIS TRAIGER
Edgerton, Germeshausen & Grier Inc., Boston, Mass.

NEW PHOTOENGRAVING techniques using specially prepared high speed etching baths are producing intricate burr-free parts quickly and cheaply. Molybdenum, titanium, tungsten, soft nickel and copper, Hastelloy, and other tough-to-handle materials commonly used in electron tube manufacturing can be shaped with the acid etching technique. Gold is the only material noted so far that presents difficult problems in chemical etching although it can be handled with electrolytic etching.

A variant of photoetching for printed circuits and nameplates, the process was developed to produce a molybdenum heating element for a super power hydrogen thyratron tube. Attempts to machine the spiral from a sheet of molybdenum produced a strained, burred piece costing nearly $75 in labor.

With experimentation, it became possible to photofabricate perfect parts in only 30 minutes. Labor saving refinements such as gang-processing and etch bath improvements have cut the time to make similar parts to seconds in large quantity, or to a few minutes for small lots. Titanium, for example, can be gang etched at 7½ mils per minute from both sides.

PROCESS—The first step in the process is to make an enlarged view of the part to any convenience scale (see A of sketch). The allowance for undercutting during etching is usually about 0.4 times stock thickness; line weight is about the same as stock thickness. This master is then photographed on a reduced scale to yield negatives the exact size of the part. Great care and precision, with attention to small details of technique, is required for good negatives. To produce parts in reasonable volume, gang-negatives can be made, but for highly accurate work, first generation negatives must be used.

The metal to be etched is coated with photosensitive material according to the manufacturer's directions, tight control being exercised to obtain a blemish free film. The coated metal is then sandwiched between negatives and exposed to a cool, intense flash of light, which exposes all coating not

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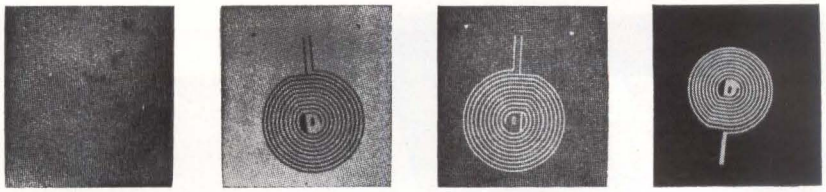


SPIRAL *heater for a high power thyratron tube; 0.005 molybdenum coated with resist, the part ready for etching, the part after etching, and the final part ready for special coating*

protected by opaque areas of the negative. The exposed pieces are developed and dried, then agitated in acid etching baths; etchants are proprietary variation of standard pickling solutions. Unexposed portions of the metal are rapidly eaten away, leaving an accurate part that needs only to be stripped of the exposed coating to be ready for immediate use. Careful control of etching time, temperature and cleanliness is required; heat buildup at etching points is kept under control by the agitation.

APPLICATIONS — **Currently,** more than 20 different thyratron and crt parts are being made to close tolerance. Many sizes of heavy spiral-strap heaters and serpentine structures are being made to resistance tolerances of ±1 percent and mechanical tolerances of ±0.001 inch. Throw-away masks for a flame-spray process are being produced in 0.020 inch stainless steel. Elaborately pierced titanium rings and plates are produced in thicknesses to 0.040 inch; double register techniques allow limited use of a third dimension to produce lands, grooves, ridges, lettering, and locating features. Maximum stock thickness is a function of the size of the smallest detail. For ordinary work, this is about 0.7 of stock thickness.

The process requires semi-skilled personnel and experienced supervisors. All steps must be closely controlled and safe practices followed. Costs depend mostly on labor utilization. Company developed exposure and processing equipment, for example, can produce accurate work as inexpensive as a few cents, depending on size and volume. Set-up costs show a wide spread, but depend on part complexity and the precision required. But costs are always well under the costs for equivalent machining or die-work.

Photofabrication is especially useful in R&D work, where flexibility is important and where machined parts are expensive. The engineer is freer to design since restraints on machining feasibility and part complexity are much less.

Design changes often involve no more than changing a drawing and rephotographing it; in some cases the negative itself can be revised with india ink or by cutting. Once a final design has been made, the negative can be used indefinitely, with no variation in part as a result of changing from temporary to permanent tooling. Variations in stock thickness or other properties can be allowed for by revising drawings alightly.

The photofabrication process allows a new part to go from original idea to finished part in ½ a working day, when necessary.

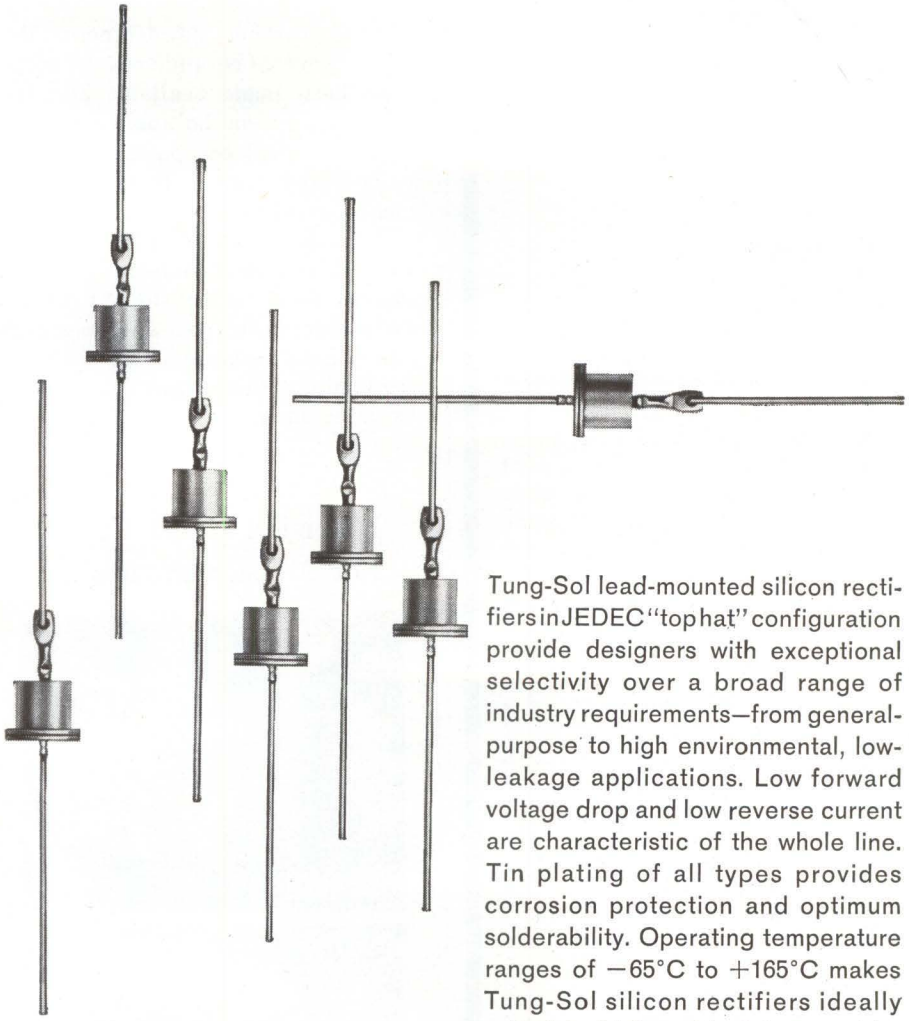
Ceramics in Magnetic Cores Allow Extreme Environment

A CERAMIC laminating process for motor and transformer cores has been developed by Ceramco Inc., Chemists, Newark, N.J.

The process employs specially prepared frits with expansion coefficients closely approximate to those of the lamination metal. The frit is applied to individual laminations which are then stacked and fired above 1,200 F.

A second coating of frit is applied and fired to cover wire slots and end laminations. The result is a vitrified ceramic bonded core free of organic binders or insulators, and rigid and stable in high temperatures and under radiation. Electrical properties of the lamination metal are retained by careful application and removal of heat during the various steps.

Although the basic process was ready in 1955, lack of suitable wire



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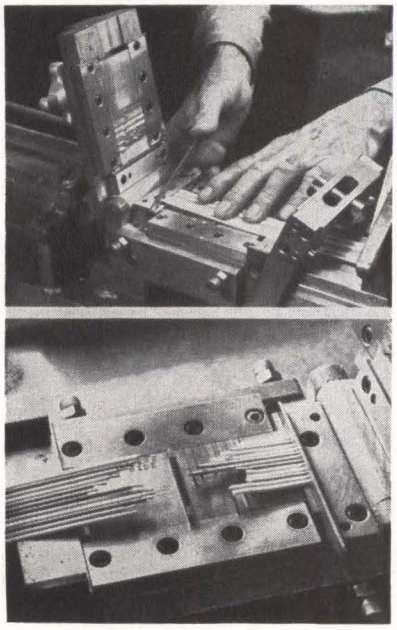
delayed further development. Recently, several ceramic coated wires have been made available and the process can now be applied to produce electrical equipment that can be operated under extreme environmental conditions.

Tolerances can be held as closely as with resinous materials. Grinding to finish dimensions presents no major problems, and excellent bonds have been achieved with inter-laminar thicknesses of 0.00025 to 0.001 inch.

Precision Cable Cutter For Missile Harnesses



CUTTING and stripping ribbon cables for missile harnesses without damaging the conductor or insulation is being accomplished by General Dynamics/Pomona, Calif., with a special tool.

Because of the close tolerances involved in fitting the wiring into the missile (sometimes to within one-thousandth inch), precise cable dimensions are necessary.

Blades are carefully positioned at both top and bottom of the die. The ribbon is first split to separate wires ends, then placed carefully in the die. The blades cut the wires to the required depth, and, using an air pressure cylinder to separate the leads, the cables are stripped of insulation.

The process works through both an outer and inner layer of insulation as well as shield braiding.

