December 22, 1961

electronics

A McGraw-Hill Publication 75 Cents

RELAY SATELLITE

Automatic tracking, p 23

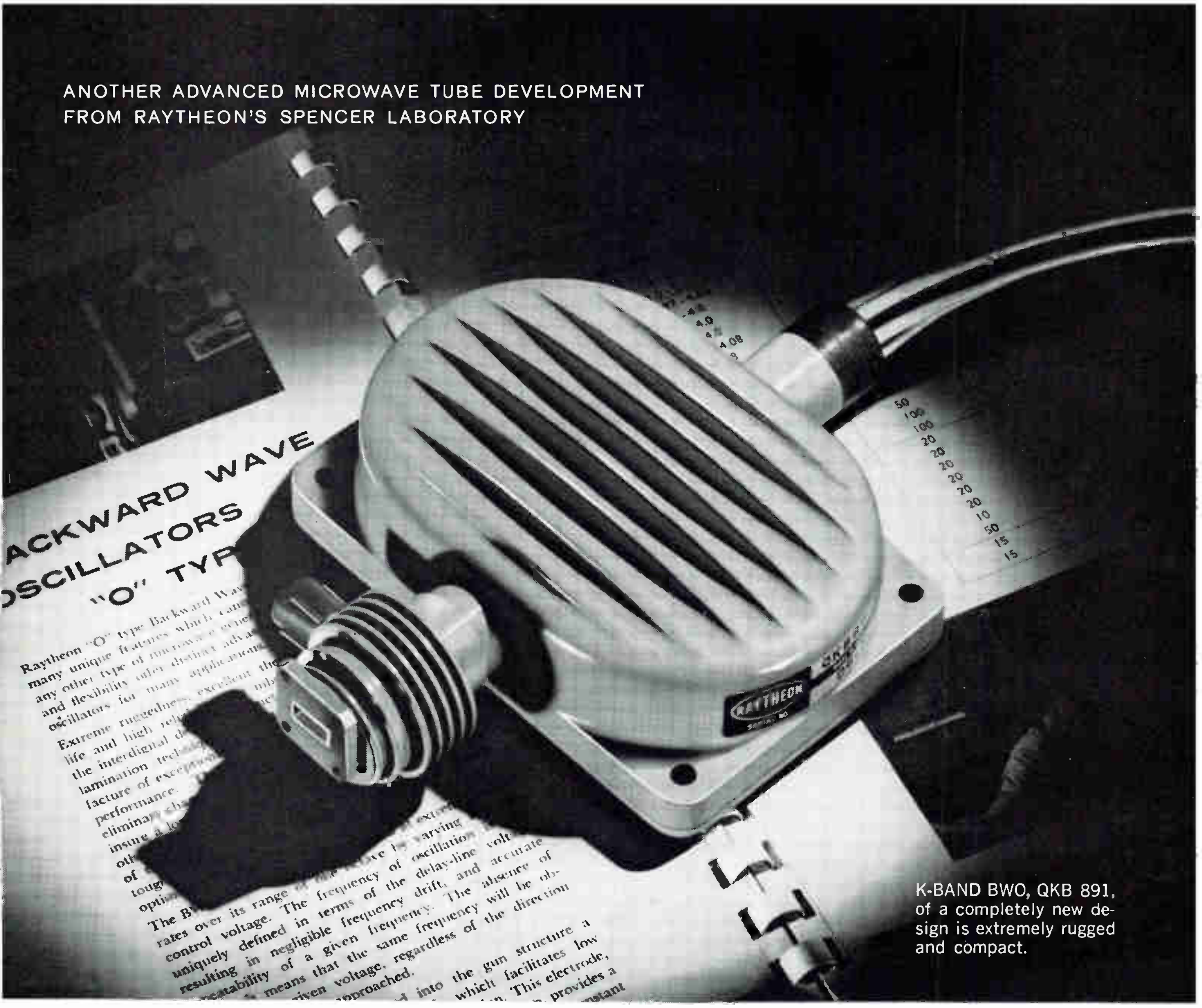
(Photo below)

COUNTER DISPLAYS

Photoconductive matrix. See p 28

DIODE A-F AMPLIFIERS

Ten-gigohm input, p 38



K-BAND BWO, QKB 891, of a completely new design is extremely rugged and compact.

New K-band O-type BWO's extend Raytheon compatible line to 26.5 kMc

Advanced design provides 40 mW minimum power output in extremely rugged and compact package.

Size and weight of these two new Raytheon backward wave oscillators are barely half that of units now in use.

The QKB 890 and QKB 891 are designed for such applications as swept local oscillators in ECM receivers and test equipment, driver tubes in frequency diversity radars, and pump tubes for broadband parametric amplifiers. Both tubes utilize PM focusing and have grids for low-voltage pulsed operation. For equipment designs requiring close mounting, only two-inch spacing between tubes is necessary.

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TYPICAL OPERATING CHARACTERISTICS

	QKB 890	QKB 891
Frequency Range	12.4-18 kMc	18-26.5 kMc
Power Output	40-180 mW	40-180 mW
Delay Line (tuning)	400-1270V	600-2100V
Anode Voltage (fixed)	125V	150V
Cathode Current	17-21 mA	21-32 mA
Filament Voltage	6.3 Volts	6.3 Volts
Waveguide Coupling	RG91/U	RG53/U

RAYTHEON

RAYTHEON COMPANY

MICROWAVE AND POWER TUBE DIVISION

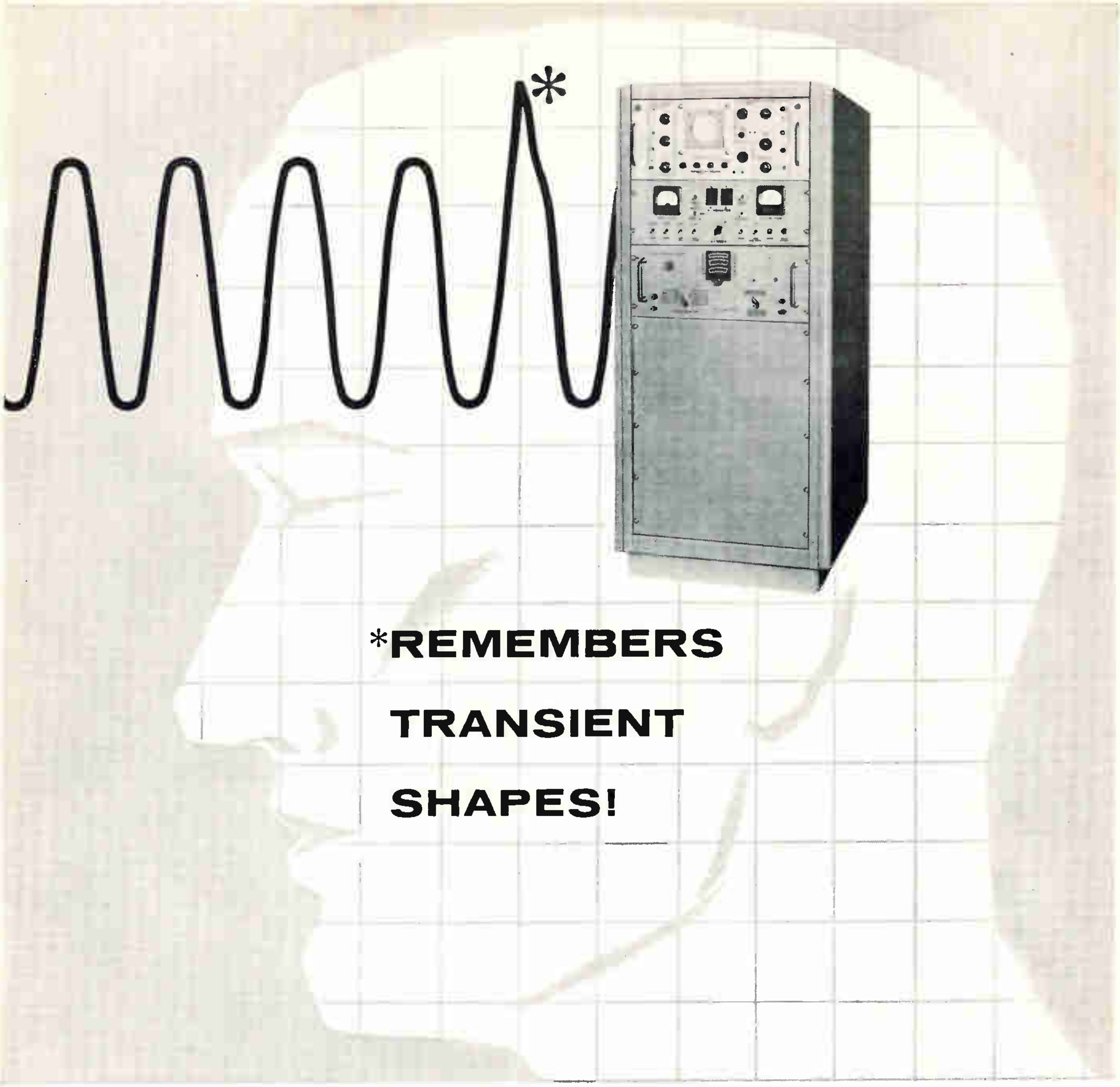
CIRCLE 251 ON READER SERVICE CARD

December 22, 1961

electronics

A McGraw-Hill Publication 75 Cents

W. W. MacDONALD, Editor



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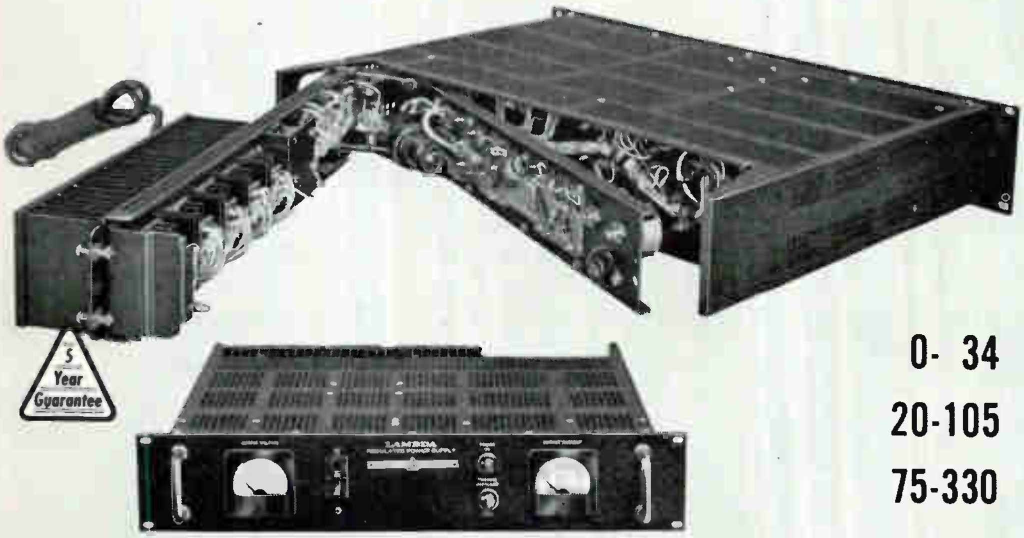

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0- 34 VDC 5, 10, 20 AMP
20-105 VDC 2, 4, 8 AMP
75-330 VDC 0.8, 1.5, 3 AMP

SPECIAL FEATURES

- Convection Cooled—No internal blowers or filters—maintenance free
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CONDENSED DATA—LA SERIES

DC OUTPUT (Regulated for line and load)

Model	Voltage Range (1)	Vernier Band (2)	Current Range (3)	Price (4)
LA 50-03B	0- 34 VDC	4 V	0- 5 AMP	$ 395
LA100-03B	0- 34 VDC	4 V	0-10 AMP	510
LA200-03A	0- 34 VDC	4 V	0-20 AMP	795
LA 20-05B	20-105 VDC	10 V	0- 2 AMP	350
LA 40-05B	20-105 VDC	10 V	0- 4 AMP	495
LA 80-05B	20-105 VDC	10 V	0- 8 AMP	780
LA 8-08B	75-330 VDC	30 V	0- 0.8 AMP	395
LA 15-08B	75-330 VDC	30 V	0- 1.5 AMP	560
LA 30-08B	75-330 VDC	30 V	0- 3 AMP	860

Regulation (line) .... Less than 0.05 per cent or 8 millivolts (whichever is greater). For input variations from 105-140 VAC.(5)

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Ripple and Noise .... Less than 1 millivolt rms with either terminal grounded.

Temperature Coefficient .... Less than 0.025%/°C.

(1) The DC output voltage for each model is completely covered by four selector switches plus vernier range.
(2) Center of vernier band may be set at any of 16 points throughout voltage range.
(3) Current rating applies over entire voltage range.
(4) Prices are for unmetered models. For metered models add the suffix "M" and add $30.00 to the price.
(5) Except for LA-200-03A which has AC input voltage of 100-130 VAC. 105-140 VAC available upon request.

AC INPUT 105-140 VAC,(5) 60 ± 0.3 cycle(6)

(6) This frequency band amply covers standard commercial power line tolerances in the United States and Canada. For operation over wider frequency band, consult factory.

Size

LA 50-03B, LA20-05B, LA 8-08B	3½" H x 19" W x 14⅜" D
LA100-03B, LA40-05B, LA15-08B	7" H x 19" W x 14⅜" D
LA200-03A, LA80-05B, LA30-08B	10½" H x 19" W x 16½" D

For complete data send for new Lambda Catalog 61

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CIRCLE 3 ON READER SERVICE CARD

electronics
December 22, 1961 Volume 34 No. 51

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CROSSTALK

Proprietary Piracy

WHEN A MAN feels that working for wages is holding him back he can, in a free country, strike out on his own. A new invention or an improved design is often the springboard to success in industry.

This is healthy. It has helped industry grow, diversify and advance technically. But even in a free country there is a limit to the right to strike out on one's own. The line is drawn at piracy.

The brains a man brings to a company, and the general education he acquires while there, he can take with him. But it is not right—morally or legally—for employees to leave an employer along with clearly proprietary information and then move into direct competition with him. This is as wrong as baldly selling someone's trade secrets to his competitors.

Most engineers abide by their written and unwritten agreements to respect proprietary rights. But lately there have been an increasing number of reports to the contrary. Some companies who have been stung blame quick-buck venture capital operators who make a practice of luring engineers into an unethical spinoff.

Consider, for example, a company that makes a line of proprietary products based on a component which it developed. A group of engineers might leave and sell customers of their former employer an almost identical product.

These employees might take with them not only general know-how gained in years of employment, but even design data and information on who the customers are. They might conceivably also hire a number of other people working for their old employer, at least momentarily knocking for a loop his ability to produce the product.

The best approach to this problem is good old-fashioned professional ethics. But if a man hasn't the good sense to found a new business on honest initiative, then his former employer most certainly has the right to land on him with both feet by all ethical means.

Coming In Our December 29 issue

SCUBA SONAR. To aid frogmen in underwater exploration, a completely self-contained, battery-powered sonar set has been developed. Its range of 120 yards gives divers greater effectiveness in opaque water, enabling them to locate unseen objects like sitting submarines, shipwrecks and schools of fish, once the operator has been trained to identify sonar returns against a background of ocean noises. However, I. R. Colldeweih, E. L. Walls and R. D. Lee, of Dalmo-Victor, authors of an article on it, think it will be some time before the price drops to a range that most scuba buffs can afford. Other articles next week are on microcircuits, digital circuits and electro-optical systems.

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METAL FILM RESISTORS OFFER 5 DISTINCT TEMPERATURE COEFFICIENTS TO MEET ALL CIRCUIT REQUIREMENTS

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Providing close accuracy, reliability and stability with low controlled temperature coefficients, these molded case metal-film resistors outperform precision wirewound and carbon film resistors. Prime characteristics include minimum inherent noise level, negligible voltage coefficient of resistance and excellent long-time stability under rated load as well as under severe conditions of humidity.

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Filmistor "Metal Film" Resistors are automatically spiralled to desired resistance values by exclusive Sprague equipment. The metallic resistive film, deposited by high vacuum evaporation, bonds firmly to special ceramic cores. Noble metal terminals insure low contact resistance.