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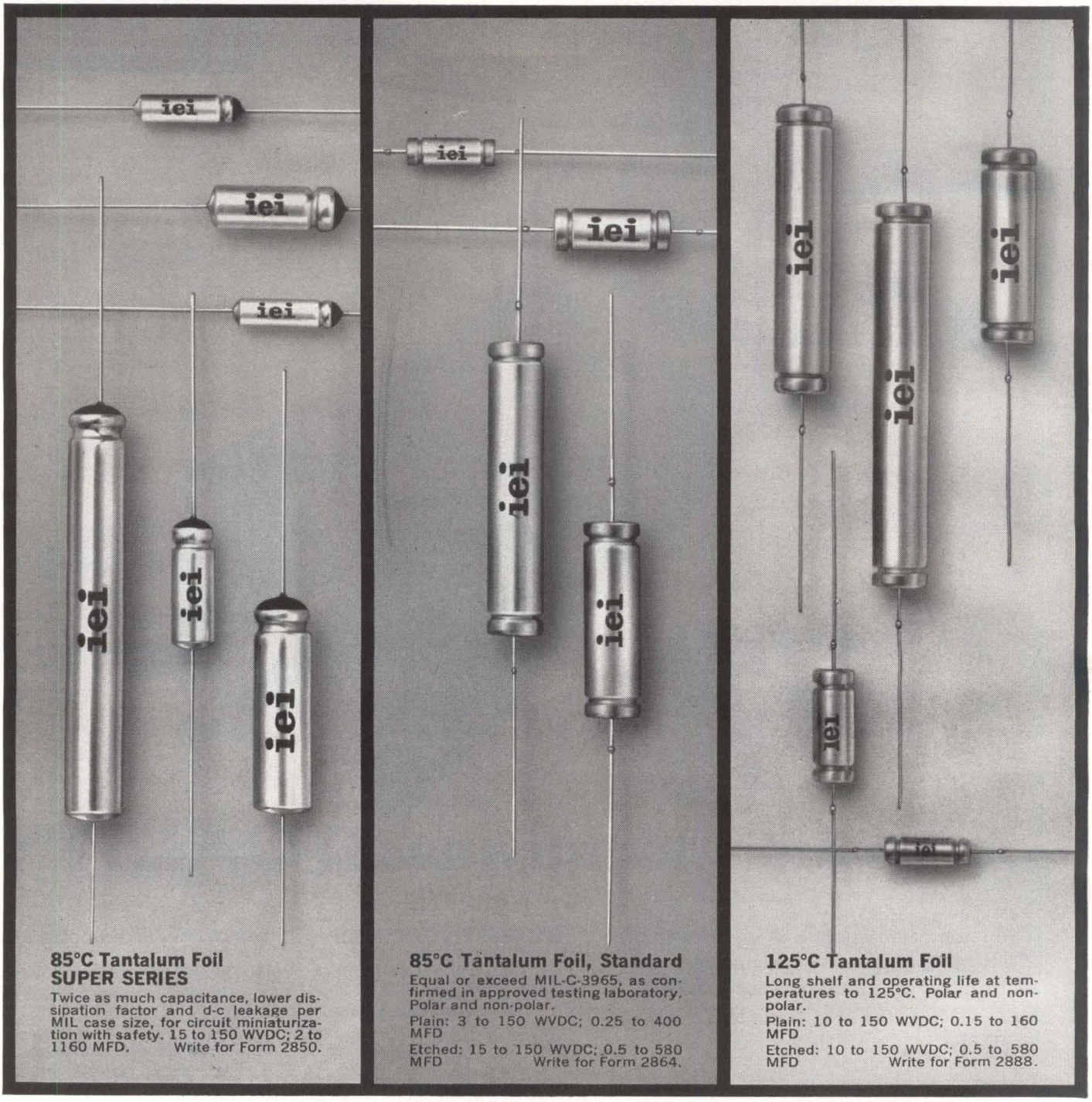

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Twice as much capacitance, lower dissipation factor and d-c leakage per MIL case size, for circuit miniaturization with safety. 15 to 150 WVDC; 2 to 1160 MFD. Write for Form 2850.

85°C Tantalum Foil, Standard

Equal or exceed MIL-C-3965, as confirmed in approved testing laboratory. Polar and non-polar.

Plain: 3 to 150 WVDC; 0.25 to 400 MFD

Etched: 15 to 150 WVDC; 0.5 to 580 MFD Write for Form 2864.

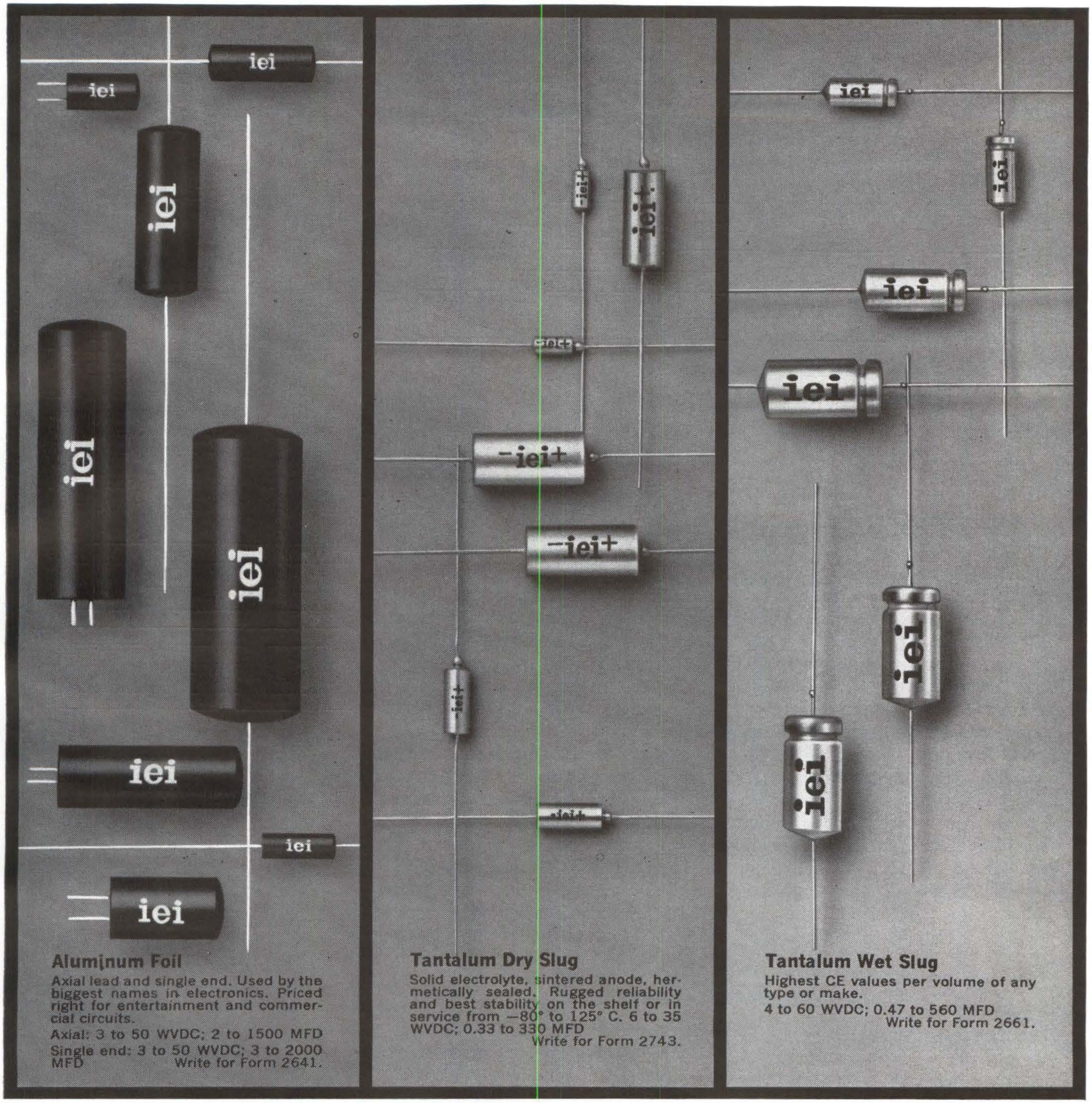
125°C Tantalum Foil

Long shelf and operating life at temperatures to 125°C. Polar and non-polar.

Plain: 10 to 150 WVDC; 0.15 to 160 MFD

Etched: 10 to 150 WVDC; 0.5 to 580 MFD Write for Form 2888.

iei = { specialist in miniature Electrolytic Capacitors



You get an extra measure of value and reliability in every **iei** capacitor. **iei**, pioneer maker and researcher, continues to be the only manufacturer specializing in miniature electrolytic units.

To your circuits, this means lowest d-c leakage, best stability and outstanding performance in the toughest environments. To you, **iei** capabilities mean friendly and prompt attention to every inquiry, on-time shipments and the certainty that each unit embodies the latest in scientific advances.

iei miniature electrolytics are now in stock at many electronics distributors. Descriptive bulletins sent on request. International Electronic Industries Division, Standard Pressed Steel Co.

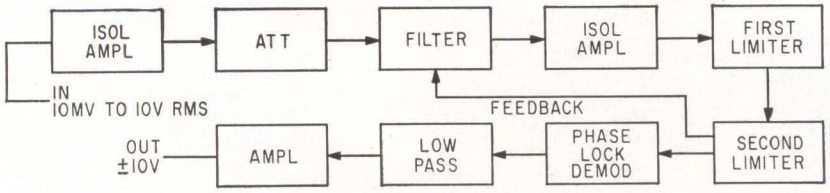
International Electronic Industries Div.

SPS

BOX 9036-94, NASHVILLE, TENNESSEE

CIRCLE 81 ON READER SERVICE CARD

DESIGN AND APPLICATION

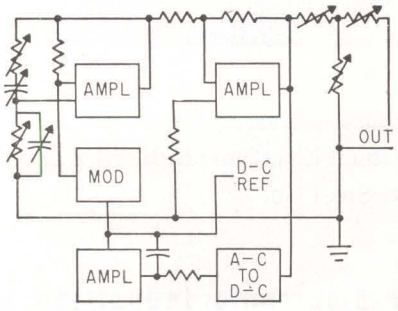


Predetection Playback to 150 Kc

Phase-lock principle allows control of bandwidth under poor signal-to-noise ratio

RECENTLY announced by Data-Control Systems Inc., East Liberty St., Danbury, Conn., the model GFD-4 transistorized predetection playback discriminator is a phase-locked, loop-type f-m discriminator designed to demodulate high frequency subcarriers or predetection recorded signals having demodulated frequency components as high as 300 Kc. Input level is between 10 mv and 10 v without adjustment with impedance of 1 megohm shunted by 50 pF. Channels are available with high band edge frequencies up to 1 Mc. Deviations from ±7.5 to ±43 percent may be used. Output is variable between ±1 to ±10 v for full bandwidth deviation with increasing frequency causing a positive output and decreasing frequency a negative output. Frequency response is d-c to 300 Kc. Loop filters are available for either frequency multiplexed or pulse-type data. The phase-lock system is used to allow control of video bandwidth when poor signal-to-noise ratio is encountered. Phase linearity of input, loop, and output filters are controlled to minimize errors in pulse systems due to transient response characteristics while amplitude linearity keeps harmonic and intermodulation products to negligible levels. The unit can drive combinations of tape recorders, and secondary demodulation equipment.
CIRCLE **301**, READER SERVICE CARD

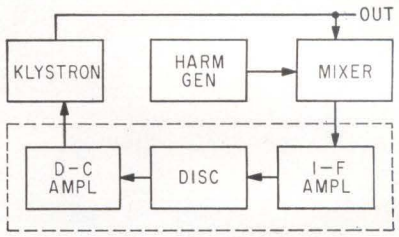
Reference Audio Oscillator Has 0.02% Stability



MANUFACTURED by Burr-Brown Research Corp., Box 6444, Tucson, Arizona, the model 9174B transistorized reference oscillator is continuously adjustable between 10 and 100,000 cps and produces sine waves with less than 0.02-percent amplitude stability and less than 0.05-percent distortion. Output is 3 v rms into a 600-ohm load. The circuit is an ultra-stable Wien bridge oscillator stabilized by applying the output to a precision a-c to d-c converter-integrator. The output is a d-c signal proportional to the amplitude of oscillations. This voltage is compared to a zener d-c reference. Any error signal is amplified, filtered and fed back to a modulator so as to maintain constant output amplitude. High-gain d-c amplifiers perform the various functions. Accuracy is ±1 percent and effects of temperature, jitter, hum, noise, line intermodulation, 20 v line changes and microphonics is less than 0.02 percent. **(302)**

Stabilizing Klystrons to 1 Part in 10^7

RECENTLY announced by Micro-Now Instrument Co., 6340 N. Tripp Avenue, Chicago 46, Illinois, the model 201 klystron frequency stabilizer will control klystrons to 25 Gc with the stability and accuracy of a crystal-controlled oscillator. Stability is 1 part in 10^7 and can be



used with any klystron delivering more than 1 mw power. The unit is used with a microwave frequency calibrator and the only frequency limitation is the power output of the microwave harmonic multiplier. As shown in the sketch, the unit consists of an i-f amplifier, discriminator, d-c amplifier and network for coupling to the reflector of any klystron. Part of the klystron output is sampled and fed to a conventional microwave mixer. Harmonics from the microwave source are also fed to the mixer. The i-f frequency is 60 Mc. Variations in klystron frequency produce error signal that correct klystron frequency to that of harmonic generator. **(303)**

Overvoltage Device Arrests Extremely Large Transients

ANNOUNCED by Electro-Neutronics Inc., 1401 Middle Harbor Rd., Oakland 20, California, is a family of transient voltage arrestors for the elimination and/or isolation of voltage transients or overvoltage conditions from com-

THREE GOOD THINGS TO KNOW ABOUT RAULAND

Scan Converter

STORAGE TUBES

- Resolution Capability of 800 to 1000 TV lines
- Erase Capability of less than 2 seconds
- Extensive research and development facilities make tubes available to you in any combination of electrostatic or magnetic deflection

Two stock types are:

(1) Magnetic write deflection and electrostatic read deflection

(2) Magnetic read and write deflection

Many other combinations are possible—and available. Your inquiries are invited.

FLAT FACE DISPLAY TUBES

Rauland's flat face tubes (16", 22", 24") minimize parallax error. Resolution capability of 1000 TV lines at a brightness of 100 foot-lamberts. We will suit your specific requirements with any type of radar display tube in any size with any type phosphor or gun.

HIGH-RESOLUTION, HIGH-BRIGHTNESS TUBE

Round 21" high voltage CRT will resolve at least 1000 TV lines at a brightness of 300-500 foot-lamberts. For displays under high ambient light conditions.
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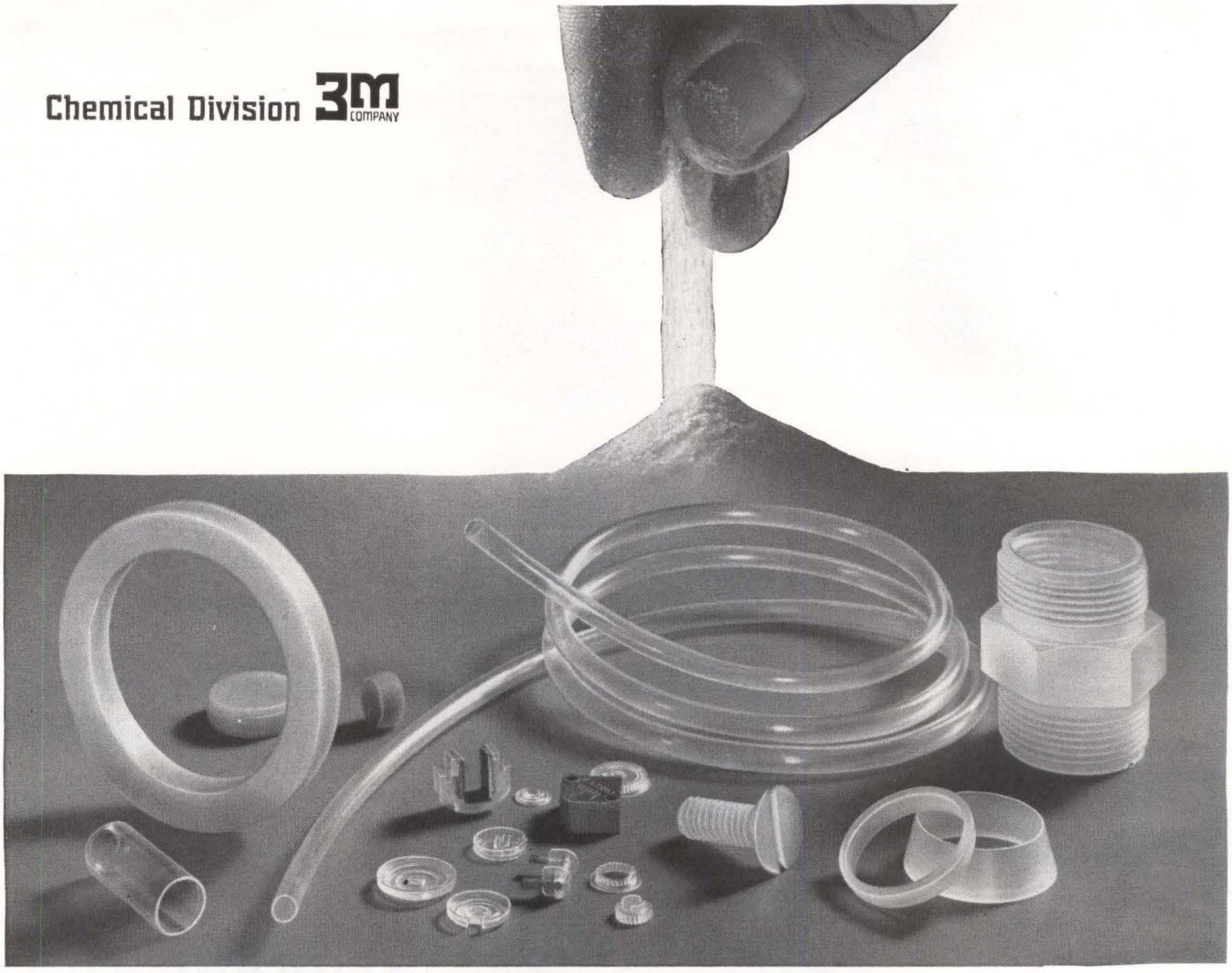


Skilled processors extrude, mold, machine KEL-F® 81 to your most critical "specs"!

BRAND PLASTIC

KEL-F 81 Brand Plastic not only defies extreme environments—it can be made into a practically unlimited variety of forms and shapes by the skilled hands of authorized processors. These processors (see list, right) provide critical components for aerospace, electronics, chemical processing, other applications—are required by 3M to utilize ZST testing to assure consistently high molecular weight and uniformity.

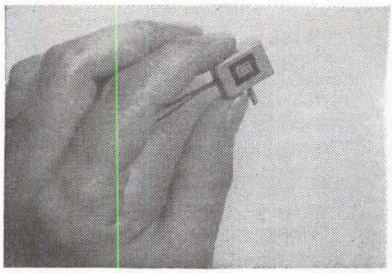
MOLD IT, EXTRUDE IT, MACHINE IT! A true thermoplastic, KEL-F 81 Plastic includes chlorine in its fluorochemical structure to facilitate processing, assure toughness. Processors extrude this non-porous plastic in almost unlimited lengths, in diameters from 1/16″ to 8″! They mold KEL-F 81 Plastic by injection, compression or transfer methods with precision as fine as ±.002″! Machining characteristics are comparable to brass, afford tolerances as small as ±.0005″! KEL-F 81 Plastic may be heat-treated to range from highly crystalline to essentially amorphous, as desired. Thin sections can have great optical clarity, permit infrared transmission.

7 ENVIRONMENT-DEFYING PROPERTIES OF KEL-F 81 PLASTIC! 1) *800-degree range:* −400 to +400°F. 2) *Chemical inertness:* resists most corrosive media, even LOX. 3) *Zero moisture absorption:* even with constant contact with corrosives. 4) *High dielectric strength:* arc resistance greater than 360 seconds. 5) *High mechanical strength:* excellent tensile, impact and compressive strengths, low cold flow. 6) *Abrasion resistance:* not easily abraded mechanically or by slurries! 7) *Radiation resistance:* retains great strength despite severe exposure. For technical assistance, see column at right.

"KEL-F" IS A REG. TM OF 3M CO.

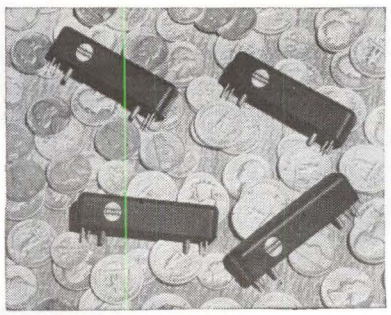
MINNESOTA MINING & MANUFACTURING CO. 3M

munications systems or electrical equipment. One typical device, the model SX550x100, clamps between 2 and 50 v (preset) with a maximum protection of greater than 5,000 v, peak current is 10,000 amperes (20 μsec or more) falling off to 1 ampere in 100 ms. Response time is less than 0.2 μsec and recovery time is less than 10 μsec at 1 Kv pulse and less than 30 μsec at 5 Kv pulse. Input-output impedance is 600-ohms balanced, frequency response between 100 cps and 14 Kc is $\pm$0.1 db and between 10 Kc and 48 Kc, response is $\pm$0.2 db. Phase delay distortion is less than 50 μsec. Special models have been developed for computer inputs, d-c circuits and power supplies.
CIRCLE 304, READER SERVICE CARD



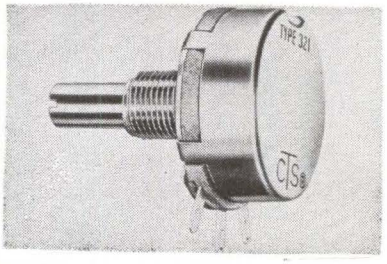
Miniature Choppers Withstand 100 G Shock

CAMBRIDGE SCIENTIFIC INDUSTRIES, INC., 18 Poplar St., Cambridge, Md., offers electromechanical choppers that withstand over 100 g shock and extreme environmental conditions. Measured into a 100 ohm load at either 60 or 400 cps, the units feature no noise. Designated 228 for 60 cps and 428 for 400 cps, they measure 0.525 by 0.750 by 0.350. Available at $50 each in quantities of 1 through 6. **(305)**



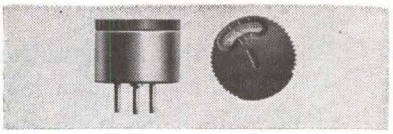
Mechanical Filters Offered in 5 Types

COLLINS RADIO CO., 19700 San Joaquin Road, Newport Beach, Calif. New family of mechanical filters include three 455 Kc center frequency filters with bandwidths of 800 cps, 2.7 Kc and 12 Kc and two 500 Kc filters with bandwidths of 200 cps and 800 cps. All have steep-skirted selectivity with 60 db to 6 db shape factors as low as 2.5 to 1. All are packaged in durable, high-impact phenolic cases and are suited for circuit board manufacturing techniques. **(306)**