The resistance elements, complete with end caps and leads attached are molded in dense, high temperature thermosetting material to form a tough molded shell for maximum protection against mechanical damage, moisture penetration and repeated temperature cycling.

Filmistor "C" Resistors, in ⅛, ¼, ½ and 1 watt ratings, surpass stringent performance requirements of MIL-R-10509D, Characteristics C and E. Write for Engineering Bulletin No. 7025 to: Technical Literature Section, Sprague Electric Co., 35 Marshall Street, North Adams, Mass.

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CIRCLE 5 ON READER SERVICE CARD

COMMENT

Heat and Hot Wind

In the *Electronics Newsletter* of Nov. 10, I noticed an interesting item about a metal-porcelain sandwich that can convert heat to power. The item states that this type of cell "could probably utilize waste heat in rocket exhausts." It seems more cogent to me that it could be used to convert the tremendous heat generated upon reentry to some more useful form of energy, such as lift or thrust. Then, instead of fighting the problem of reentry heat, NASA and the Air Force could put the heat to work, and also diminish the probability of detection by infrared means. I believe the Air Force is trying to do exactly this, and so one should expect more, and more sophisticated, devices of this sort.

If your Israeli correspondent F. J. Goldwater (*Comment*, p 6, Nov. 17) had spelled *khamsin* in the Latin alphabet instead of in Hebrew (*hamsin*), you would have found it in your dictionary. It's a hot southerly wind that blows regularly in Egypt (and I believe in the Sinai peninsula) for about 50 days each year, starting in March. Some exegetes have attempted to connect the khamsin with the plagues visited upon Egypt at the time of the Mosaic exodus. The word, incidentally, is derived from the Arabic word for fifty.

FRANK LEARY
New York, N.Y.

Reader Leary, a former associate editor with this magazine, is up on his heat conversion and Arabic. Two weeks ago he began working on Science Week, McGraw-Hill's new weekly newsletter that will begin publication in February.

Cryogenic Inductors

In the Nov. 10 issue, there were two errors on page 96 in my article, Cryogenic Inductors May Become Power Source. In the first column, second paragraph, average current densities of 100 kilamps per sq cm (rather than 100 amps) were observed in Nb_3Sn. In the third column, bottom paragraph, the helium evaporation rate should be ¼ liter per day rather than per hour.

Since the relatively short time ago that this paper was written, the strides in cryogenics have been rapid and far-reaching. One of the most significant is described by J. H. Wernick of Bell Telephone Laboratories in a paper presented at the First International Conference on High Magnetic Fields, MIT 1961. This describes evidence that an alloy of vanadium gallium ($V_{2.95}Ga$) can remain superconductive in magnetic fields exceeding 500 kilogauss. This compares favorably with the 88-kg field that I referred to, particularly since the energy storage capability of a coil tends to be proportional to the square of the critical field; that is, energy $= \frac{1}{2} LI_{max}^2$ where $I_{max} = N\phi_{max}/L$.

A. HEMEL
Motorola Inc.
Chicago, Illinois

We published a summary of the cryogenic magnets reports given at the conference (p 24, Dec. 1).

Gas Combinations for Lasers

In the Oct. 27 issue you treated the subject of Lasers (p 39) and referred on page 47 to gas combinations that have been proposed for use: mercury and krypton, mercury and zinc. You did not give in this connection any reference, which I should appreciate very much obtaining.

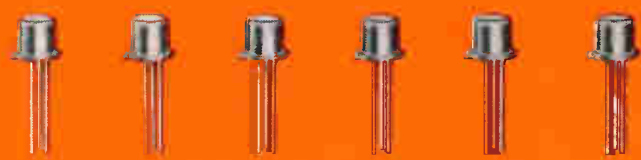
GEORG CZERLINSKI
University of Pennsylvania
Philadelphia, Pa.

The mercury-krypton gas combination was referred to in a Physical Review Letter by Dr. A. Javan of Bell Labs, in Vol. 3, No. 2, July 15, 1959, p 87, under the title, Possibility of Negative Temperature in Gas Discharges.

The mercury-zinc gas combination should have been referenced to the No. 8 reference; this Phys. Rev. Lett. of Feb. 1, 1961 was titled Population Inversion and Continuous Optical Maser Oscillation in a Gas Discharge Containing a He-Ne Mixture, by A. Javan, W. R. Bennett and D. R. Herriott of Bell Labs. This letter referred briefly on page 10 to the Hg-Zn combination and gave a reference (No. 11 of their letter) that reported work on this gas combination.

THESE 6 NEW MOTOROLA EPITAXIAL MESA SWITCHES REPLACE MICRO-ALLOY, DRIFT and OTHER MESA TYPES

ACTUAL SIZE



REPLACEMENT CHART*

Process Group	2N960	2N961	2N962	2N964	2N965	2N966
Micro-alloy Diffused	2N501 2N846 2N588 2N1500	2N769 2N768	2N1499A	2N779	—	—
Mesa	2N781 2N705 2N710	2N711	2N782	2N1301 2N795 2N1683 2N934	—	2N1300 2N794
Micro-alloy	2N1122A	2N1122	2N393 2N1427 2N1411	—	—	
Surface Barrier	—	2N128	2N210 2N344 2N345 2N346	—	—	—
Alloy	2N583	—	—	2N582 2N584	—	—
Drift	—	2N643 2N644 2N645	2N1450 2N602	—	2N609	2N603

*Interchangeability of types shown is on the basis of performance in most switching circuit applications.

for improved performance of both old and new designs

This new Motorola germanium epitaxial switching series – the 2N960-62, 2N964-66 – will supplant nearly all other germanium micro-alloy, drift, mesa, and other transistor types for high-speed switching applications . . . in many cases at considerably lower prices.

In comparison with the older devices, these six new universal switching transistors offer major design advantages that contribute to improved performance of both old and new designs.

- faster switching time ($\tau_{RE} = 0.6$ nsec)
- guaranteed minimum Beta over wide current range . . . specified at 10, 50 and 100 mA
- low saturation voltage even at 100 mA
- rugged Mesa construction
- the most comprehensive published specifications of any similar switching transistors
- proven reliability from the world's largest manufacturer of germanium epitaxial transistors

For applications where the advantages offered by this new epitaxial series are not essential, Motorola also offers eight new non-epitaxial germanium mesa transistors – the 2N968-75 series – at even lower prices.

MOTOROLA GERMANIUM EPITAXIAL SWITCHING TRANSISTORS

	2N960	2N961	2N962	2N964	2N965	2N966	UNITS
h_{FE} (MIN) 10, 50, 100 mA	20	20	20	40	40	40	—
V_{CE} (SAT) MAX @ 10 mA	.20	.20	.20	.18	.18	.18	Volts
@ 50 mA	.40	.40	.40	.35	.35	.35	Volts
@ 100 mA	.70	.70	.70	.60	.60	.60	Volts
f_T (MIN) I_E=20 mAdc V_{CB}=1.0 Vdc	300 mc all types						
Q_T (MAX) I_C=10 mAdc I_B=1 mAdc	80	80	90	80	80	90	pc
I_C=100 mAdc I_B=5 mAdc	125	125	150	125	125	150	pc
τ_{RE}	0.6 nsec typical all types						
τ_{FE}	0.5 nsec typical all types						

All types have 150 mW dissipation in free air, 300 mW at 25°C case temperature

FOR MORE INFORMATION on either of these important new mesa series, contact your Motorola District Office, or call or write: Motorola Semiconductor Products Inc., Technical Information Department, 5005 East McDowell Road, Phoenix 8, Arizona.

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ELECTRONICS NEWSLETTER

Air Force To Buy Advanced Space Trackers

SECOND GENERATION satellite detection and tracking system, one radar and one optical, are being sought by the Air Force as part of its long-planned improvements to the space surveillance network (ELECTRONICS, p 32, Nov. 24 and p 20, Mar. 3).

Goal of the two new systems is to make Spadats, the operational satellite tracking center, capable of continuous surveillance of cislunar space and cataloguing of all objects in orbit.

Last week, qualified contractors received formal requests for proposals on development of the first radar specifically designed to detect and track satellites. It will be located close to the equator—which satellites cross twice each orbit—and will give complete orbit information on each pass. Rome Air Development Center will handle procurement.

This week, Electronic Systems Division at Hanscom Field briefed some 35 firms on requirements of a prototype optical surveillance device to update the 496L Space Track network. An optical system would be used for ranges at which radar is not yet practical. Bids on both projects are due in early 1962.

Germans Planning Ground Station for Satellites

CONSTRUCTION of Germany's first satellite ground station under the NASA program is scheduled to start next spring and to be completed in 1963. It will be built at a Bavarian village located near Munich. It will have only one antenna initially, but two more will be added later for commercial satellite use. The German Federal Post is expected to award contracts to Siemens and Telefunken.

AEC Wants Another Very Fast Computer

INVITATIONS to bid on a new computer has been sent some 30 manufacturers by the AEC. The computer, for use at Lawrence Radiation Laboratory, Livermore, cal., must be "seven to nine times" faster than the IBM 7090. AEC has \$5.8 million available, as a result of agreement by IBM to reduce the price of its newly installed 7030 from \$13.5 million to \$7.8 million. Tests rated the arithmetical and logical capabilities of the 7030 as four to 4.5 times that of the 7090, an AEC spokesman said.

National Meetings Will Replace EJCC and WJCC

WASHINGTON—The last of the Joint Computer Conference was held here last week.

Willis Ware, chairman of the sponsoring American Federation of Information Processing Societies announced at the Eastern JCC that it and its Western counterpart, WJCC, will no longer be held. Instead, there will be spring and fall meetings with no absolute regional tie-ins.

AFIPS grew out of difficulties the IRE, AIEE and ACM had in handling through their National Joint Computer Committee the events relating to the computer field. Founded last May, AFIPS will begin full-scale operations in January. It will serve as an information source to the public, government and industry, will sponsor conferences and represent the U.S. on international organizations like IFIPS.

IFIPS, organized in 1960, has 19 member nations. It announced at EJCC that it would hold a world congress on information processing in Munich, Germany, Aug. 27-Sept. 1, 1962.

Micromodules Go Into Army Tactical Radios

RCA REPORTED last week that it will produce 350 manpack radios using micromodules, as part of a previously announced \$9 million contract to produce 8,598 AN/PRC-25 transistor sets. The 350 hybrid sets and the others will be operationally interchangeable.

This is the first time that the Army has specified the modules in a tactical equipment production contract, RCA said. Micromodule (ELECTRONICS, p 62, May 15, and p 51, May 22, 1959) R&D began in 1958.

World's Fair Will have 21st Century Library

INFORMATION storage and retrieval techniques are integrated in an automated library introduced in Chicago last week. Library 21 is considered a prototype of the next century's core libraries, serving other libraries in a vast region

Satellite Oscar Says "Hi" to Hams Everywhere

OSCAR, the Orbiting Satellite Carrying Amateur Radio, hitchhiked into space aboard the Air Force's Discoverer 36, launched last Tuesday from Vandenberg Air Force Base.

Its signal—HI repeated in Morse code 10 times a minute—was received at the South Pole, in Alaska and Hawaii, establishing that it had gone into the planned orbit.

Oscar was designed, financed and built by amateurs, with government authorization. It operates in the two-meter band at 145 Mc. Life expectancy is three weeks to one month. Sponsors request that information on radio pickups, and inquiries, be mailed to PO Box 183, Sunnyvale, Calif.

through communications networks.

It was developed for the 1962 World's Fair in Seattle. Some 72 selected librarians will go to Seattle for instruction in information retrieval. They'll staff the library in a move to help bring the profession abreast of new techniques to cope with the "information explosion."

Univac Solid State 80, primed with some of the basic ideas and Great Books topics, prints out answers to queries. The computer can tailor answers to the patron's sex, personality and comprehension level. Future systems are to analyze psychological and emotional requirements as well.

A photo process developed by National Cash Register, reduces documents 40,000 to 1 to put the text of a 400-page book in an area the size of a postage stamp. Images can be erased, altered, added to or subtracted from while in storage, and selected and magnified for reading.

Magnavox, IBM, TRW and RCA will demonstrate accessibility of worldwide documentary materials through video and color film communications, listening booths, teaching machines and language labs.

From Sonar to Stockings —That's Ultrasonics Now

SNUGGER STOCKINGS for ladies is apparently the purpose of a new ultrasonic processing technique begun this week by Berkshire Knitting Mills. The company says it alters the molecular structure of hosiery nylon, giving the fibers elasticity and absorbency like natural fibers. Applications to other synthetic fibers are anticipated. The equipment was made by the Danish firm, Hans Christian Anderson, of Copenhagen.

Institutes Start Major R&D Construction Projects

PLANS FOR a $50 million, 40-acre research park were revealed last week by the Illinois Institute of Technology. It will be located next to IIT's present Technology Center in Chicago. Construction is to begin next fall.

Massachusetts Institute of Technology will build centers for the earth and materials sciences next year, at cost of $11 million. Centers for communications, aeronautics and astronautics, and life sciences, costing $12.5 million, will be built when funds are sufficient.

Educational facilities recently completed include a $3 million data-processing facility at New York University, a $2.3 million science building at Boston University and a $2.2 million electronics and plastics building at Lowell (Mass.) Technological Institute.

Ford Does Not Plan to Merge R&D with Philco

THERE ARE no plans to merge Ford's Aeronutronics division with Philco or Western Development Laboratories, Charles E. Beck, Philco's new president, stated last week. He said Philco's electronics and development activities and Aeronutronic "will remain separate."

Beck emphasized that Ford's interest was in growth, citing hopes to expand Philco's Government and Industrial division. He said careful attention will be paid to opportunities in Philco's computer operations. Philco has no plans at present to acquire any other businesses, Beck said.

Film, Tape and Tv Get Information From Storage

INFORMATION STORAGE system being demonstrated to government agencies makes a paper copy of a document, or shows it on a tv screen. The document's code number can be dialed over a long-distance closed-circuit system.

Documents are filmed in reduced size and assigned code numbers. Each 10-in.-sq film can carry images of 10,000 pages. Films are automatically filed in modules providing storage for one million pages. Subject indexes can be coded on magnetic tape for high-speed searches.

The system was developed by Avco Corp. Electronics and Ordnance division with the assistance of the Council on Library Resources.

In Brief . . .

MOTOROLA'S new tv line features 27-inch sets priced from $370. portables with front-facing loud speakers and transistor remote control on continuous standby.

NASA EXPECTS to use in future satellites a 30-lb video recorder, developed by Ampex.

COMMAND and control system contracts include $2.1 million to ITT; $3.75 million to Electronic Communications for airborne stations. Hughes has a $21 million order for tactical displays.

ARMY gave Raytheon a $5 million order for Hawk missile ground equipment and services, and $3.3 million for components and materials to support Hawk production in NATO nations.

DEFENSE system contracts include $14.3 million to Western Electric for Nike Hercules radar and ground gear; $11 million to RCA for Bmews; $1.8 million to GE for early warning against air-breathing planes and missiles.