Variable Resistor Meets Mil Specifications

CTS OF BERNE, INC., Berne, Ind. Type 321 is a 1 1/16 in. diameter military grade variable resistor with full 3-w rating at 70 C and highly reliable carbon-ceramic element. It provides reliability and stability of MIL-R-94B under extreme environmental conditions, but at the price of a conventional 2-w industrial control—55 to 65 cents in production quantities. The unit's resistance range is 250 ohms through 2.5 megohms linear taper and 2,500 ohms through 1.0 megohm audio taper. **(307)**

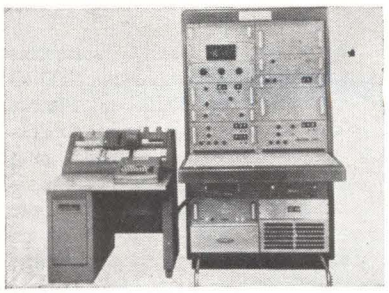


P-C Potentiometer Has Panel Mount Quality

WATERS MFG., INC., Wayland, Mass. The JPD/2 is a $\frac{1}{2}$-in. diameter p-c potentiometer with panel mount quality. Operational in a temperature range from -55 C to $+$ 150 C, it has been thoroughly tested to meet and surpass MIL-R-19A requirements. When mounted on an insulated p-c board the JPD/2 dissipates 1 w at 85 C. Available in a resistance range from 10,000 to 20,000 ohms. For fast and accurate reading of the wiper position there

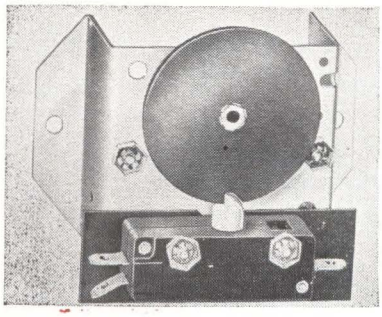
are numbered positions on the housing with a scribe mark on the dial.

CIRCLE 308, READER SERVICE CARD



Capacitance Test System Features High Speed

OPTIMIZED DEVICES, INC., Pleasantville, N. Y. Model 1800 automatic capacitor data logging system provides capacitance and dissipation factor readings accurate to 0.5 percent of reading at a speed of less than 1 sec per measurement. Capacitors from 100 $\mu\mu$f to 1,000 μf can be measured and modules for either 1 Kc or 120 cps measurements are available. **(309)**



Low-Cost Cycle Timer Has Custom-Cut Cam

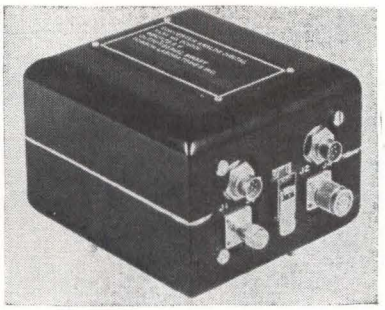
HAYDON DIV. of General Time Corp., Torrington, Conn. The RL71 is designed to fulfill the need for an inexpensive cycle timer on applications requiring speeds of not more than 1 rpm, and a minimum off time of 3 sec. Timer cam is cut to the specifications of individual applications. The RL71 employs one spdt combination quick disconnect and solder switch to repeat a set cycle or switching operation. **(310)**

Pressure Transducers

SEMTRAN INSTRUMENTS, INC., Route 73 Industrial Center, Maple Shade, N.J. Model 1000 pressure transducers designed and priced for

OEM and industrial applications feature an unamplified output of up to 2 v.

CIRCLE 311, READER SERVICE CARD



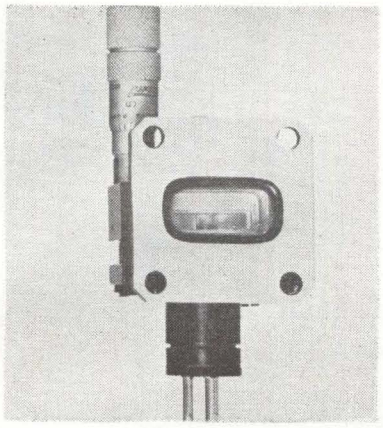
Airborne Converter Uses Few Components

TOWSON LABORATIORIES, INC., 200 E. Joppa Road, Baltimore 4, Md. Model OC-1001 is an airborne model of capacitive charge transfer analog to digital converter. Units are capable of wide temperature operation and other environmental conditions typical of MIL applications. They offer high input impedance, sampling aperture of 1.3 μsec, $\pm$ 2.5 v full scale, 10 bit resolution plus odd count parity bit, 23,000 encodings or more per sec, serial binary NRZ output code format. It is approximately 3¾ by 6 by 5 in. and weighs 3.5 lb. **(312)**

A-C Line Regulator Gives Precise Control

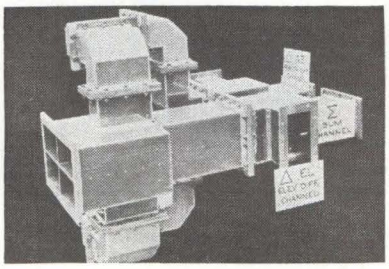
ACME ELECTRIC CORP., Cuba, N. Y., announces an a-c line voltage regulator that provides precise, stepless voltage control for power loads up to 60 Kva (single phase), and 180 Kva (three phase). Designed for industrial application, the de-

vice is suited for use with automated machinery, process control instrumentation, data processing machines, and other equipment with critical, voltage sensitive circuits. **(313)**



Reflex Klystron Equipped with Screw Tuner

METCOM, INC., 76 Lafayette St., Salem, Mass. The 6310, designed for plug-in electrical operation, has a single screw tuner for ease in changing frequency. It offers rugged construction, tuning in the X band from 8.5 to 10.0 Gc with 70 mw power output over the entire range. Tuner is set for a uniform 60 in. oz torque over the range. Small lot price is $175. **(314)**

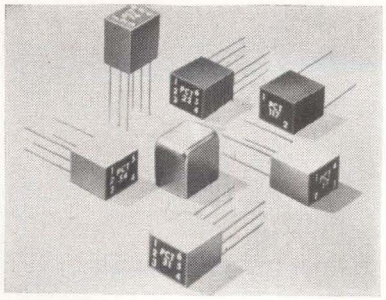


Monopulse Comparator Used at L-Band

ANTENNA SYSTEMS, INC., Hingham, Mass., offers a compact, high-power, all-waveguide comparator for use at 1,250-1,350 Mc. Input vswr of the sum arm is less than 1.1, of the elevation difference arm is less than 1.12, and of the azimuth difference arm is less than 1.07. Isolation between the sum arm and elevation difference arm is greater than 40 db, between the sum arm and the azimuth difference arm is greater than 42 db and between the elevation arm and azimuth differ-

ence arm is greater than 42 db. Differential phase variation between any two outputs is less than 2 deg.

CIRCLE 315, READER SERVICE CARD



Transformers Are Color Coded

STANCOR ELECTRONICS, INC., 3501 Addison St., Chicago 18, Ill. Series of miniature transistor transformers are designed for p-c plug-in applications. They are called Polychromatrans because of the color coding technique used to differentiate their function. There are 22 different transformers in the line, covering most of the frequently used transistor applications. All are the same size, measuring 0.410 by 0.310 by 0.465 in. **(316)**

Standing-Wave Bridge Can Handle 1,000 W

AMECO EQUIPMENT CORP., 178 Hericks Road, Mineola, L. I., N. Y. Model SWB is an inductive type bridge that is continually left in the line. It reads swr's from 1.8 Mc to 225 Mc and can handle 1,000 w. It has negligible insertion loss. Contains two SO-239 uhf connectors. Size: $1\frac{5}{8}$ in. by $2\frac{1}{4}$ in. by $4\frac{1}{2}$ in. Net cost, $9.95. **(317)**

Retaining Rings

WALDES KOHINOOR, INC., 47-16 Austel Place, Long Island City 1, N.Y. New Truarc N-type retaining rings (basic, bowed and beveled) are said

THE NEW *SUPER* WEE-DUCTOR

An ultra reliable MOLDED SHIELDED r.f. subminiature inductor—available in inductances from 0.1 μH to 100,000 μH in 73 values.

The **SUPER** WEE-DUCTOR is shielded for minimum coupling in high density packaging and has extremely low dc resistance. Only 0.410" long and 0.157" in diameter, the **SUPER** WEE-DUCTOR meets all the requirements of MIL-C-15305B (Amendment #1), Grade 1, Class B, including moisture and immersion resistance and operation from −55°C to +125°C.

For complete engineering data, write Dept. WL-29, or phone 201-464-9300. All values available from stock.

NYTRONICS, INC.

550 Springfield Ave., Berkeley Heights, N.J.

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STANDARD components to meet CUSTOM requirements

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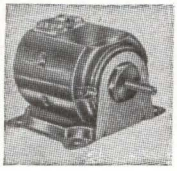
MIDGET DC MOTORS for Consumer Products

LOW DRAIN, QUIET, LONG LIFE—LOW COST!
PRODUCTION—UP TO 2,500,000 PER MONTH
INFORMATION, SAMPLES, PRICES—RIGHT HERE IN U.S.A.



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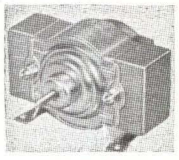
World's Leading Line
Large or small orders shipped on schedule. Over 30 sizes & types from 1½ to 12 volts. Modifications made to fit your needs. Also sub-assemblies.

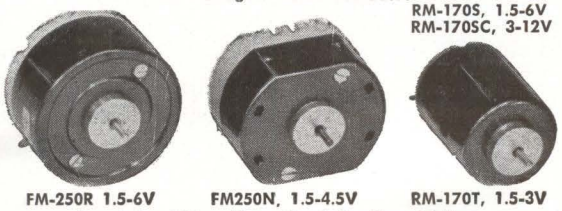


PER-MAG

APPLICATIONS: Tape Recorders, Record Players, Clocks, Shavers, Music Boxes, Cameras, Turntables, Appliances, Toothbrushes, Displays, Toys, Hobbies, Etc.

Write for Catalog, Specs, Samples, Quotations. State intended use.

Also—miniature & sub-miniature "grain of wheat" light bulbs. All voltages. Write for data.