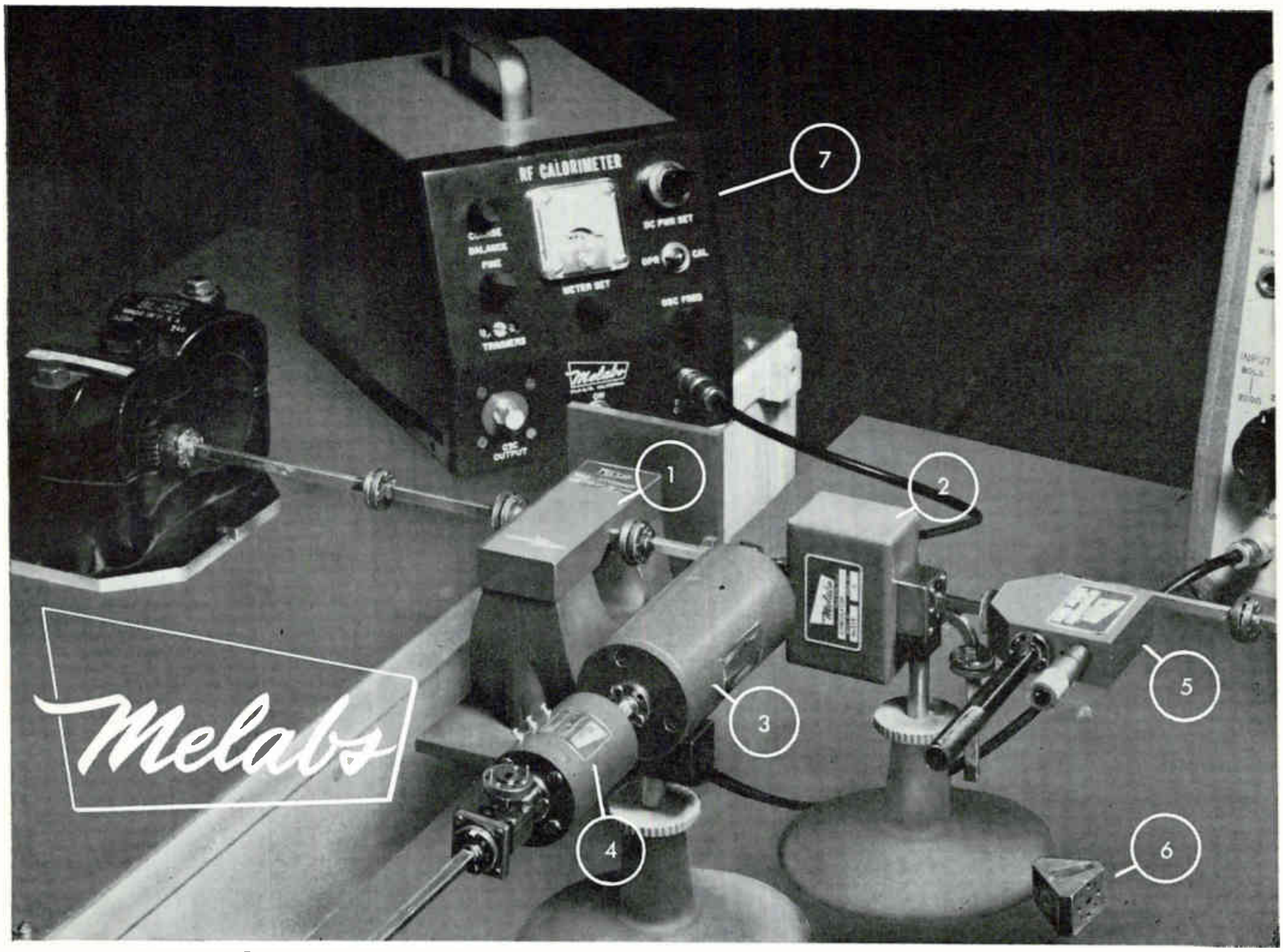
OTHER MISSILE contracts include $3 million to General Precision for gyros and stellar inertial guidance; $534,000 to American Electronics for Terrier and Tartar components; $100,000 to Trans-Sonics for Polaris instrumentation.

JOINING Atlantic Missile Range instrumentation contractors are Dynatronics, with $1.2 million in contracts, and Canoga Electronics, $635,000.

AIRCRAFT equipment orders include $7.5 million to Texas Instruments for bombing indicators; $2.3 million to Burroughs for reconnaissance plane equipment; $500.000 to Electrosolids for inverters.

SEMICONDUCTOR diodes able to operate in K band equipment at 150 C temperature are being produced by Philco under a $475,000 Air Force order.

ELECTRONIC ASSOCIATES has $192,000 AEC contract for a 300-amplifier analog computer to control a nuclear reactor powering Project Pluto ramjet missile.



70 Gc COMPONENTS HANDLE 12 KW!

MELABS continues its leadership in the design and production of microwave components, offering several outstanding new units in the 70 Gc range for use in advanced high power millimeter systems.

Several of these new 70 Gc items are pictured above. The isolator (#1) and the Circulator (#2) handle the *maximum power* that can be produced by any of the currently available millimeter high power sources! The Pulsed Attenuator (#3) is an exclusive MELABS design—providing over 50 db of mixer protection in addition to the circulator isolation. There is no commercial counterpart.

Specific information can be furnished on any of these MELABS components, individually or in combination as an advanced millimeter system. Your inquiries are welcomed.

1. **70 Gc, LOAD ISOLATOR**—8% bandwidth—handles 12 KW.
2. **70 Gc, 4-PORT CIRCULATOR**—8% bandwidth—handles 12 KW.
3. **70 Gc, FERRITE PULSED ATTENUATOR**—switched from 1 to 50 db in less than 1 µsec.
4. **70 Gc, SPDT FERRITE SWITCH**—Switch-time 1 µsec—gives 20 db isolation.
5. **POWER SPLITTER**—adjustable 1-20 db.
6. **ULTRA-MINIATURE 3-PORT CIRCULATOR**—6% bandwidth.
7. **MILLIMETER WAVE CALORIMETER**

MELABS DV-1A Calorimeter provides precision power measurements as low as 50 microwatts over the frequency range of 50-75 Gc. This is a dry-load type—has no circulating liquids and is constructed in RG98/U waveguide. The instrument is capable of measurements to accuracy of ±5%—or better. DC calibrator is built in. Unit is transistorized—battery operated—self contained. Other units can be supplied in waveguide sizes up to 150 Gc.

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Employment opportunities at Melabs are exceptional for ambitious engineers and physicists; write in confidence.

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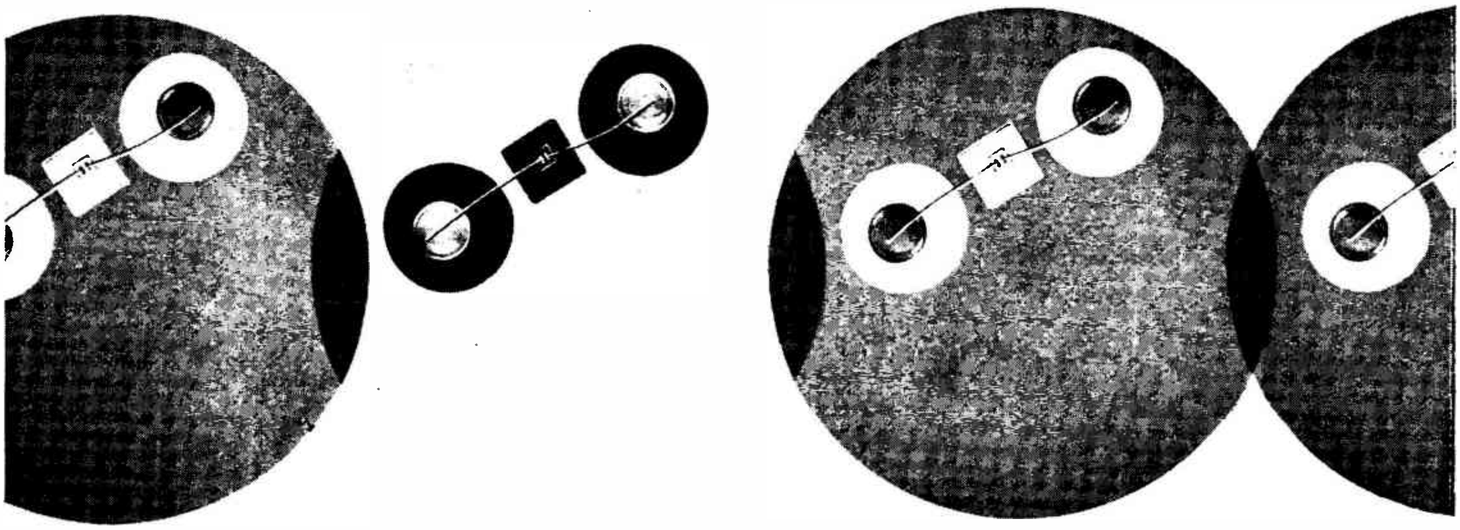
DEPT. B-6



t_{total} < 80 nsec.

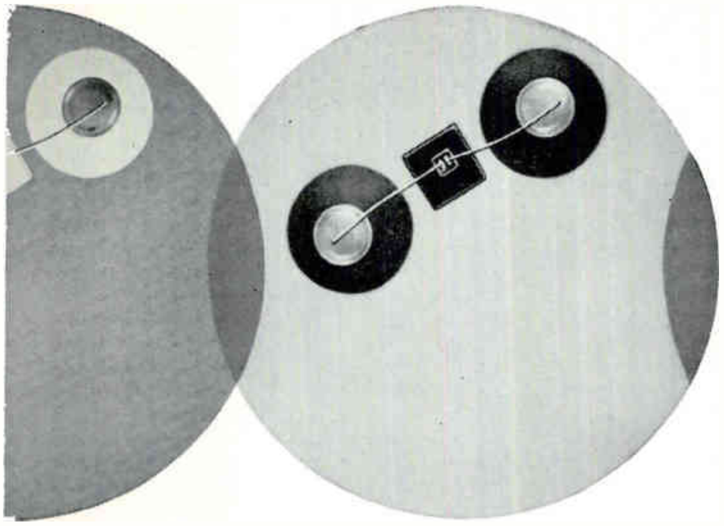
1000 mc GAIN BANDWIDTH PRODUCT

I_{CBO} 18 μa MAX. @ +70°C

200 mw POWER DISSIPATION

h_{FE} 20 min. @ -55°C

STOCKED BY YOUR G-E SEMICONDUCTOR DISTRIBUTOR



GENERAL ELECTRIC 2N994

GERMANIUM EPITAXIAL *ULTRA-FAST* MESA

Looking for extra speed, improved performance and tighter specifications for your very high speed switching applications? This new G-E germanium PNP epitaxial mesa was designed for you. 2N994 offers 80 nanoseconds switching speed, a beta spread of only 3 to 1, a high temperature I_{CBO} guarantee, and a specified beta at low temperature . . . all of which greatly help "worst-case" design. I_{EBO} is also specified. And in addition, the high current capability of 2N994 provides extra "fan-out" and "fan-in" capability in computer logic designs. Just check the specs shown for a few examples of the tightly controlled parameters of 2N994.

2N994 ABSOLUTE MAXIMUM RATINGS: 25°C

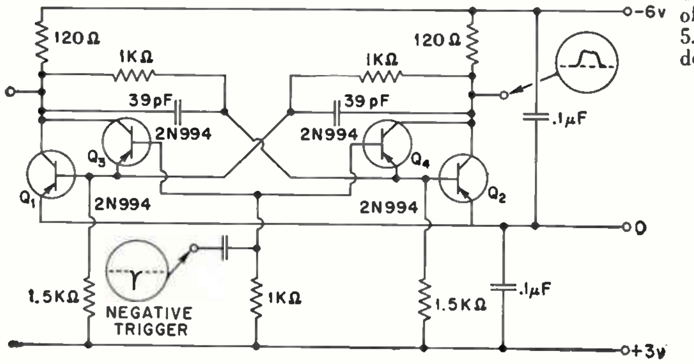
Current			
Collector	I_C	−150	ma
Dissipation			
Total Power*	P_t	200	mw
Storage Temperature	T_{STG}	−65, +150	°C

* Derate 2.67 mw/°C for increase in ambient temperature above 25°C

2N994 ELECTRICAL CHARACTERISTICS: 25°C (unless otherwise specified)

		Min.	Typ.	Max.	
Collector Emitter Saturation Voltage	V_{CE} (SAT)				
(I_C = −10 ma, I_B = −.4 ma)				−.18	volts
(I_C = −50 ma, I_B = −4 ma)				−.30	volts
(I_C = −100 ma, I_B = −8 ma)				−.45	volts
Static Characteristics					
Collector Cutoff Current (V_{CB} = −6V)	I_{CBO}		−0.4	−3.0	ua
Collector Cutoff Current (V_{CB} = −6V, T_A = +70°C)			−5	−18	ua
Emitter Cutoff Current (V_{EB} = −2V)	I_{EBO}		−3	−15	ua
DC Forward Current Transfer Ratio (I_C = −10 ma, V_{CE} = −.25V)	h_{FE}	45	75	140	
DC Forward Current Transfer Ratio (I_C = −10 ma, V_{CE} = −.25V, T_A = −55°C)	h_{FE}	20	33		
High Frequency Characteristics					
Gain Bandwidth Product I_E = 10 ma, V_{CE} = −5V	f_t		1,000		mcs
Switching Characteristics					
Turn On	t_{on}		17	35	nsec
Turn Off	t_{off}		28	45	nsec

30 MEGACYCLE FLIP-FLOP



The 30 megacycle flip-flop circuit shown indicates the speed capability of the G-E 2N994. Typical transition time is 10 nanoseconds. Output is 5.5 volts peak to peak. Other mesas used in the same circuit cannot deliver this performance.

OTHER G-E GERMANIUM MESA TYPES AVAILABLE

2N705	2N711B	2N828	2N964
2N710	2N725	2N960	2N965
2N711	2N781	2N961	2N966
2N711A	2N782	2N962	2N1646

For complete specifications, call your G-E Semiconductor Products District Sales Manager. Or write Semiconductor Products Department, Section 16L115, General Electric Company, Electronics Park, Syracuse, New York. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: International General Electric, 159 Madison Ave., New York 16, New York.

GENERAL ELECTRIC

WASHINGTON OUTLOOK

FOREIGN TRADE POLICY of the Kennedy administration, shaping up more clearly, is not as distasteful to industry spokesmen as they had expected. Eventual goal is free flow of goods between the U.S. and Western Europe, but not membership in the European Common Market.

The White House is willing to make concessions to domestic industries injured by competition, to tide them over the years of most serious impact. While details are not yet ironed out, odds are concessions will include tax assistance for hardest hit industries, federal aid to injured industries and local communities, and a federally financed worker retraining program.

There may even be tariff adjustments for industries proving excessive injury from a more liberal trade policy.

McDONNELL AIRCRAFT will get about $200 million to build 12 two-man capsules for NASA's $500 million addition to the Mercury program. Launcher will be Martin Marietta's Titan II booster.

Under plan to develop space rendezvous techniques in 1963-64, an Atlas-Agena-B fuel capsule will be orbited at 200 mi. The manned capsule will join it in orbit, then separate and land at Edwards Air Force Base, Calif. If perfected on schedule, the technique will be used for the trip to the moon by a three-man Apollo in 1967-69.

GOVERNMENT LURES to get and keep top scientists and engineers may be increased next year. A top level study and specific recommendations will go to the President soon, then will probably be sent to Congress as proposed legislation. The White House may install some recommendations administratively.

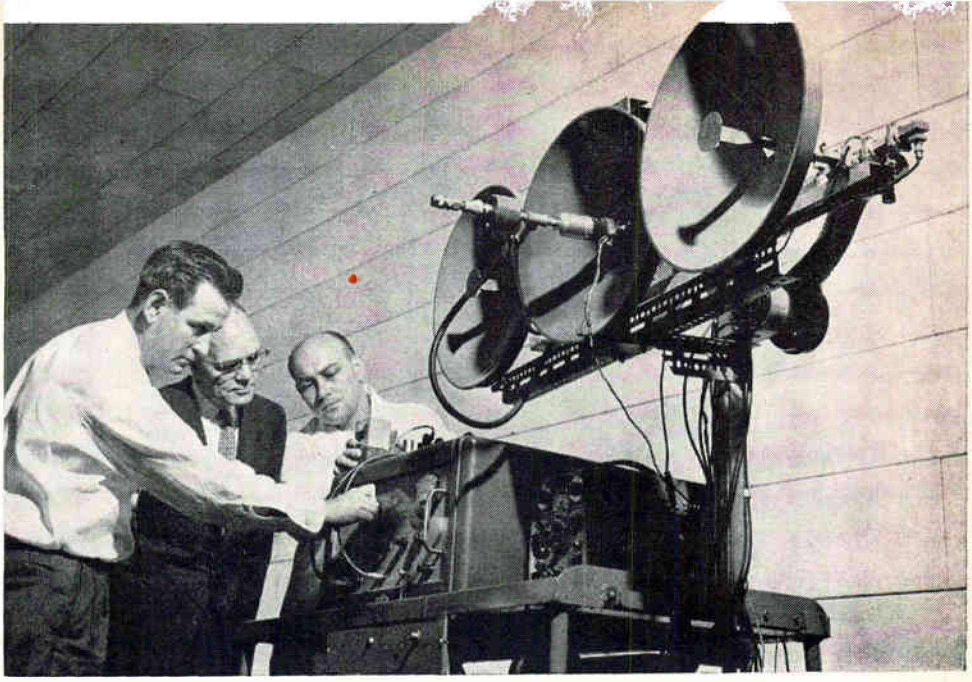
The study says industry pays $4,000 more to people qualified for $15,000 to $19,000 in government pay. Other drawbacks are restricted opportunities to participate in decision making and the necessity of filtering through blocks of subordinates to communicate with top officials.

The report also says government should change its popular image of bigness, inefficiency and red tape.

U.S. INTELLIGENCE experts discount Moscow's announcement it will boost Soviet defense spending in 1962 by 44 percent over its original 1961 budget. Washington believes the actual increase is probably no more than 10 percent and the remainder represents some massive reshuffling of budget bookkeeping.

The Soviets lump many costly defense programs in with such civilian budget items as financing the national economy and science. This makes direct comparisons of U.S. and USSR defense outlays almost meaningless.

Civilian items in the new Soviet budget have been cut or have not been increased as substantially as anticipated, indicating that Soviet defense boosts are probably of the same magnitude as scheduled increases in the U.S. defense budget.

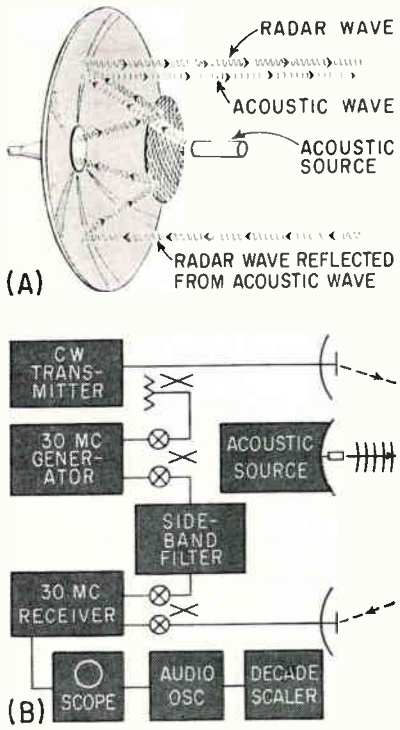


Midwest Research Institute team tunes experimental model of electromagnetic acoustic probe

Doppler shift of radar wave reflected from acoustic wave tells wind speed

Acoustic Radar Reads Wind Speed Remotely

KANSAS CITY, MO.—Developers of Midwest Research Institute's radar-acoustic remote air velocity measuring system are predicting it will find many uses: assisting jet landings on carriers, as a wind tunnel calibration standard, for air pollution studies and micrometeorology. It originated as a helicopter air speed sensor.



Acoustic bursts reflect microwave signal (A), 30-Mc i-f improves doppler section sensitivity (B)

Called Emac (for Electromagnetic Acoustic Probe), the system determines air velocity by measuring the doppler frequency shift of an electromagnetic wave reflected from a propagated acoustic disturbance. Subtracting the sound velocity constant from the sum of local sound and wind gives wind velocity.

Multiple soundings in selected directions yield wind direction. Feasibility trials for the Army Rocket and Guided Missile Agency indicated three-dimensional wind field could be determined from an array of the probes. The use of one unit to measure velocity in three dimensions is to be investigated.

MRI's development program is now aimed at boosting accuracy and efficiency and increasing range. Maximum range which currently may be expected from the probe is 1,600 feet.

Range increase is expected from a probe operating at r-f of 2.5 Gc and sound of 5.5 Kc. Short, high-power pulse techniques look promising. Automatic profile scanning data analysis and readout system may also increase its versatility.

An r-f range of 1 to 10 Gc can be used. Because X band equipment and techniques were readily available, experimental equipment uses 10 Gc. Sensitivity of the c-w doppler circuits was improved by addition of the 30-Mc i-f stage illustrated.

The sound source is a small, high-frequency siren driven by a synchronous motor and mounted in an 18-inch reflector. It radiates 140 db within a 5-deg beamwidth at 10 feet. The acoustic signal can be pulsed, at 3 to 20 msec, by a high-speed air valve.

Developers expect to reduce probe size and alignment problems by going from the experimental three-antenna array (photo) to a coaxial beam array.

Automated Subway Is Postponed in New York

NEW YORK CITY'S plans to try out an automated subway shuttle train went awry last week when the Transport Workers Union threatened to strike. A mediator asked the Transit Authority and TWU to negotiate on the impact of automation on employees and to make provision in a new union contract.

There is a large potential market for subway automation systems. More than a dozen cities considering modern rapid transit systems are watching developments in New York. They include Washington, Atlanta, Montreal, Los Angeles and San Francisco, which has written a specification for a five-county system announces train departure to passengers.

The New York system employs a programmer, pulse transmission and inductive pickups to control operation. The basic 24-hour schedule of the train is on 35-mm punched film tape. Union Switch and Signal division of Westinghouse Air Brake and General Railway Signal have each supplied equipment for one direction of the half-mile run.

Signal pulses for speed control are received by induction pickups on the end cars as they pass over insulated rail sections. The 60-cps current is pulsed at zero, 75, 180 or 270 pulses per minute. Top speed is limited by an electronic governor to 30 mph.

Pickup coils feed into transistor amplifiers which control motors and brakes. Timers at stations determine stopping time between runs and door-open time. A warning system announces train departure to passengers.

The safety override system uses a series of proximity detectors strung along the right-of-way. These sense train passage by a null circuit with two overlapping eight-inch coils. If a train goes by two detectors at an excessive rate, indicating runaway, emergency air brakes are operated.

Color Television Sales Go Ahead in November

RCA REPORTS that its color tv shipments in November surpassed black and white set volume by 10.4 percent. Annual volume of color shipments is fast approaching that of black and white, RCA said. It attributes the rise to increased color programming and rising interest among dealers and consumers. The company is now introducing 11 new color sets, making a total of 23, priced from $495.

Laser Space Weapon in R&D

LASER capable of beaming a million-degree ray 40 to 200 miles to vaporize hostile space weapons is being developed as an Air Force defensive weapon by the advanced programs division of Martin Marietta Corp.

Considering future requirements for policing space, Carl Kober, division director, predicts such a ray weapon—perhaps employing an infrared laser—will be in use by the 1970's.

Source of the beam would be hydrogen conversion, from ortho to para state as proposed by Nuclear Research Associates, Long Island. Optical lenses would focus the pulsed 85-micron beam down to a 1-cm cross section.

Prototypes under development for the past six months (the work has not been done under Air Force contract, but as in-house R&D) will deliver a beam with a temperature over 1,000 F. These are to be tested by 1963. Initial tests will be made in a 200-foot evacuated tube.

A cryogenic hydrogen laser of sufficient size and with beam power in the megawatt range could produce a million-degree beam, Kober said. Nuclear power sources can provide at least part of the power required.

Disintegrator ray is being designed for use at altitudes of 100,000 feet or farther out in space. It would be the size of a large army searchlight.

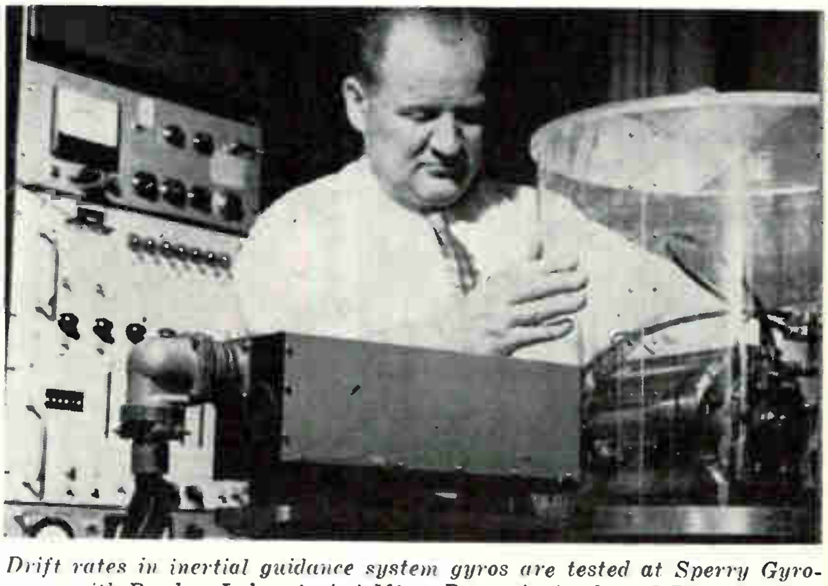
The weapon's intricacy and cost are expected to make it uneconomical for use in terrestrial warfare, since atmospheric attenuation of the beam would limit its range to less than a mile.

Possible size of the space vehicle is 10 feet in diameter and 30 feet long, with the nuclear power source on a strut. The men operating the weapon would be protected by shielding. The system could be launched in sections and assembled in space.

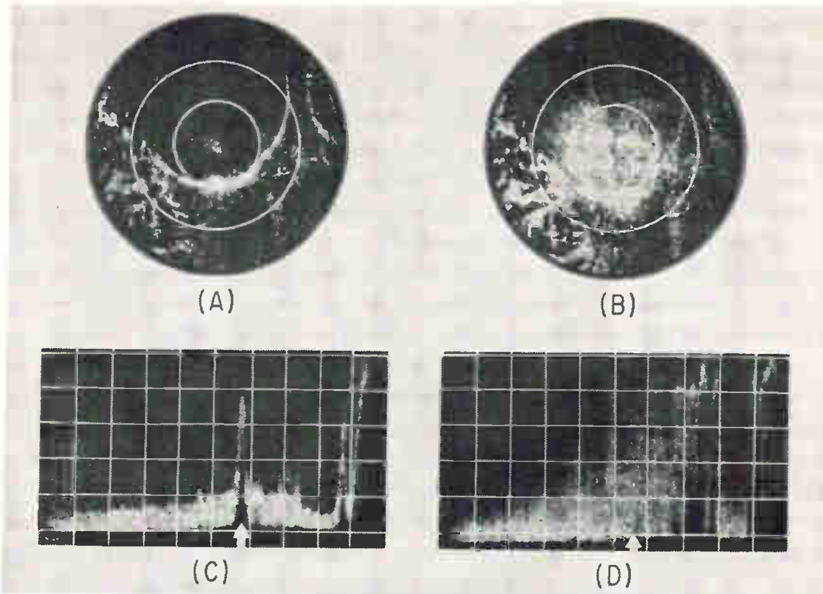
Laser weapons have been suggested as an ICBM defense (ELECTRONICS, p. 81, Nov. 10).

Since other countries are believed working on similar projects, consideration is being given to methods of shielding space systems from enemy rays. One approach is to establish a method of dispersing the light beam over a wide area, destroying its heat concentration.

Autocollimator Tests Gyroscopes



Drift rates in inertial guidance system gyros are tested at Sperry Gyroscope with Razdow Laboratories' Micro-Dynamic Angle and Rate Monitoring System. A collimated beam is projected to a mirror mounted on the rotating member. Measuring signals are obtained by reflecting the beam to two photo sensors, one for control and one for reference. Accuracy is reported as one part in 100,000



Harbor buoy seen by radar with circular polarization (A) is obscured by rain in ppi of radar with horizontal polarization (B). Lower two radar scope photos taken during typhoon show how a target (arrow) visible in a set using a logarithmic sensitivity receiver (C) is obscured by sea clutter in a set using linear sensitivity (D)

Radar Tells Wood from Steel

TOKYO—Radar that can discriminate between targets of different materials—showing wood and steel ships, for example, in different color traces—was reported here at the meeting of the Japanese Institute of Communications Engineers.

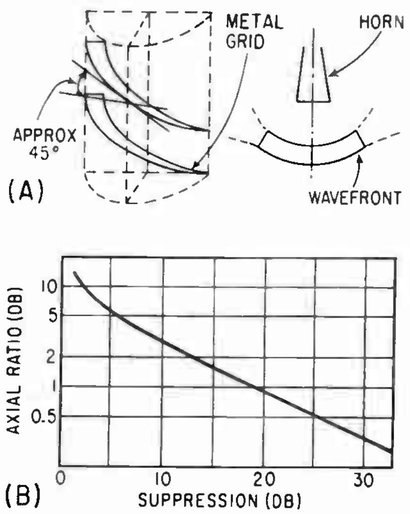
Noriomi Ochiai, of Tokyo Keiki Seizosho KK, also reported successful elimination of rain and snow interference and sea clutter in X band radar by the use of circular polarization and logarithmic sensitivity receivers. These have been incorporated in working systems.

Target discrimination by material and shape is obtained by using radiations of two or three different polarizations. The reflections of the various returns are traced in different colors, such as red, green and blue.

Ochiai said that at present it is possible to discriminate between rain and general targets, wood and steel ships, electric train lines or gas tanks and general land targets, and between towns and cultivated plains.

Circular polarization, to prevent rain and snow interference, is obtained by a metal grid circularizer (see sketch). This was developed for marine radars which customarily use horn-fed reflectors. With an axial circular polarization ratio of 1.09, interference from rain reflections is reduced to one percent of the original value, Ochiai said.

He gave examples of how a receiver with logarithmic sensitivity will reduce clutter due to sea return. Radar pips almost completely masked by grass when using a receiver with linear sensitivity became very clear, Ochiai said.



Circular polarization is obtained by metal grid (A). The graph (B) is the theoretical relationship between axial ratio and interference suppression ratio

MEETINGS AHEAD

RELIABILITY AND QUALITY CONTROL Symposium, PGRQC of IRE, AIEE, ASQC, EIA; Statler Hilton Hotel, Washington, D. C., **Jan. 9-11, 1962.**

OPTICAL CHARACTER RECOGNITION Symposium, Nat Bur of Standards; Dept. of Interior Aud., Wash., D. C., **Jan. 15-17, 1962.**

ELECTRICAL ENGINEERING Exposition for electrical-electronics industry, AIEE; N. Y. Colisium, N.Y.C., **Jan. 29-Feb. 2, 1962.**

REDUNDANCY TECHNIQUES FOR COMPUTING SYSTEMS, Office of Naval Research; Dept. of Interior Aud., Washington, D. C., **Feb. 6-7, 1962.**

MILITARY ELECTRONICS, 3rd Winter Convention PGMIL of IRE; Ambassador Hotel, Los Angeles, **Feb. 7-9, 1962.**

SOLID STATE CIRCUITS, Internat. Conf., PGCT of IRE, AIEE; Sheraton Hotel and U. of Penn., Philadelphia, Pa., **Feb. 14-16, 1962.**

APPLICATION OF SWITCHING THEORY TO SPACE TECHNOLOGY Symposium, USAF, Lockheed Missiles & Space; at Lockheed, Sunnyvale, Calif., **Feb. 27-Mar. 1, 1962.**

SCINTILLATION AND SEMICONDUCTOR Counter Symp, PGNS of IRE, AIEE, AEC, NBS; Shoreham Hotel, Washington, D. C., **Mar. 1-3, 1962.**

MISSILES & ROCKET TESTING Symposium, Armed Forces Communications & Electronics Association; Cocoa Beach, Fla., **Mar. 6-8, 1962.**

EHV COMMUNICATION, CONTROL & RELAYING, AIEE; Baker Hotel, Dallas, Tex., **March 14-16, 1962.**

IRE INTERNATIONAL CONVENTION, Coliseum & Waldorf Astoria Hotel, New York City, **Mar. 26-29, 1962.**

QUALITY CONTROL Clinic, Rochester Soc. for Q. C.; Univ. of Rochester, Rochester, N. Y., **Mar. 27, 1962.**

ENGINEERING ASPECTS OF MAGNETOHYDRODYNAMICS, AIEE, IAS, IRE, U. of Rochester; U. of Rochester, Rochester, N. Y., **Mar. 28-29, 1962.**

SOUTHWEST IRE CONFERENCE AND show; Rice Hotel, Houston, Texas, **April 11-13, 1962.**