RM-170S, 1.5-6V
RM-170SC, 3-12V

FM-250R 1.5-6V **FM250N, 1.5-4.5V** **RM-170T, 1.5-3V**

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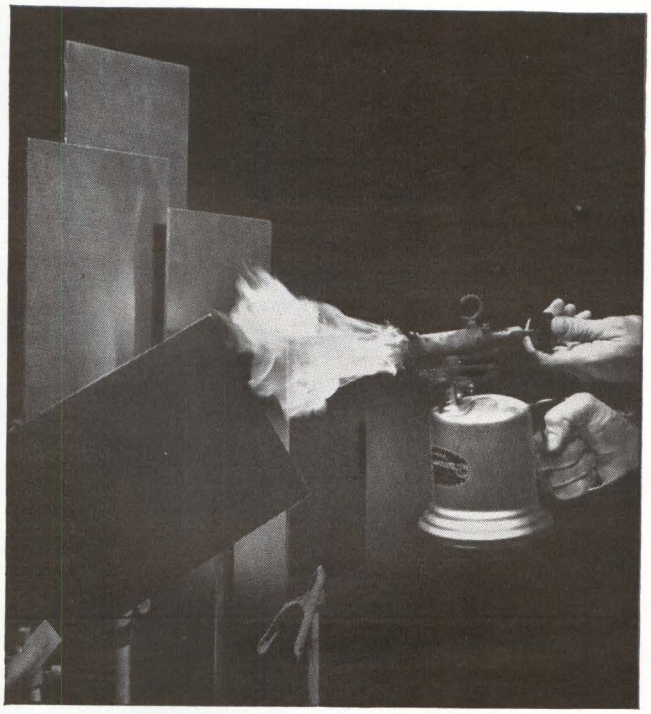
314 FIFTH AVE., N. Y. 1, N. Y. — BRyant 9-9034

CIRCLE 204 ON READER SERVICE CARD

Flame-Retardant laminated plastics for electrical and electronic applications



There are now 4 flame-retardant Synthane laminates to help the designers of computers, missile control equipment, transformers, circuit breakers or any other components subject to flame or heat.

These four grades FR-1, FR-2, FR-3 and FR-4 not only have excellent flame retardance but they combine many more properties desirable in an electrical insulation, such as low moisture absorption, low dielectric losses, mechanical strength and machinability. Supplied plain or copper clad. It will pay you to send for samples for your own evaluation and test . . . or write for information.

SYNTHANE
CORPORATION **OAKS, PENNA.**
GLendale 2-2211 TWX Valley Forge 735U
Synthane-Pacific, 518 W. Garfield Ave., Glendale 4, Calif. TWX GLDL 4417U

Synthane Corporation, 36 River Rd., Oaks, Pa.

Gentlemen:
Please send me your Engineering Bulletins on:
☐New Flame-retardant Grades ☐New High-temperature Grades

Name_____

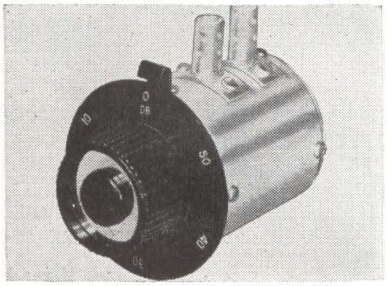
Address_____

City_____ Zone____ State_____

CIRCLE 91 ON READER SERVICE CARD

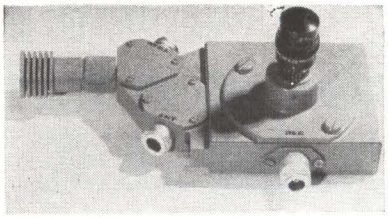
to provide approximately 20 percent higher thrust load capacity than conventional retaining rings of the same type and size.

CIRCLE **318**, READER SERVICE CARD



R-F Attenuator Handles 1 W of Power

TELONIC INDUSTRIES, INC., Beech Grove, Ind. The TE-50 turret-type r-f attenuator has a range of 0-50 db in 10 db steps. It will handle 1 w of power, even in the 50 db position. Attenuating r-f signals from d-c to 1,250 Mc, it uses individual 50 ohm resistive pi-pads, mounted in a precision-machined rotor assembly. Accuracy is typically ±2 percent at 30 Mc and 5 percent at 400 Mc. Insertion loss, negligible to 300 Mc and not more than 0.2 db to 900 Mc; vswr, near unity. Price is $65. **(319)**



Duplexer-Limiter Compactly Packaged

SPERRY MICROWAVE ELECTRONICS CO., P.O. Box 1828, Clearwater, Fla., offers a three-port ferrimagnetic beacon duplexer-limiter package. The unit, operating from 5.4 to 5.9 Gc at power levels up to 40 Kw peak 40 w average with a max antenna mismatch of 2:1, uses modified type N connectors. It affords protection to mixers with 1N23 type crystals. The transmitter-to-antenna insertion loss is nominally 0.7 db, and the antenna-to-receiver loss is nominally 0.9 db. Unit also provides preselection to received signals. Price is approximately $1,200. **(320)**

INTEGRATING MOTOR GENERATORS are temperature compensated. Motors include standard 6-pole, and low inertia 4 and 6-pole units. Kearfott Div. General Precision Inc., Little Falls, N. J. **(321)**

DIGITAL VOLTMETER/OHMMETER for systems integration. The transistorized unit can measure d-c volts, d-c ratios and ohms. Electro Instruments, Inc., 8611 Balboa Ave., San Diego 12, Calif. **(322)**

AUTOMATIC RESPONSE PLOTTER is a high-speed, accurate unit. It covers 20-20,000 cps range in one continuous sweep. Hathaway Instruments, Inc., 5800 E. Jewell Ave., Denver 22, Colo. **(323)**

ELECTRONIC DATA PRINTER operates in high speed communication systems. It permits transmission and reception of 5, 6, 7 and 8 level codes. Kleinschmidt Div. of Smith-Corona Marchant, Deerfield, Ill. **(324)**

MAGNETOSTRICTIVE DELAY LINES in sealed or unsealed cases. Delay length is 3,500 μsec. Tempo Instrument Inc., Plainview, N. Y. **(325)**

BEZELS for Nixie tube displays. They are offered preassembled or as component parts. Burroughs Corp., P. O. Box 1226, Plainfield, N. J... **(326)**

A-C LINE REGULATOR is all solid state. Input is 45 to 70 cps, 95 to 135 v. Dressen-Barnes Electronics Corp., 250 No. Vinedo Ave., Pasadena, Calif. **(327)**

LINEAR ACTION SWITCHES meet MIL-S-6743 and MIL-S-22885. Available in spst through 6pdt, in either momentary or alternate action versions. Strader Corp., 21531 Strathern, Canoga Park, Calif. **(328)**

COSINE PHASE PLOTTER compares frequency standards from 10 Kc to 5 Mc. Price is $225. RMS Engineering, Inc., 486-14th St. N.W., Atlanta 13, Ga. **(329)**

D-C MICRO-VOLT-AMMETER has 1 percent basic accuracy. It covers 10 μv to 1,000 v and 10 μμa to 1,000 μa. Millivac Instruments, Box 997, Schenectady, N. Y. **(330)**

NOISE GENERATOR provides dual output. A solid state chopper provides the desired stable l-f spectrum. Elgenco, Inc., 1231 Colorado Ave., Santa Monica, Calif. **(331)**

CABLE CLAMPS can reduce harnessing time by 50 percent. Clamps may be applied before or after wiring. Panduit Corp., 17301 Ridgeland Ave., Tinley Park, Ill. **(332)**

CERAMIC MAGNET MATERIAL for d-c motors. Index II features high energy product and high intrinsic coercive force. Indiana General Corp., Valparaiso, Ind. **(333)**

OPERATIONAL D-C AMPLIFIERS are octal based. They are designed for analog simulator and servo drive ap-

plications. Embree Electronics Corp., West Hartford, Conn. **(334)**

STEPPING MOTOR is less than 1 cu in. It has speeds up to 800 steps/sec. Sigma Instruments, Inc., 170 Pearl St., So. Braintree, Mass. **(335)**

DECADE RESISTANCE-STANDARD SETS have 100 ohm and 1 megohm primary standard resistors. Stability is better than ± 0.0015 percent absolute. Julie Research Laboratories, Inc., 603 W. 130th St., New York 27, N. Y. **(336)**

DIGITAL COMPUTER of average transients. It is designed for use in field and lab. Mnemotron Corp., Pearl River, N. Y. **(337)**

ALL-PURPOSE PACKAGED TRIGGER CIRCUIT is hermetically-sealed. Units are for use with silicon controlled rectifiers. VecTroL Engineering, Inc., 85-85 Magee Ave., Stamford, Conn. **(338)**

A-C RELAY is a 4pdt device. It measures $1\frac{9}{32}$ in. high by $\frac{55}{64}$ in. wide by $1\frac{7}{64}$ in. deep. Potter & Brumfield, Princeton, Ind. **(339)**

SERVO CLAMPS are used to fasten the housings of components to mounting plates. Price is 10¢ each. Theta Instrument Corp., Saddle Brook, N. J. **(340)**

DIGITAL VOLTMETER has automatic polarity, automatic ranging. Price is $995. Beckman, Berkeley Division, Richmond, Calif. **(341)**

C-BAND RADAR TRANSPONDER is lightweight, high power unit. It is pressurized and designed for operation in typical missile environments. Aero Geo Astro Corp., Alexandria, Va. **(342)**

RESISTANCE DECADE BOX is compact and accurate. It is calibrated to a standard set of 3 ft test leads. Riedon Division, On Mark Engineering Co., 7929 Hayvenhurst St., Van Nuys, Calif. **(343)**

REFERENCE POWER SUPPLIES in component packages. Price is $300 to $600 in the up to 5 w power range. Glentronics, Inc., 748 E. Alosta Blvd., Glendora, Calif. **(344)**

DIODE TESTER has 0-1 Kv piv, 0-1.5 amp peak forward current. Price is $185. Disc Instruments, Inc., 3014-B S. Halladay, Santa Ana, Calif. **(345)**

BANDPASS FILTER automatically tracks signals. Bandpass is adjustable from 2.5 to 100 cps. Interstate Electronics Corp., 707 E. Vermont Ave., Anaheim, Calif. **(346)**

FLAT-DIPPED CAPACITORS with high moisture-resistance properties. Temperature range is from — 55 C to +85C. General Electric Co., Schenectady 5, N. Y. **(347)**

S-BAND PULSE KLYSTRON yields 200 Mc bandwidth. It is designed to operate at 6 Mw peak. Eitel-McCullough Inc., San Carlos, Calif. **(348)**

SILICON ALLOY TRANSISTOR with extremely low collector leakage. All are pre-aged at 200 C for 150 hr. Kearfott Div., General Precision, Inc., Little Falls, N. J. **(349)**

Literature of the Week

D-C AMPLIFIER Elco, Inc., 1225 W. Broad St., Falls Church, Va. Bulletin 43-562 gives complete specifications for the model DCA-50C wideband d-c amplifier... **(350)**

TWO-WAY COLOR MEASUREMENT Instrument Development Laboratories, Inc., 67 Mechanic St., Attleboro, Mass., has published a 12-page booklet describing the Color-Eye combined colorimeter and abridged spectrophotometer. **(351)**

SIGNAL TRACER Don Bosco Electronics, Inc., Littell Road, Hanover, N. J., has a flyer on the Stethotracer, a transistorized, pen size, self-contained signal tracer. **(352)**

BLOCK READERS Electronic Engineering Co. of California, 1601 E. Chestnut Ave., Santa Ana, Calif. Circuit advantages of employing block readers for punched tape programming are shown in a brochure. **(353)**

HALL GENERATORS Helipot Division of Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. Data sheet presents a complete line of Halleflex solid state voltage generators. **(354)**

EARTH SATELLITE COMMUNICATIONS Lenkurt Electric Co., Inc., San Carlos, Calif. Vol. II, No. 5 of the *Demodulator* contains a well-illustrated article on earth satellite communications. **(355)**