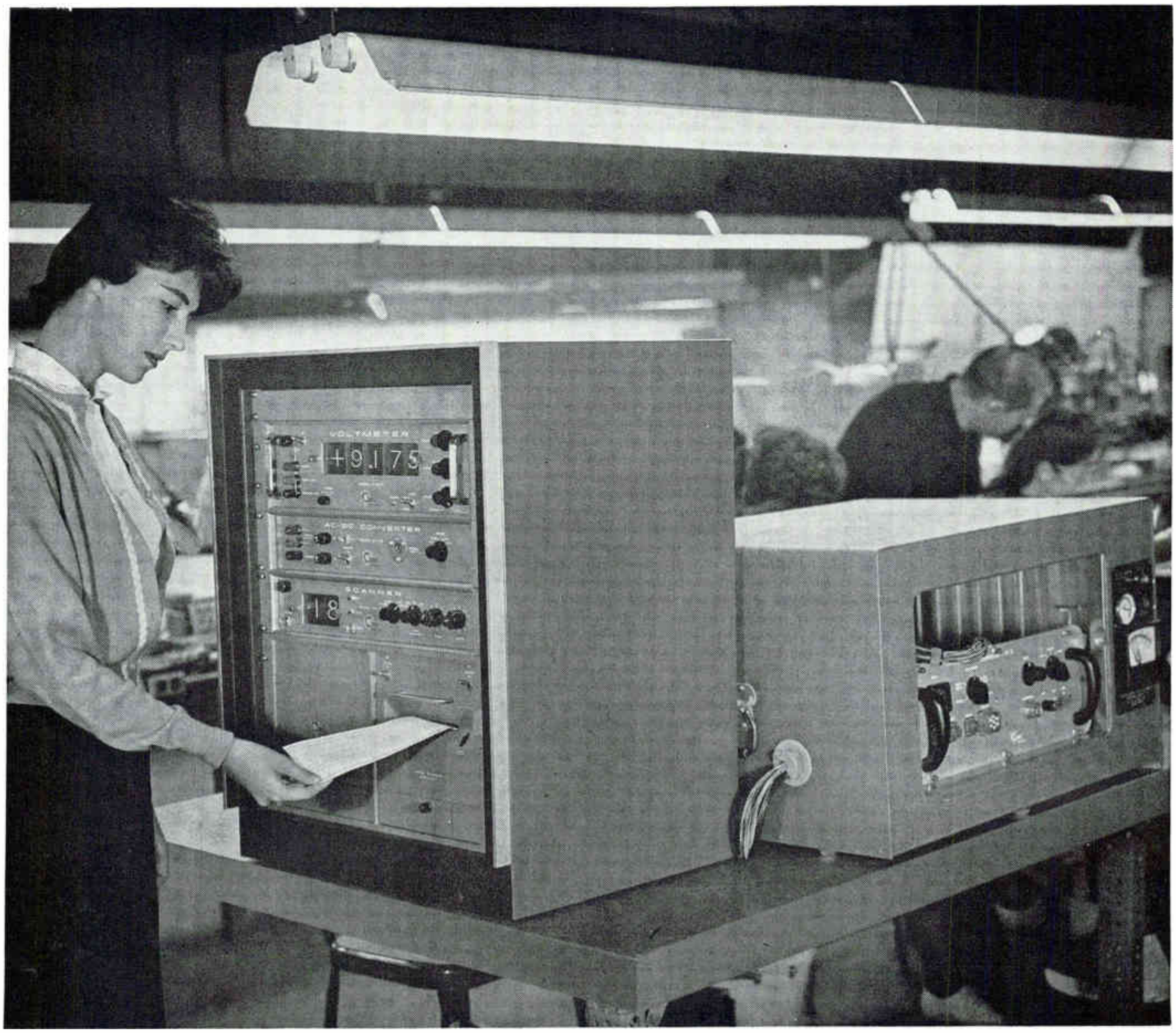
JOINT COMPUTER CONFERENCE, PGEC of IRE, AIEE, ACM; Fairmont Hotel, San Francisco, Calif., **May 1-3, 1962.**

HUMAN FACTORS in Electronics, PGHFE of IRE; Los Angeles, Calif., **May 3-4, 1962.**

ELECTRONIC COMPONENTS CONFERENCE, PGCP of IRE, AIEE, EIA; Marriott Twin Bridges Hotel, Washington, D. C., **May 8-10, 1962.**

NATIONAL AEROSPACE Electronics Conference, PGANE of IRE; Biltmore Hotel, Dayton, Ohio, **May 14-16, 1962.**

MICROWAVE Theory & Techniques National Symposium, PGMTT of IRE; Boulder, Colo., **May 22-24, 1962.**



Low Cost Cubic S-70 Data System Reads 100 Channels/Minute

Because of the high operating speed of the reed relays (used in the digital voltmeter) the new Cubic S-70 Data System gives readings 6 times faster than any others using stepping switch voltmeters. The Cubic S-70 monitors up to 100 separate channels, provides instantaneous large digital readout on the voltmeter, and prints out a permanent record on paper tape of 100 readings a minute. Yet it costs only $4650, a fraction of the cost of most data systems now in use. Price includes the Cubic V-70 Reed Relay Digital Voltmeter, the Cubic Scanner to rapidly sample 100 channels, and an 11-column printer. An ac-dc converter or a pre-amplifier may be added at slight additional cost. The reed relays in the voltmeter assure you of at least a decade of flawless service without periodic maintenance. This is a simple, pre-packaged, standard system made up of production modules. You simply plug it in and start recording data. For more details on the S-70 Data System, write to Department E-111.

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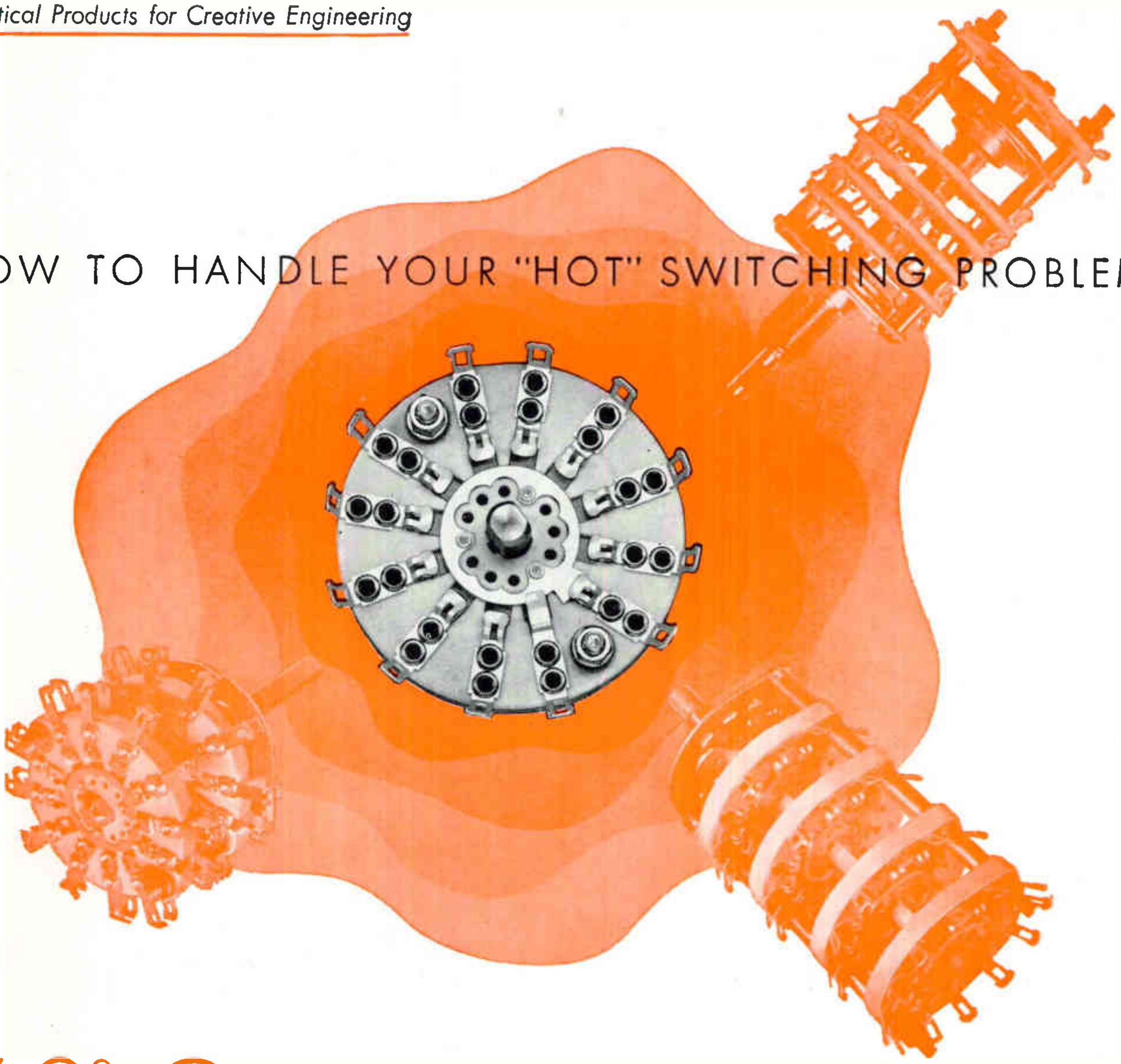
HOW TO HANDLE YOUR "HOT" SWITCHING PROBLEMS



160° C

OAK HIGH TEMPERATURE SWITCH SECTIONS have the stamina to stand up under a constant ambient temperature of 160°C. In fact, their clips have been life-tested for more than 800 hours at this temperature and still maintained their tension. There are several reasons why Oak high temperature switch sections perform with such exceptional reliability. First, positive contact is maintained by Oak's special double-wiping, spring clip contact design. Next, Oak has developed a special alloy that's downright reluctant to lose its spring tension at these high temperatures. Last, Oak *rolls* a .0006″ layer of gold on this clip to doubly-assure exceptional stability and contact performance. You can order these sections in ceramic or Mycalex insulation for Types FIX, HC, DHX, DHC, NC, JC, DLX, FC, and FX switches. For more information, contact your local Oak sales representative or send details of your application to our Applications Engineering department.

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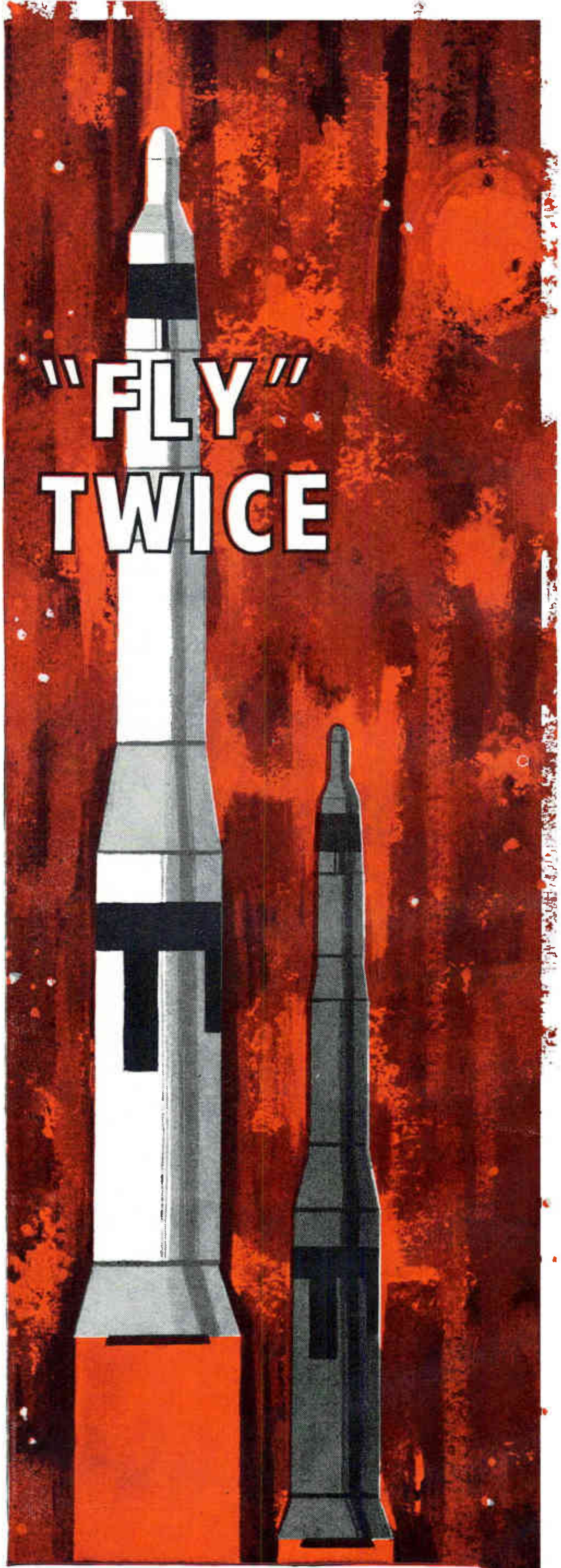
CIRCLE 21 ON READER SERVICE CARD

2N2187 Matched pair of Philco type 2N2185 SPAT Choppers, in TO-18 Packages.

New PHILCO matched Silicon Choppers

HELP A MISSILE "FLY" TWICE



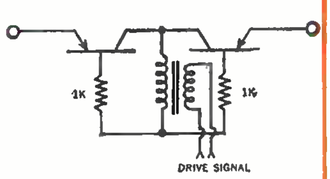
Philco SPAT* choppers, industry's most reliable telemetry multiplex switches, assure highest fidelity in multiplexing data from a missile's many sensors such as strain gauges and thermocouples—data that is the only legacy of a multi-million dollar missile flight. For this data is used in post-flight simulations which, in effect, make the missile "fly" twice.

Philco's missile-proved SPAT choppers are produced on industry's only fully-automatic chopper transistor production line—to assure the uniformity so important to matched pairs.

Only Philco Choppers offer you these 6 advantages:

1. *Low Offset Current—1 nanoampere maximum;*
2. *Low Offset Voltage—50 μvolts maximum (for the matched pair);*
3. *Guaranteed Match over a temperature range—25° to 85° C;*
4. *Guaranteed maximum offset voltage for a wide range of base current values;*
5. *High gain-bandwidth product;*
6. *Meet all requirements of MIL-S-19500B.*

TYPICAL CHOPPER CIRCUIT



2N2185 CHARACTERISTICS

Emitter Voltage, BV_{ECO}	—30 volts
Collector Cutoff Current I_{CBO} (V_{CB}=—10V)	.001 μa max.
Emitter Cutoff Current I_{EBO} (V_{EB}=—10V)	.001 μa max.
Offset Voltage V_{EC} (I_B=—200 μa, I_E=0)	1.5 mv max.
Offset Voltage V_{EC} (2N2187 Matched pair, I_B=—1 ma at all temperatures from 25°C to 85°C.)	50 μv max.

To assure maximum reliability in systems for telemetry, multichannel communications, analog computers, and other low level data handling applications, be sure to specify Philco SPAT choppers. There's a Philco SPAT chopper for every application. You can choose from seven types (2N2181 through 2N2187).

For complete data, write Department E 122261.

Philco SPAT Choppers are immediately available from your Philco Industrial Semiconductor Distributor.