ANALOG COMPUTER Electronic Associates, Inc., Long Branch, N. J. A 12-page brochure describes the PACE TR-10 desk-top size analog computer and its components and accessories. **(356)**

SERVO MOTORS Kearfott Div., General Precision, Inc., Little Falls, N. J. Catalog sheet contains data and a dimensional drawing for size 8 inertial damped servo motors. **(357)**

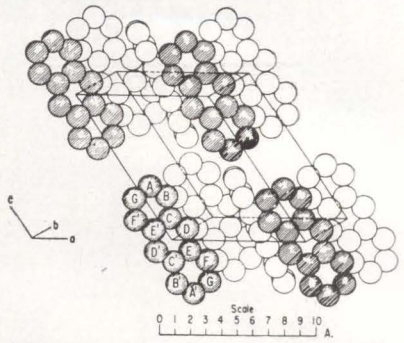
POWER TRANSISTORS Clevite Transistor, Waltham 54, Mass., has issued technical data sheets on its new 5 ampere and 15 ampere germanium power transistors. **(358)**

MICROWAVE COMPONENTS Guide Mfg. Co., 7602 San Fernando Road, Sun Valley, Calif., offers an easy-to-use product index and price list for waveguide and microwave components. **(359)**

RELAY PRODUCTION Swanson-Erie Corp., 814 E. Eighth St., Erie, Pa. How one machine processes, assembles and inspects 1,000 electrical relays in one hour is the subject of a 4-page brochure. **(360)**

ELECTRONIC PRINTER Hull Instruments, 726 Mission St., So. Pasadena, Calif. A six-page brochure describes a digital alpha numerical printer which, through the use of fiber optics, can print 6000 characters per sec. **(361)**

NEW BOOKS



Arrangement of molecules in a unit cell of anthracene material

Organic Semiconductors

Edited by J. J. BROPHY and J. W. BUTTREY

The Macmillan Company, New York, 1962, 243 *p*, $9.

This volume is based on papers presented at the inter-industry conference on organic semiconductors held in April 1961, which was cosponsored by the Armour Research Foundation and ELECTRONICS. It begins with a semitechnical survey of the field, followed by several groups of papers organized by subject matter in the order of increasing speculativeness.

The book will serve as a fine introduction to the subject for engineers in the semiconductor field; it is balanced to indicate the variety of directions in which research is proceeding. The last paper, by James F. Bourland, appraises the future of organic semiconductors from the point of view of management.—G.V.N.

Advances in Quantum Electronics

Edited by JAY R. SINGER

Columbia University Press, New York, 641 *p*, $15.

Collection of the 70 papers presented at the Second International Conference on Quantum Electronics. Topics covered include: masers, lasers, infrared-light detection, modulation and mixing; resonance phenomena such as cyclotron resonance, coherence and incoherence, and information-carrying capabilities in the presence of quantum effects. Although there is a wealth

of information and ideas here, non-specialists will find the going rough since the authors are first-class physicists who have written these conference papers for their peers. —S. V.

Static Power Convertors

Edited by ROBERT WELLS

John Wiley & Sons, Inc., New York, 1962, 275 *p*, $7.

Static Power Converters is a useful book in that it brings together many topics normally found scattered throughout specialized texts on motors, controls, rectifiers and other aspects of a-c to d-c conversion.

Two aspects of the title are misleading: first, the book is largely about mercury arc rectifiers, which although not rotary, are not static in the modern sense. Only 17 pages are devoted to semiconductors, confined to the germanium diode, leaving a vast field of transistors, diodes, rectifiers, silicon controlled rectifiers etc. undiscussed. Secondly, the term converters connotes, at least to American readers, a device other than a plain rectifier. There is no mention of frequency converers or d-c to a-c converters. A better title might have been, Mercury Arc Rectifiers as Power Sources.

Since the book covers a great deal of ground, including supplies for powering d-c motors, it provides a very useful survey of basic principles involved in many branches of mercury-arc rectifier application.—S.F.

Information Theory

Edited by COLIN CHERRY

Butterworth, Washington, 488 *p*, $16.50

This volume contains the thirty-six papers presented at the Fourth London Symposium on Information Theory late in 1960. The first three symposia were held in 1950, 1952 and 1955. Despite the title, this symposium is not devoted purely to information theory, but covers a wide ground with papers on learning mechanisms, on sensory information and biological models, syntactics and semantics, and human reaction to information. This volume will not be of particular inter-

est to design engineers and their ilk, but certainly will be to those who are farming the interdisciplinary areas that information theory has propagated. Ten years from now these areas may be sufficiently domesticated to provide design engineers a fair portion of their bread and butter work.—N.L.

Introduction to Microwave Theory

By H. A. ATWATER

McGraw-Hill Book Co., Inc., New York, 1962, 244 *p,* $8.75.

An outgrowth of notes used in a one-semester course in microwave theory given to upper division and first-year graduate students that supposes a background in electromagnetic theory, the book emphasizes the philosophy and methods of the analytical approach to in terms of electromagnetic fields.

The chapters deal with subjects such as transmission line theory, wave equations, discontinuities and impedances in waveguides, microwave resonators, klystrons and magnetrons, magnetic materials and millimeter waves. The appendix is well stocked with useful reference material, primarily mathematical—B.A.B.

Electroluminescence

By H. K. HENISCH

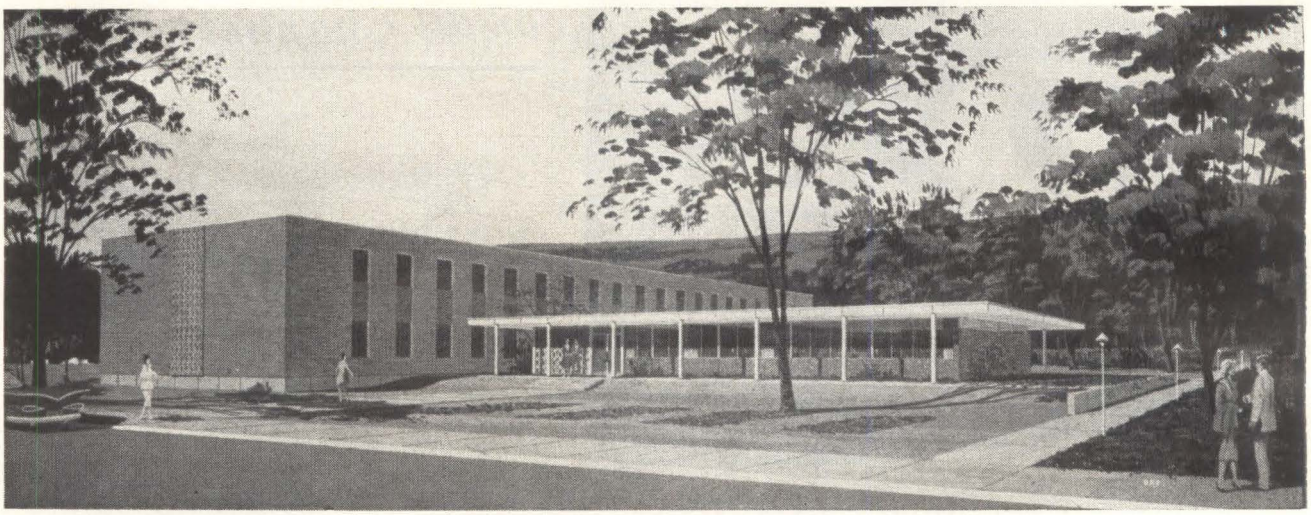
Pergamon Press, New York, 1962, 368 *p,* $12.50.

This is probably the first textbook published that is devoted to a comprehensive treatment of electroluminescent theory, including an outline of devices that use electroluminscent phenomena.

Fundamentals and techniques for achieving particular operating characteristics are generously treated in the first 250 pages; the rest gives a broad coverage of the uses of electroluminescence both as light sources and for coupling elements in electroluminescent-photoconductor logic systems.

Particularly valuable is the elaborate array of references, indexed by year of original publication. One is surprised to discover that electroluminescent phenomena were observed well before Destriau published his paper in 1936.—S.F.

Sprague Readies Basic Research Center



SPRAGUE ELECTRIC CO., 36-year-old electronic components manufacturer, will formally open on Oct. 11 the new Sprague Research Center, located across the street from the main entrance to its North Adams, Mass., headquarters plant.

James R. Killian, Jr., chairman of the corporation of MIT, will be principal speaker.

The 40,000-square-foot laboratory will be the focal point of Sprague's R&D program, currently pegged at $7 million annually. The new laboratory will concentrate on basic research, including such fields as solid-state physics, chemistry and the physics of dielectric materials. Development work will continue to be carried on in the North Adams plant and other product facilities.

Frederick M. Fowkes has been named director of research under Frederick R. Lack, senior vice president in charge of research. Fowkes, a physical chemist previously associated with the Shell Development Company, will administer the new research laboratory.

Sprague Electric reported 1961 sales of $77,650,168 and has nearly 30 manufacturing operations in the U. S. and five foreign countries. Sprague's American operations employ 8,000 persons.

In terms of sales, Sprague ranks 495th among the 500 largest U. S. corporations, but it ranked 65th among the 500 in terms of percentage earned on invested capital in 1961.

Hazeltine Research Elects Loughlin

B. D. LOUGHLIN has been elected vice president for research of Hazeltine Research, Inc., a subsidiary of Hazeltine Corp., Little Neck, N. Y.

Holder of the Vladimir K. Zworykin Television Prize of the IRE and the David Sarnoff Gold Medal Award of the SMPTE, Loughlin joined Hazeltine in 1939. In 1956 he was named chief engineer of the research division of Hazeltine Research Corp. The following year, he became a research consultant to Hazeltine along with other companies.

In his new post, Loughlin and his engineering group will continue to concentrate their efforts on the simplification of color television receivers.

PRL Electronics Names Charshafian

PRL ELECTRONICS, INC., Rahway, N. J., announces the appointment of former Curtiss-Wright vice president, J. O. Charshafian, as its new president.

Company manufactures electronic power supplies for military,

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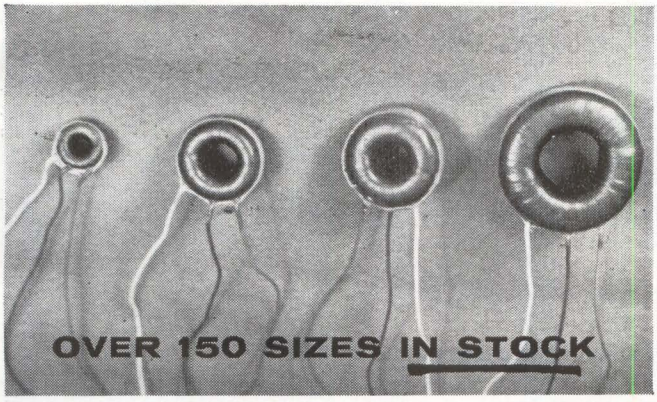

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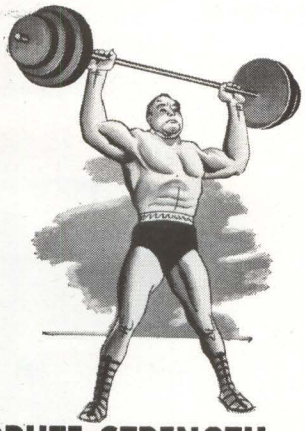

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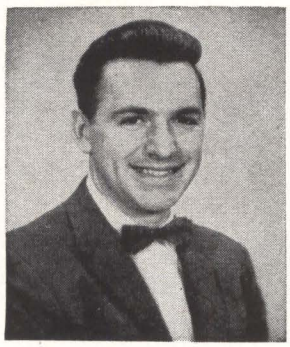

General Electric Names Hodges

DAVID J. HODGES has been appointed manager of voltage-tunable magnetron engineering at General Electric's Power Tube department, Schenectady, N. Y. A department project engineer since 1954, Hodges succeeds M. Weinstein who recently left the company.

Rixon Electronics Hires Miller

J. WILLIAM MILLER has joined Rixon Electronics, Inc., Silver Spring, Md., as a project manager for communications subsystems.

Before coming to Rixon, Miller was with Page Communications Engineers, Inc., for over seven years as project manager and engineer.

Technical Materiel Appoints Shalag

THE TECHNICAL MATERIEL CORP. of Mamaroneck, N. Y., announces the appointment of W. C. Shalag as executive vice president to head up operations of its wholly owned

subsidiary, TMC Systems, in Alexandria, Va.

Prior to this appointment, Shalag has acted in the capacity of vice president in charge of operations at TMC Systems for the past several years.

TRW Promotes Paul McGarrell

PAUL H. MCGARRELL has been named chief engineer in the electrical products department of Thompson Ramo Wooldridge's TAPCO division, Cleveland, O. Since joining TRW in 1956, McGarrell has had responsibility for key programs.

PEOPLE IN BRIEF

Richard H. Tuznik, formerly with Westinghouse Electric Corp. and Bliley Electric Co., joins Systems Inc. as a senior engineer. General Instrument Corp. promotes **John L. Herre** to v-p/government relations of its Radio Receptor div. **Robert T. Campion** and **John J. Burke** advance at Lear Siegler, Inc., to senior v-p's. **Charles M. Price** moves up to associate head of the Astrodynamics dept. of the Research and Planning div. of Aerospace Corp. Bendix-Scintilla ups **Donald S. Jones** to asst. g-m. **Robert H. Johnson** promoted to quality control mgr. of Phillips Control Co. **Carl David Todd** and **Richard S. Simpson** elevated to head of engineering and supervisor of production engineering, respectively, of the packaged assemblies dept. of the electronic products div. of Hughes Aircraft Co. **Ronald L. Bentley** advances to administrative mgr. of the Instrumentation div. of Microdot Inc. **H. T. Deverell,** previously with The Thomas & Betts Co., named executive engineer responsible for all product engineering for its subsidiary, Kent Mfg. Corp. **Murray Hoffman,** ex-Philco Corp., joins Airtron as engineering mgr. for ferrite devices. **Edwin J. Bradley,** from Sperry Rand to Diodes, Inc., as mgr. of marketing. **Helmut J. Schwarz** transfers from the Hamilton Standard div. to the Research Laboratories of United Aircraft Corp. as a senior research scientist.

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DOUGLAS AIRCRAFT CO. Missile and Space Systems Division Santa Monica, California	37	4
GENERAL DYNAMICS/ELECTRONICS A Div. of General Dynamics Corp. Rochester, New York	108	5
HOUSTON INSTRUMENT CORP. Bellaire, Texas	110	6
INTERNATIONAL BUSINESS MACHINES CORP. New York, N. Y.	89*	7
JET PROPULSION LABORATORY Pasadena, California	108	8
MICROWAVE SERVICES INTERNATIONAL INC. Denville, New Jersey	110	9
MOLONEY ELECTRIC CO. St. Louis 20, Mo.	110	10
PHILCO WESTERN DEVELOPMENT LABS. Sub. of Ford Motor Co. Palo Alto, California	107	11
REPUBLIC AVIATION CORPORATION Farmingdale, Long Island, New York	109	12
SPACE TECHNOLOGY LABORATORIES, INC. Sub. of Thompson Ramo Wooldridge Inc. Redondo Beach, California	15	13
U. S. NAVAL CIVIL ENGINEERING LABORATORY Port Hueneme, California	108	14

* This advertisement appeared in the 8/31/62 issue.

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CITY .....ZONE.....STATE.....

HOME TELEPHONE .....

Education

PROFESSIONAL DEGREE(S) .....

MAJOR(S) .....

UNIVERSITY .....

DATE(S) .....

FIELDS OF EXPERIENCE (Please Check)

9762

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☐ Antennas	☐ Human Factors	☐ Radio—TV
☐ ASW	☐ Infrared	☐ Simulators
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☐ Communications	☐ Medicine	☐ Telemetry
☐ Components	☐ Microwave	☐ Transformers
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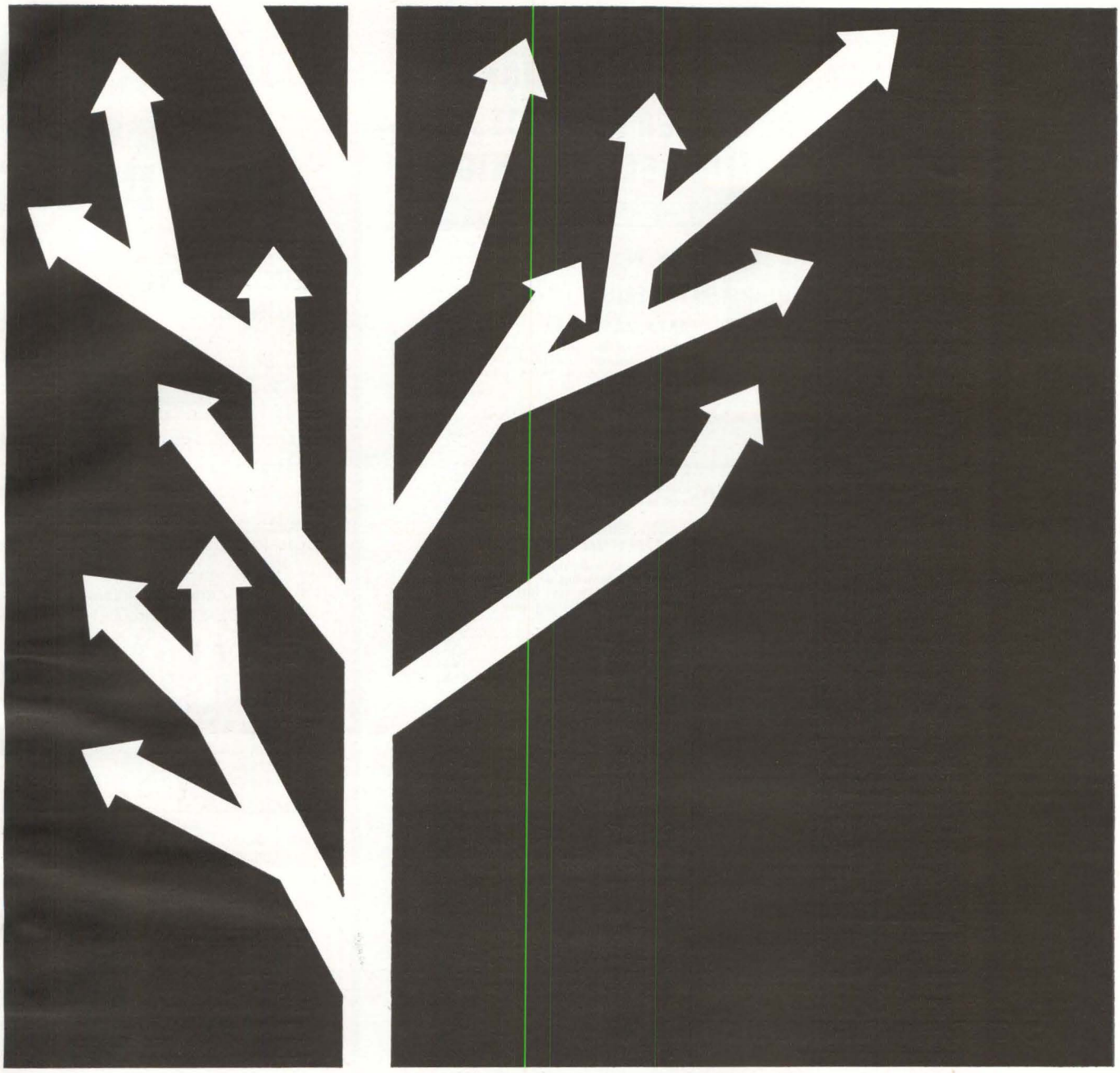

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SR. DESIGN ENGINEERS

BS with 8 years experience, of which 5 must have been in design in two or more of the following: digital, RF, pulse, audio, CRT, photorecorders, magnetic recorders, pulse multiplex and frequency multiplex. To assist in evaluation of complex electronic reconnaissance systems.

DESIGN ENGINEERS

BS with 3 to 5 years experience in RF and microwave receivers, digital display circuits, data handling and CRT displays including storage tube circuits. To assist in evaluation of complex electronic reconnaissance systems.

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SENIOR SONICS ENGINEER

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● TEST EQUIPMENT & INSTALLATIONS

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To supervise design and integration of test stations. Knowledge should include 1 or more of the following areas: flight control systems, radar indicators, HF-VHF navigation and communication equipment, microwave equipment, antenna systems and ECM. Should be familiar with all types of testing techniques and equipment associated with particular areas of interest. BSEE.

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BSEE with thorough background in one of the following: microwave signal generators and receivers; low frequency signal generators, HF-UHF signal generators, digital and pulse circuits. AGE Systems.

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Will direct programs involving communication circuits or systems. Position requires substantial experience in operation, design or evaluation of communication systems, as well as background in the inter-relations of antenna, transmitter, receiver, propagation, and terminal equipment.

ELECTRONICS ENGINEER

Will work with Test Manager on design, selection, modification and supervision of activity concerning instrumentation components and systems used in testing propulsion units. BS or MS in EE or physics and experience, preferably in the rocket instrumentation field.

INSTRUMENT ENGINEER

To work with Rocket Test Manager coordinating activities of instrumentation staff with other segments in the test group and throughout ARC. Responsibilities include design, selection, modification, and operation of instrument components and systems used in static testing of propulsion units. BS or MS in EE or physics and several years' experience.

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Director, Professional Personnel

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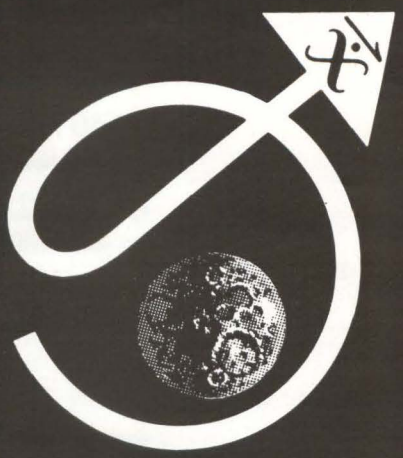

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Design and develop ground station and on-board data handling systems for re-entry and space vehicle applications.