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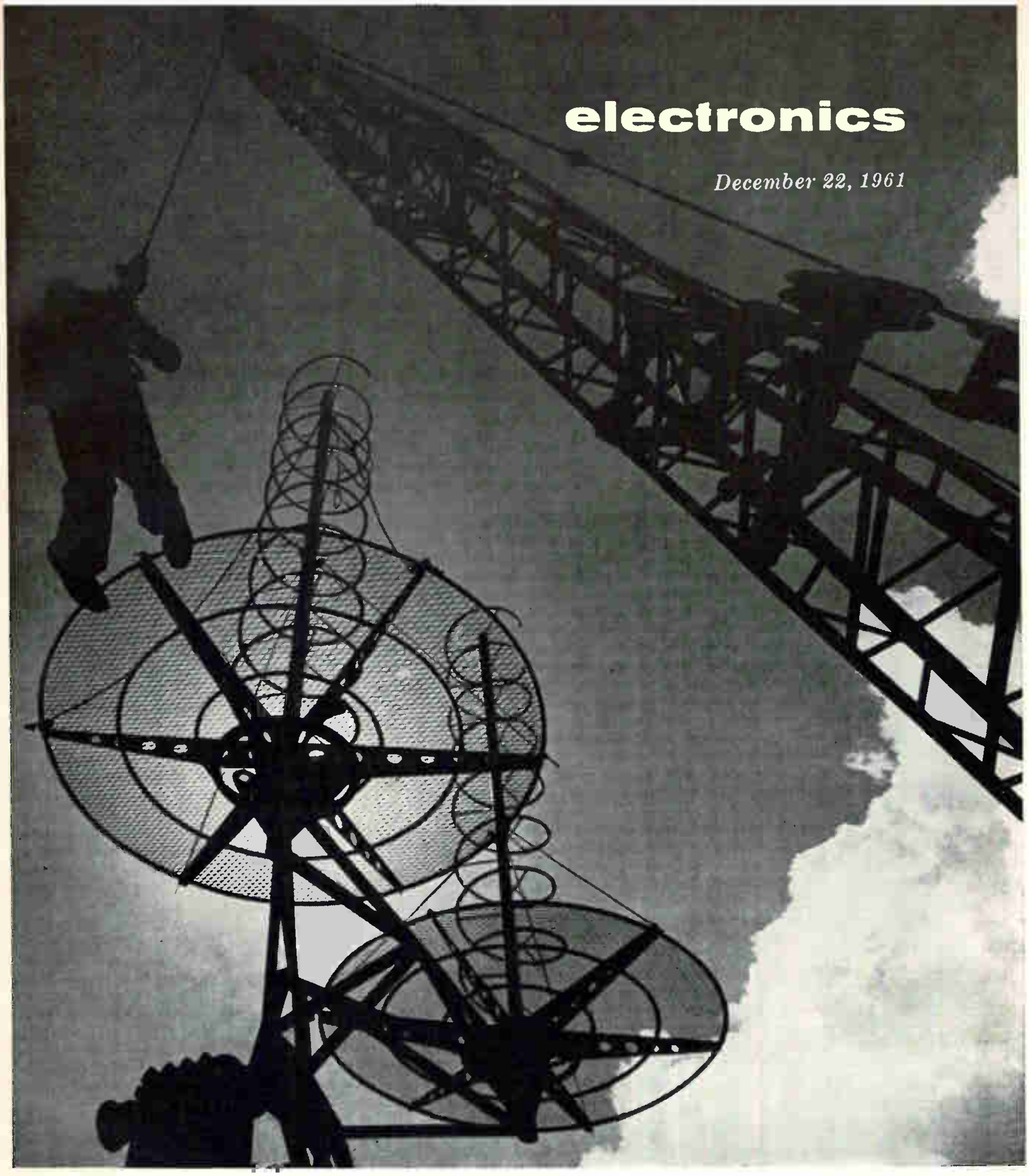

Pair of helix antennas being assembled form half of array for tracking communications satellite

Automatic Tracking Antenna

FOR TELSTAR COMMUNICATIONS SATELLITE

System locates satellite at horizon and then tracks it. Helix antennas also transmit command signals and receive telemetry data

By DONALD F. SHINGLER, RF Division, Radiation, Inc., Melbourne, Fla.

COMMAND TRACKER, an antenna system designed to establish and maintain a satellite communications link, has three primary functions. First, it must achieve initial acquisition of the satellite as it appears on the radio horizon. Using a beamwidth of about 20 degrees at 3-db points, the antenna achieves acquisitions without precise knowledge of the satellite's orbit by locking on a vhf beacon transmitted from the satellite.

When the command tracker system has locked on to the satellite, a precision tracker is slaved to the system to enable precision tracking by a narrow beam of about 2 degrees beamwidth. When the precision tracker has locked-on and is tracking the satellite, a narrow-beam shf horn antenna is slaved to the precision tracker. The shf horn antenna must be positioned precisely to establish communication with the satellite in orbit.

Second, the command tracker serves as an antenna for a ground-based vhf transmitter which transmits various coded signals to the satellite. The command tracker has a transmitter output of 200 watts of unmodulated cw.

Third, the command tracker receives vhf telemetry data signals from the satellite. These telemetry signals could be simultaneously distributed to up to eight separate telemetry receivers with 50 db isolation between receivers.

Command tracker transmit and receive frequencies are separated by approximately 13 Mc with the transmit frequency lower than the receive frequency. A diplexer and additional filters in the command tracker permit simultaneous transmission of command signals and reception of telemetry data.

Two command tracker antenna systems are to be installed, one at Andover, Maine and the second at Cape Canaveral. The ground system at Andover will be controlled from a master control console; the Cape system is to be used primarily for gathering telemetry data from and transmitting commands to the satellite during the launch phase. Once the satellite is in orbit, the Cape system will continue to gather telemetry data and transmit command signals as directed by the Andover station.

The command tracker must provide (1) widebeam acquisition, (2) precise angular tracking, and (3) reliable operation. Both sequential lobing and simultaneous lobing techniques can provide the required angular tracking accuracy with a wide beam. The phase monopulse technique was chosen because it is insensitive to amplitude variations of the signal such as occur with signal fade. Also, this technique permits the use of a quad helix array with no moving elements. A typical monopulse antenna pattern, Fig. 1, shows a sharp difference pattern null 30 db below the sum pattern peak.

For good system reliability, the servo control system is solid state. Transistors are used in amplifying, demodulating and limiting circuits; power transistors are used in the servo power amplifiers to drive the field of a d-c generator. The transistorized power amplifier provides increased system performance capability by removal of the long inductive time constant inherent with magnetic amplifier and saturable reactors.

The output of each helical antenna element, Fig. 2, is fed through a quarterwave matching line (100 ohms to 50 ohms) into a comparator consisting of four hybrid rings. Each hybrid ring has two outputs; sum and difference. Hybrid configuration is such that the two input signals arrive at the sum output shifted in phase by the same amount as at the two input terminals while at the difference output, one of the signals is shifted in phase by an additional 180 degrees. The hybrid rings are interconnected so that three useful outputs are obtained from the comparator; a sum signal (Σ), elevation difference signal (ΔEL) and azimuth difference signal (ΔAZ). The angular error information is contained in the phase of the difference signal relative to the sum signal. This scan is called phase-sensitive monopulse.

Sum and difference signals are fed through high-pass filters into a three-channel phase monopulse tracking receiver, Fig. 3. Overall receiver noise figure, determined primarily by the preamplifier noise figure, is 3.5 db. Conversion to the 30 Mc first i-f is made by using a crystal-controlled local oscillator mounted in a temperature-controlled oven. Stability is 0.001 percent. More than ± 60 degrees of phase adjustment is available on each of three independent and isolated outputs from the first local

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TELSTAR—THE PRIVATE SATELLITE

Project Telstar is a Bell Telephone System experimental communications satellite. Radiation Incorporated, under contract to Bell Laboratories is developing and fabricating two antenna systems. One of the systems is to be installed at Andover, Maine, the other at Cape Canaveral. Work on the antenna is proceeding according to schedule. The satellite equipment is being assembled at Bell Laboratories and is expected to be ready by the Spring 1962 launching date. The entire project is being financed by AT&T. NASA is providing the Thor Delta launching vehicle, tracking and range services, all to be paid for by AT&T

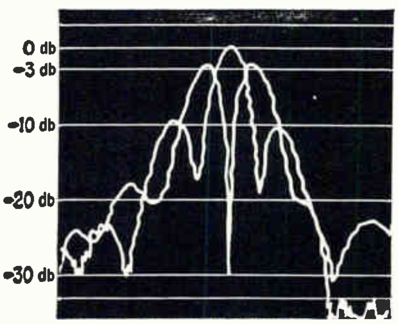


FIG. 1—Monopulse antenna pattern of quad helix array. Difference pattern null is 30 db below sum pattern peak

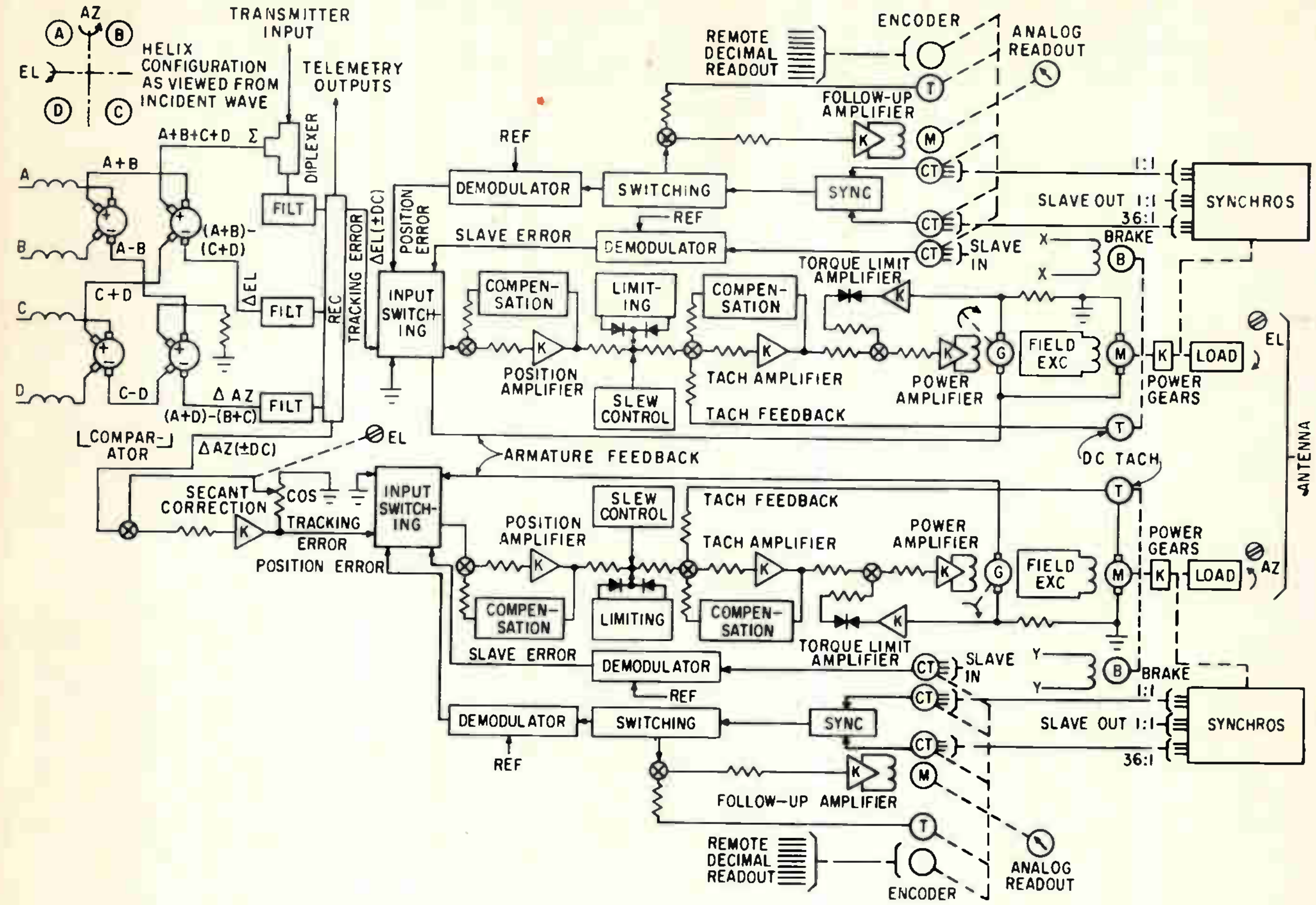


FIG. 2—Helix antennas, left, are fed into the command tracker system through hybrid rings

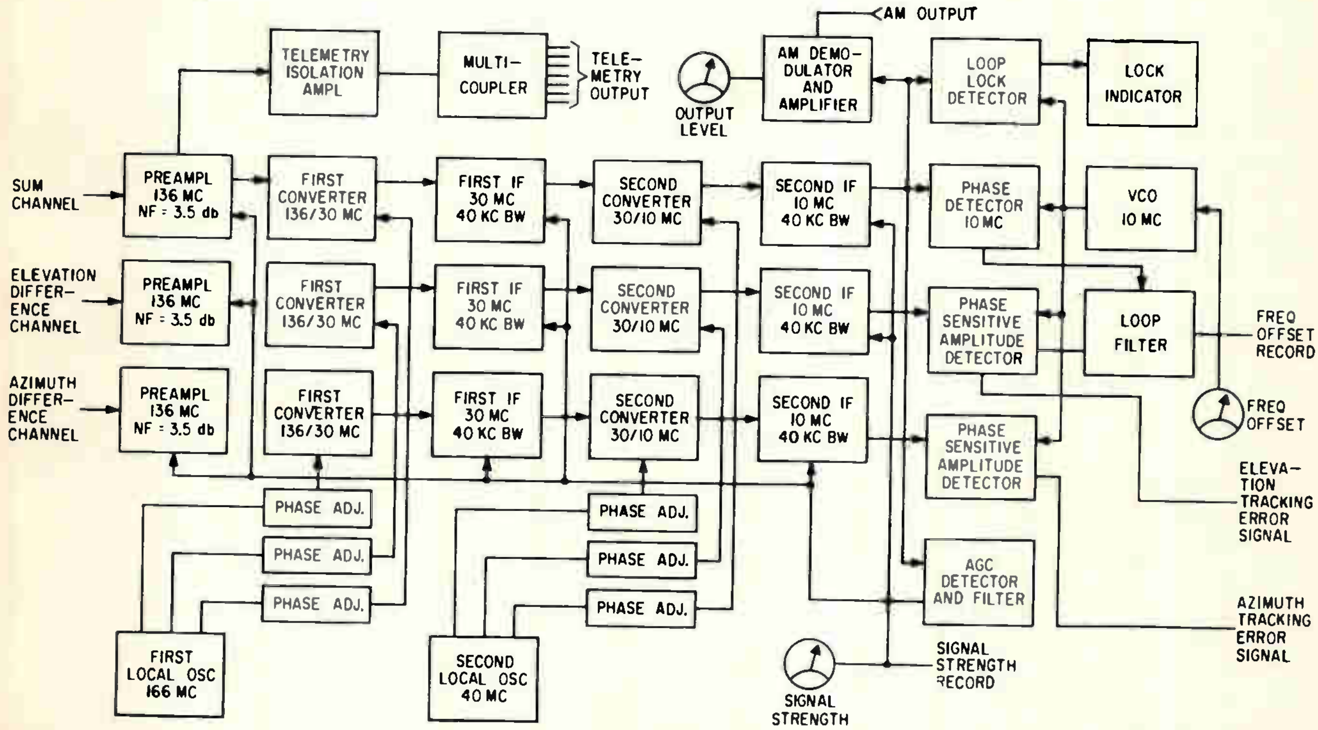


FIG. 3—Three-channel receiver features a common automatic-gain-control circuit

oscillator. This adjustment eliminates the need for phase shifting trombone sections.

The preamplifier, first Converter and first i-f in each channel are in the antenna pedestal. The remainder of the receiver is in the control console. Conversion is made to 30 Mc i-f at the antenna pedestal to minimize phase shift and voltage imbalance in the long coaxial lines to the control console.

Identical amplifier and conversion circuits, common local oscillators, and agc developed in the sum channel is applied to all amplifiers in each channel to maintain phase coherence between sum and difference signals. A phase-locked loop is utilized in the sum channel to improve receiver threshold and provide sum channel reference input to a phase-sensitive amplitude detector in each difference channel. Output of the detector is a d-c voltage, the magnitude and polaxity of which represents angle and direction respectively, off-boresight of the telemetry beacon receiver from the satellite.

The azimuth tracking error signal requires secant correction since the azimuth tracking error signal is a function of the cosine of the elevation angle, Fig. 4. At an elevation angle ϕ an off-target error E_1 is viewed along the boresight as angle B which, when referred to the azimuth plane, is an azimuth angular error equal to angle A. At an elevation angle of ϕ^1, an off-target error E_2 refers back to the azimuth plane as angle A. However, error E_2 is subtended by an angle B' which is smaller than angle B. The azimuth error signal is determined directly by the off-target angle B as viewed along the boresight of the antenna array. Since $B = A \cos \phi$, then the azimuth tracking error signal is a function of $\cos \phi$. The required correction factor is inserted by placing a cosine function potentiometer (mechanically driven by the elevation angle) in the feedback loop of a d-c amplifier. The transfer function of the secant correction circuit is $\frac{K}{\cos \phi}$ where K is adjusted to provide the same scale factor input to the azimuth position amplifier as is input to the elevation position amplifier.

$$e_0 = Te_i$$
$$= \frac{K}{\cos \Phi} (K' \cos \Phi)$$

Therefore, $e_o = KK'$, independent of ϕ.

The position amplifier and tach amplifier circuits provide gain for the input error signals and compensate for system parameters such as backlash and compliance between motor shaft and antenna load. Voltage output of a tachometer is geared to the drive motor and fed back degeneratively to increase stability of the closed loop system. Armature feedback cancels the ef-

SYSTEM CHARACTERISTICS

Receive frequency	136–137 Mc
Minimum receive level at sum channel preamp input	–135 dbm
Transmit frequency	121–125Mc
Maximum transmit power	200 watts c-w (unmodulated)
Antenna gain	
Receive	18.5 db
Transmit	17.5 db
Beamwidth	
Receive	21 deg
Transmit	24 deg
Sidelobe level	−11 db
Polarization	right circular
Axial ratio	1 db max
VSWR	2:1 max
Receiver noise figure	3.5 db
Telemetry output	
Gain above sum preamp input	20 db min
Noise figure	3.5 db
Receiver output scale factor	0.25 v/deg
Servo velocity constant (K_v)	50 min
Tracking accuracy	0.1 deg at 5 deg/sec
Maximum velocity	15 deg/sec
Maximum acceleration	5 deg/sec^2
Operational limits	
Azimuth	
Servo	±345 deg
Electrical	±355 deg
Elevation	
Servo	−4 deg to +87 deg
Electrical	−7 deg to +92 deg
Mechanical stops	−10 deg and +98 deg
Wind load	
Specified operation	45 mph
Survival	120 mph
Overall system accuracy	0.8 deg peak 0.57 deg rms

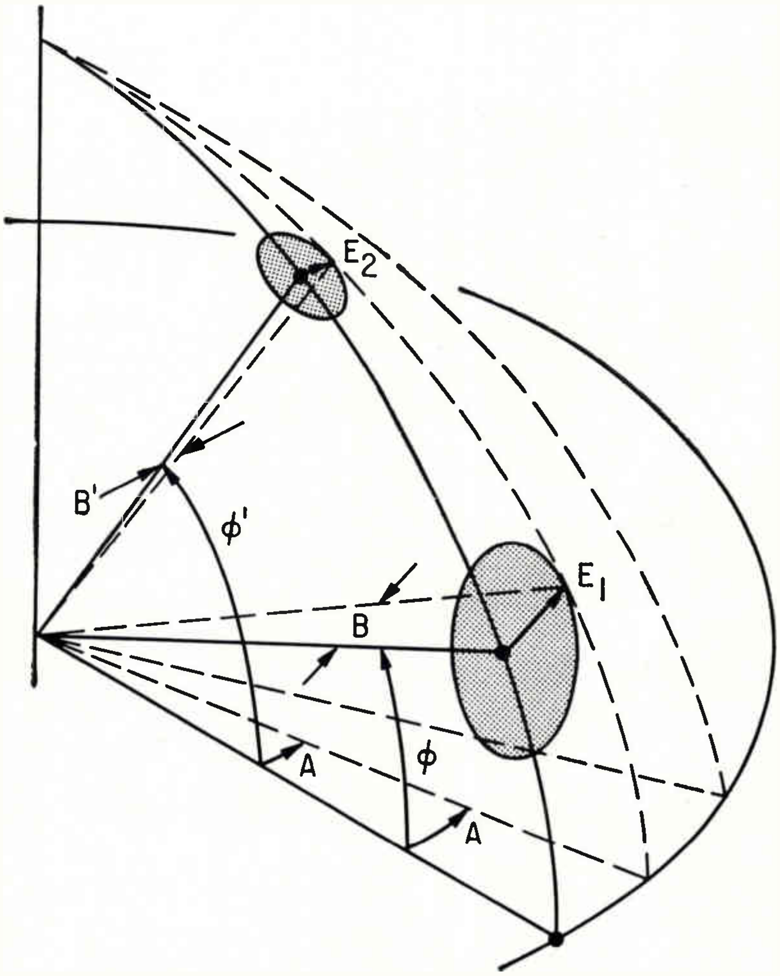


FIG. 4—Geometry of secant correction analysis

fects of bias and residual generator field whenever the system is in a standby condition.

Whenever the antenna is stationary, the tach loop is open because there is no voltage fed back from the tachometer. If a high-level transient signal were fed to the Servo System under these conditions, large drive signals would be developed momentarily because of the high forward gain of the open tach loop. Not until the tachometer actually started to move would the tach loop be closed and the drive signal reduced to a normal level. The torque limit circuit prevents the generator armature current from exceeding 200 percent of full load, thus protecting the load, gear train and shafts from damage due to excessive torques.

Operational mode is selected by momentarily depressing one of five active mode pushbuttons on the antenna control and monitor panel, Fig. 5. These pushbuttons operate a relay contact bailing circuit that automatically deactivates the previous mode whenever a new mode is selected. Slew controls inject a voltage into the input of the tach amplifier; this amplifier drives the antenna at speeds up to 15 degrees per second. Slew control is nonlinear to provide slow speed capability over most of the arc of travel of the slew control. Limit overrides are provided on each antenna axis.

Meters display the azimuth and elevation tracking error voltage in addition to the receiver carrier signal level. The operator can track the satellite manually by using the two slew controls and monitoring the cluster of three meters. If he so chooses, the operator can select the auto-track mode in which the tracking is accomplished automatically. In the auto-acquire mode, the antenna system will automatically lock-on and track a target that appears within the half-power sum channel beamwidth (± 10 degrees). In the precision-tracker mode, the antenna system is slaved to the narrow-beam precision tracker.

A two-speed (1:1 and 36:1) follow-up instrument-type servo provides slave input through a synchro control transformer to enable this antenna system to be slaved to another system, decimal digital readout information accurate to within 0.1 degrees, and synchro loop position control to hold the antenna against external disturbances such as wind.

All of the circuits are packaged on interchangeable cards. Included is the power amplifier for the azimuth and elevation channels of the servo system. Spare plug-in modules are to be available in case of failure of one of the operating units. All test points and bias adjustments are accessible without the necessity of removing the card. Use of transistors, especially in the power amplifiers, makes this type of packaging possible.

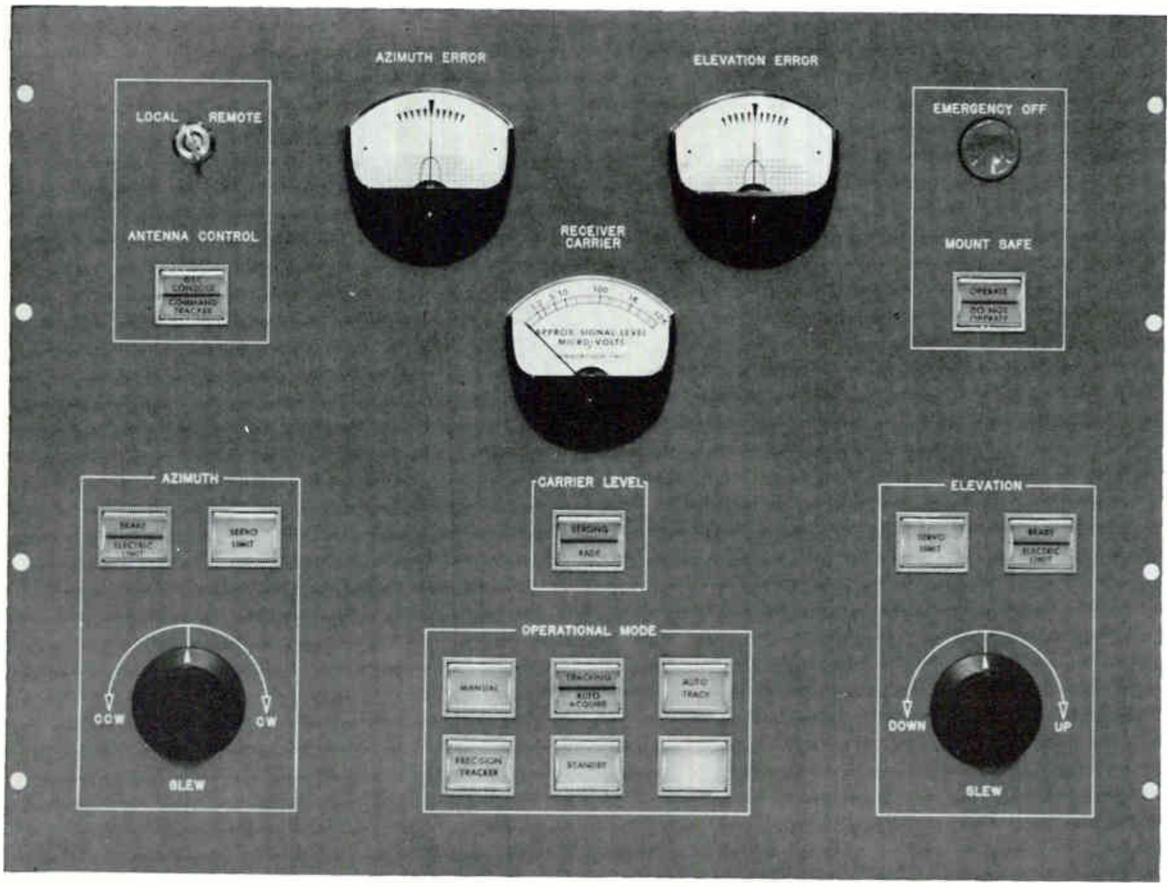
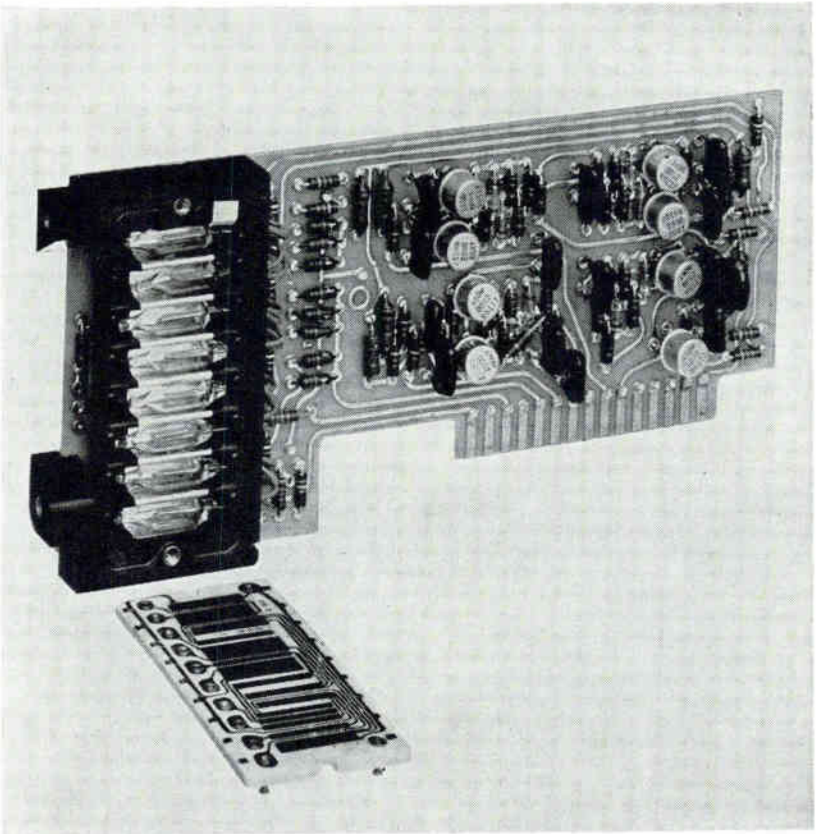


FIG. 5—Antenna control and monitor panel provides meter readings for azimuth and elevation error

Photoconductive Matrix

Photoconductors provide decoding logic and gain to drive decimal indicators of binary coded decimal counter. Matrix also provides storage

By BLAIR H. HARRISON, Hewlett-Packard Co., Palo Alto, Calif.



Assembly details show how photoconductor plate is fixed over the neon array to provide decoding

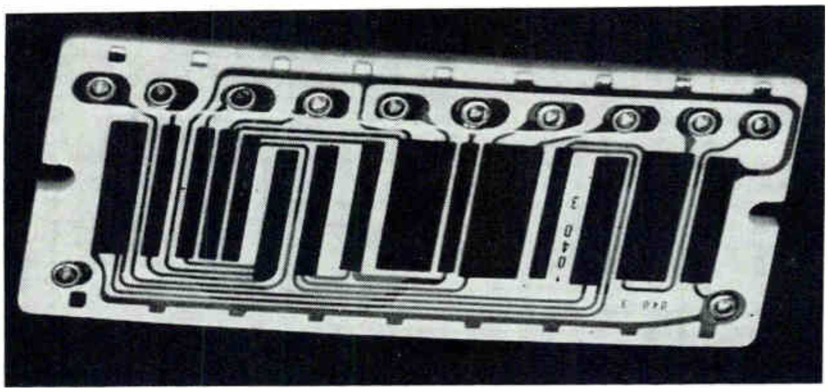


FIG. 1—Decoding matrix uses photoconductor to simplify readout

IN SOLID STATE decimal counters, many indicating devices require high voltage or high current inputs. In these devices, transistors cannot conveniently supply the drive for a readout matrix and still perform reliably at high speeds. Usually the binary information is decoded to decimal and then sufficient gain is provided to drive decimal indicating devices. Such an approach usually requires a resistive or diode matrix plus ten transistor amplifiers per readout decade.

A recently developed technique using photo-conductors and neon bulbs provides the necessary gain and performs the decoding logic in less space. A feature of the photoconductor-neon matrix is its storage capability.

The photoconductor (Fig. 1) is driven by eight neons that function in binary pairs and are driven directly by the binaries in a binary coded decimal (BCD) counter. The photoconductor is manufactured on a ceramic plate. Figure 2 shows the photoconductor decoding matrix. The letters associated with the individual elements show which of the eight binary neons across the top is physically associated with other elements. For example, when neon A is lighted all elements labeled A are in the high conductance state.

In the truth table, a binary ONE in the A column indicates that neon A is lit, while a ZERO indicates that neon $\overline{A}$ is lit. For example, at the count of seven, A B C and D are in the 1 0 1 1 states, respectively. This means that the A $\overline{B}$ C and D neons are lit. Inspection of Fig. 2 shows the only complete conducting path for this condition is the one in series with the number seven. Hence, the number seven would be displayed. Similar paths are present for the other nine states.

The photoconductors make an effective switching network. The OFF-to-ON ratios for individual elements approach 10^5, even when the neons are run at low current (200 μa).

Simplifies Counter Display

The photoconductors replace a circuit requiring 10 transistors, 10 diodes and 52 resistors.

The photoconductive matrix can be adapted to other codes by replacing the photoconductor with one having the proper matrix. Thus, if binary information in the form of lights is available, it is possible to derive an output in any four-line, eight-line, or ten-line code. Another advantage is unilateral coupling. The neon bulb is not affected by what happens to the light it emits so that variations in readout load cannot affect counter operation.

The photoconductor-neon matrix system permits storage. While transistors cannot presently drive a decoding matrix and decimal readout while performing reliably in a BCD decade, they can drive a binary readout. A photoconductor matrix in counters takes advantage of this as shown in Fig. 3.

The count flip-flops are driven in a conventional manner. Their outputs are coupled through diode transfer gates to the storage flip-flops. These flip-flops are actually the eight storage binary neons (Fig. 2) that operate the photoconductor matrix to determine display. When a count is completed, the transfer gate opens and the count information is transferred to storage and display. Now the transfer gate closes, allowing the count flip-flops to gather new information without disturbing the display of the previous count.