COMMUNICATION TECHNIQUES — B.S., M.S.
Develop advanced communications techniques for aerospace and space craft, includes communications theory and network synthesis.

ADVANCED SPACE RADARS — B.S., M.S.
Develop concepts and components for advanced space radar including rendezvous, mapping, acquisition and tracking applications.

RADAR INTEGRATION — B.S.
Develop specifications, install and integrate advanced radar in hypersonic and space vehicles, including antennas, transmitters, receivers, displays, power supplies, controls.

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RADAR TEST (GSE) — B.S.
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RE-ENTRY INSTRUMENTATION — B.S., M.S.
Design instrumentation for specific re-entry and space vehicles including telemetry systems.

MATHEMATICAL ANALYSIS CONTROLS — PhD.
Theoretical analysis of noise effects and non-linear mechanisms on automatic controls. Includes optimal control theory and generalized stability criteria.

ELECTRONIC INSTRUMENTATION — B.S., M.S.
Develop instrumentation for space vehicles. Knowledge of system integration and telemetry desirable.

SPACE GUIDANCE SYSTEMS — M.S., PhD.
Develop and analyze navigation and guidance systems using inertial and Doppler techniques and advanced nuclear gyros.

ECM REQUIREMENTS — B.S., M.S.
Mathematical analysis of ECM requirements for advanced aerospace and space craft, and specification of equipment.

FLIGHT CONTROL DESIGN — M.S.
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PYROTECHNIC CIRCUIT DESIGN — B.S., M.S.
Develop pyrotechnic missile circuits including safe arm, squib ignition and RFI elimination devices.

EXPERIMENTAL PHYSICIST — PhD.
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ENVIRONMENTAL TESTING — B.S., M.S.
Undertake test programs to estimate component and system reliability using AGREE type methods; monitor offsite testing.

DESIGN REVIEW — B.S., M.S.
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STATISTICAL ANALYSIS — B.S., M.S.
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Interested applicants are invited to write in confidence to: Mr. George R. Hickman, Technical Employment Manager, Dept. 11J-1

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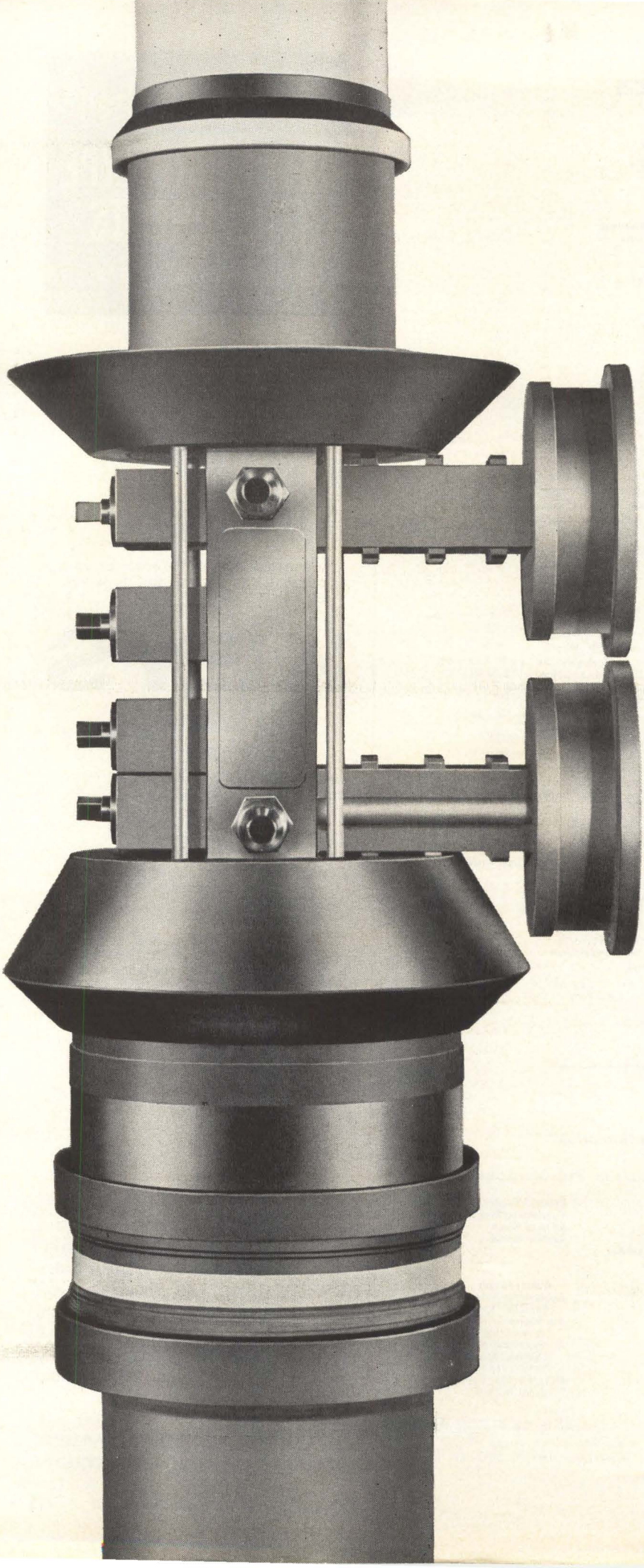

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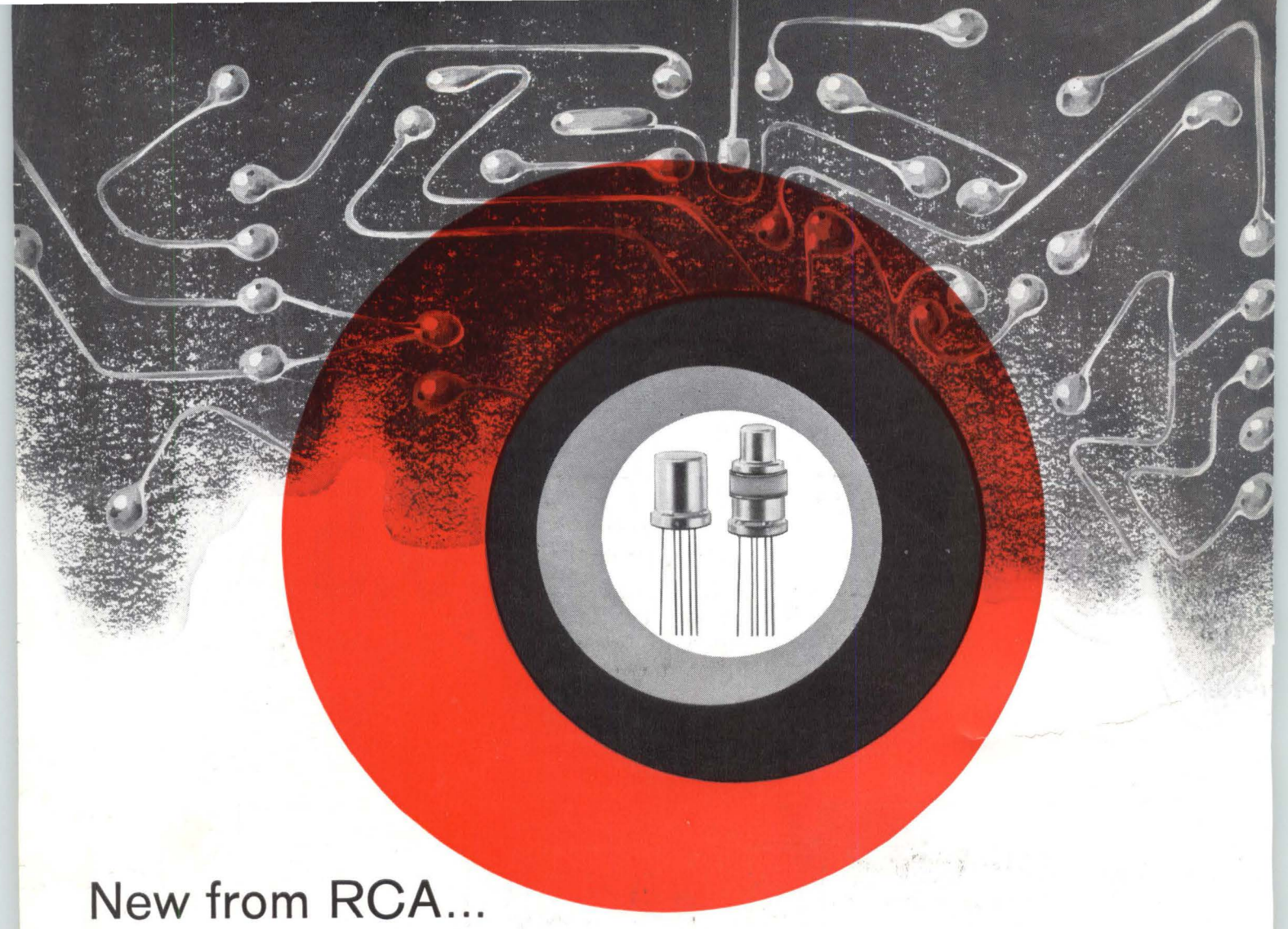

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Developmental **LONG-LEAD NUVISTORS**
for applications requiring solder-in components

RCA is now developing a series of long-lead nuvistor types designed to be soldered directly into printed circuit boards ... without sockets. This simplification can:

- cut assembly cost and time
- save space
- eliminate the undesirable loading effects sometimes encountered with sockets in high-frequency applications.

Nuvistors are a perfect choice for high-frequency solder-in applications because of their high reliability and long life. (Recent tests proved the reliability factor of RCA-7586 nuvistors to be only 0.36% or less failures per thousand hours with a 95% confidence level.)

The table at right indicates the long-lead nuvistor types now in development.

Developmental Number	Commercial Prototype	Developmental Long-Lead Nuvistors Description
A-15212	RCA-7586	General-purpose industrial medium-mu triode
A-2702	RCA-7587	General-purpose industrial sharp-cutoff tetrode
A-15321	RCA-7895	Industrial high-mu triode
A-15319	RCA-8056	Medium-mu triode for low B+ and HYBRID equipment applications
A-15320	RCA-8058	Double-ended high-mu rf power amplifier triode for UHF applications
A-15317		Triode for low-level Class C service
A-15318		Double-ended triode for low-level Class C service
Following types offer EXTRA low failure rates in early life periods, for applications where the primary objective is high and reliable performance for periods up to 100 hours: e.g., sonobuoys, minibuoys, rocketsondes, weathersondes.		
A-2707		Tetrode for oscillator-multiplier applications through 100 Mc
A-15307		Triode for oscillator-multiplier, and amplifier applications through 200 Mc
A-15309		Triode for low B+ and HYBRID equipment applications

Still other nuvistor types are in early stages of development– including a nuvistor with a 13.5-volt heater for low B+ and HYBRID equipment applications in mobile communications. These long-lead nuvistor types constitute another dramatic step forward in the rapidly expanding field of nuvistor receiving tube design. For details about specific types, talk with your RCA Field Representative.

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