The specific relationships of the count flip-flops, transfer, and storage flip-flops for one binary pair are shown in Fig. 4. Four such pairs are cascaded to provide the operation shown in Fig. 2 and 3.

TRUTH TABLE

No.	Binary D (1)	C (2)	B (2)	A (1)
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	1	0
5	0	1	1	1
6	1	1	0	0
7	1	1	0	1
8	1	1	1	0
9	1	1	1	1

In Fig. 4 transistors Q_1 and Q_2 are the active elements in the transistor binaries, and in the quiescent condition one of the two is always saturated and the other is cut off. Voltage at the collector of the saturated transistor is zero, while the collector of the cut-off transistor is −30 v. Lamps *NE-A* and *NE-$\overline{A}$* are preaged neons matched with respect to firing and running voltages. Assume that they are typical bulbs that run at 55 v and ionize at 70 v. Diodes D_1 and D_2 can be assumed to be back-biased and, therefore, represent impedances sufficiently large that their effect on the circuit is negligible. With the conditions shown (Q_1 saturated and Q_2 off), *NE-A* will be conducting and will drop 55 v across its terminals.

The current drawn will be $(150 \text{ v} - 55 \text{ v})/(390 \text{ K} + 56 \text{ K}) = 213$ μa.

The voltage at *A* will be $56 \text{ K} \times 213\ \mu\text{a} = 12$ v and the voltage at *C*, $12 + 55 = 67$ v. The voltage across *NE-$\overline{A}$* is 67-30 = 37 v, which is well

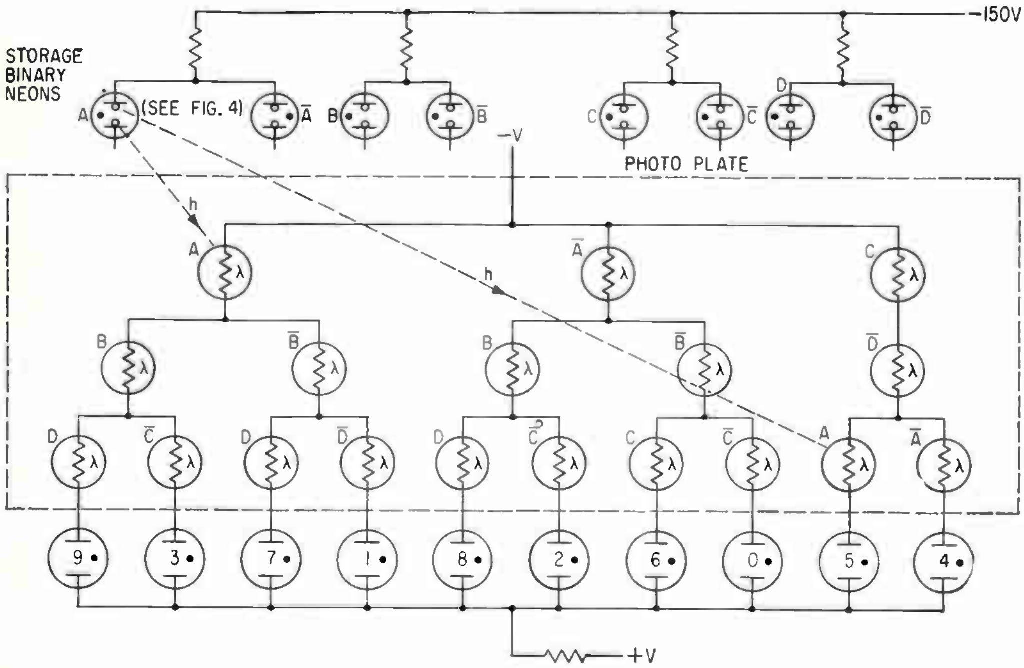


FIG. 2—Matrix for 4-2-2-1 BCD counter shows how decoder lights lamps directly

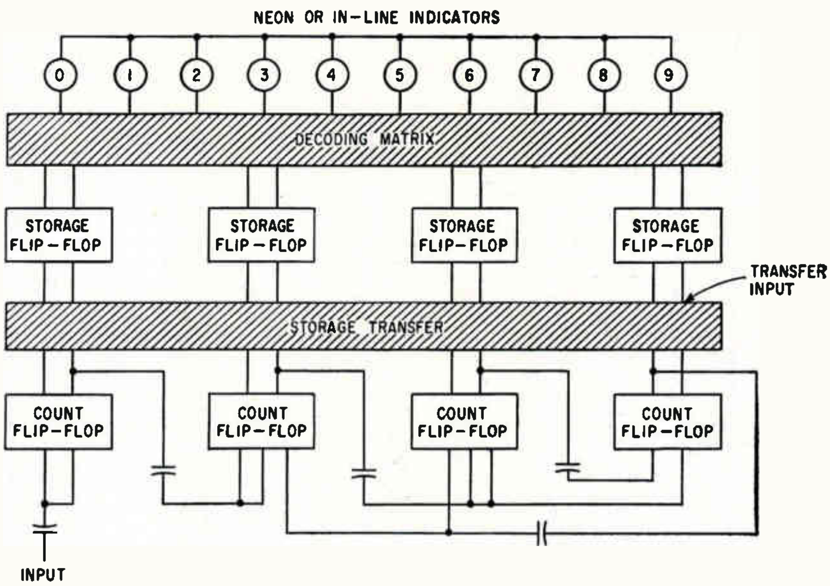


FIG. 3—Storage technique can be used to obtain continuous readout. Relationship of count to storage is shown

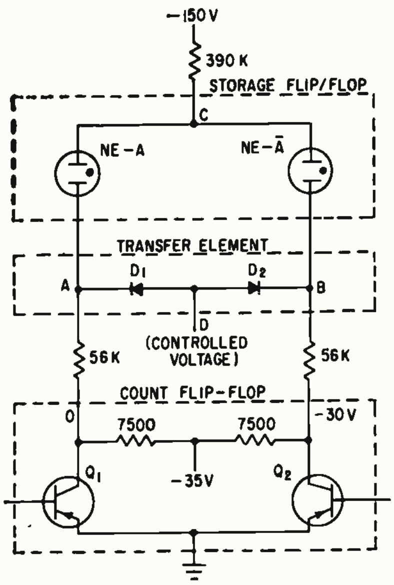


FIG. 4—Voltage at D stores information in neon bulbs

below the firing and running potentials, and *NE-$\bar{A}$* will be extinguished.

This is a stable configuration and will remain so until the binary changes state. When a change of state occurs, the collector of Q_1 changes to -30 v, and Q_2 saturates, placing its collector at zero.

Now the voltage at *A* is

$$30 + \frac{56K}{390K + 56K}(150 \text{ v} - 55 \text{ v} - 30 \text{ v}) = 38 \text{ v}$$

and the potential at *C* is 38 v + 55 v = 93 v.

This full 93 v appears across *NE-$\bar{A}$* and, since the ionization potential is 70 v, *NE-$\bar{A}$* ionizes. With *NE-$\bar{A}$* conducting and Q_2 saturated, the voltage at *C* is the same as it was when *NE-A* conducted and Q_1 was saturated. As before, the voltage across *NE-A* can be shown to be only 37 v and, hence, *NE-A* extinguishes and another stable condition exists.

Thus, as long as D_1 and D_2 are reverse-biased, *NE-A* and *NE-$\bar{A}$* will follow the binary in such a way that the neon connected to the collector of the saturated transistor will be ionized in the quiescent state.

To store the information in the neons, it is necessary only to shift the voltage at point *D* in a positive direction to zero volts. When this is done, both diodes are forward-biased and the potentials at *A* and *B* are equal. Since *NE-A* and *NE-$\bar{A}$* are now in parallel, and since one of them is conducting, the voltage across the pair is clamped at 55 v and the nonconducting neon will not ionize, since this requires 70 v. This is a stable configuration and the binary information is stored. The binary can now change state without changing the information in the neons.

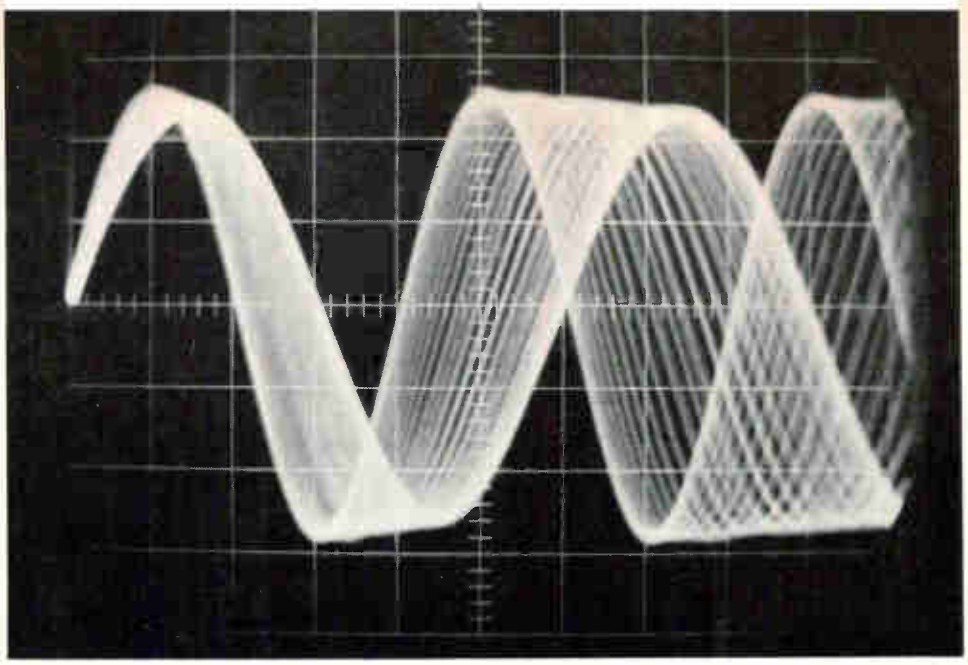
Since point *D* is driven by a monostable multivibrator (not shown) and all four transfer diode pairs are connected to *D*, the transfer and storage of information is accomplished simultaneously.

Life expectancy of the neons in this circuit is good because the firing voltage can increase by more than 20 v, compared to the running voltage of the other neon, before it will cease to ionize. Running voltage can increase by 15 v, compared to the firing voltage of the other neon before the storage will fail. Indicated neon life expectancy is in excess of 40,000 hours. This storage system, when used with a photoconductive matrix, can realize almost any desired output with a memory.

Another consideration is the speed of response. When the photoconductor is used as a switch, its conductance changes through several orders of magnitude. Thus the rise time of a circuit is affected by the impedance of the circuit. At one impedance level the response might be complete when only a small part of the total change in conductance has taken place. At another impedance level, however, total response would require the total change in conductance and, therefore, a much longer time. Thus, switching time becomes a function of conductance rate of change and of the circuit impedance.

After a circuit has been designed and impedances optimized, the photoconductor becomes the variable that must be controlled to get the proper switching speeds. By proper use of materials and construction, the speed of response can be in the 300 μsec region. Usually, however, the parameters that affect the switching speed of the device also affect other characteristics important in a switching circuit.

For a device that has good resistance stability over a large temperature range and good lifetime expectancy, it is generally necessary to establish total switching time of a few milliseconds. These speeds are excellent for visual displays because the eye itself has much greater limitations.



Oscillator output waveform, with a 10-cps control voltage varying the frequency ± 20 percent from the center frequency of 1,000 cps

VOLTAGE CONTROLLED

Wide-Range Oscillator

Small-signal a-c resistance of junction diode is related to reciprocal of junction current over a two-decade range. Using this characteristic in a two-section R-C shift network provides voltage-controlled phase shift

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THE PROBLEM in the design of a wide-range voltage-controlled sinusoidal oscillator is to find a voltage or current sensitive impedance that will vary predictably over a wide range. Vacuum tubes[1,2] and transistors[3] have been considered as control impedances in voltage-controlled oscillators. Semiconductor devices have small-signal impedances that vary over a considerable range with bias conditions.

A control element was chosen and incorporated in a two-section phase-shift network to provide a voltage-controlled phase shift. This controllable phase shift, when coupled with an amplifier and an automatic gain control, constitutes a constant-amplitude voltage-controlled oscillator with a frequency range of over two decades.

The quest for a voltage or current-sensitive impedance in semiconductor devices was pursued on a theoretical basis by examining the small-signal equivalent impedance of *p-n* junctions. A complete analysis of the equivalent impedance is complex, but for a range of bias currents of a few decades and with applied frequencies in the audio range, the approximate equivalent circuit can be considered to consist of a capacitor and a resistor in parallel.

The small-signal *p-n* diode resistance is derived from the ideal diode equation.[1] It is given by

$$r_{ac} = \frac{kT/e}{I_o + I_j} \qquad (1)$$

Thus for I_j much greater than I_o, the small-signal resistance is proportional to the reciprocal of the junction current. This holds true only for the ideal diode; with an actual diode the ohmic resistance of the semiconductor and leads must be taken into account. For the audio range, the capacitive reactance of both the transition and diffusion capacitance of the diode is much greater than signal resistance at a given bias level, hence the diode is almost purely resistive.

The effect of changes in junction-temperature on the equivalent small-signal resistance depends on the applied bias. For constant-current bias with I_j much greater than I_o and at a temperature of 300 Kelvin, the relationship

$$r_{ac} = \frac{kT/e}{I_j} \qquad (2)$$

shows that the resistance changes

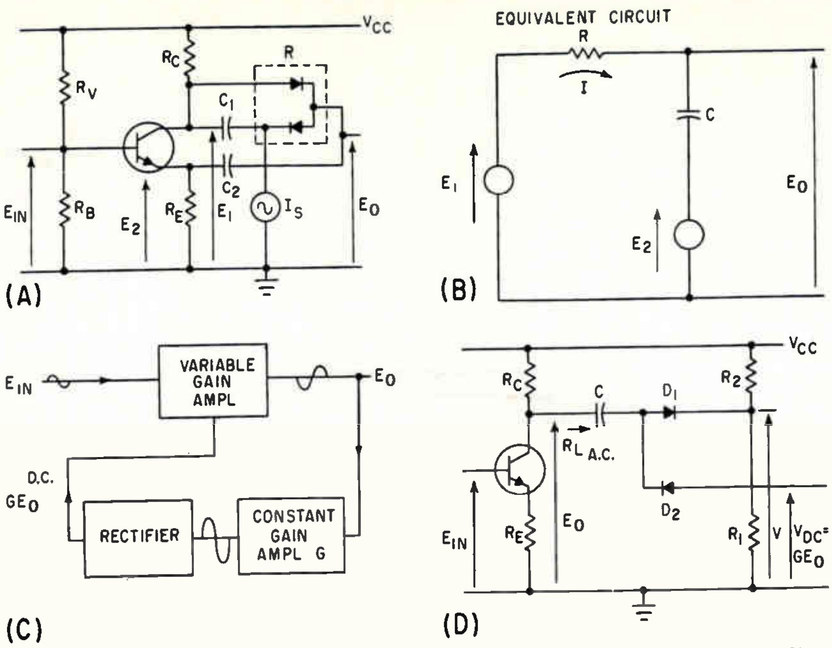

FIG. 1—Phase-shift circuit, (A); its equivalent circuit, (B); block diagram of automatic gain control circuit, (C); simplified schematic of the agc circuit, (D)

about 0.3 percent per degree Kelvin. Because of surface leakage current, Eq. 2 is not exact for the silicon diodes finally used, but it gives close to the correct magnitude of the temperature dependence. For constant-voltage bias, the ratio of junction currents at different temperatures is[4]

$$\frac{I_j}{I_{jo}} = \frac{T^3}{T_o}\exp\left[\frac{E_g - eV_o}{K}\left(\frac{1}{T_o} - \frac{1}{T}\right)\right] \quad (3)$$

where I_{jo} is the current at T_o, I_j the current at T, E_g the energy gap of the material, V_o the externally applied junction voltage, e the charge of an electron, and k is Boltzmann's constant. At 300 degrees Kelvin, Eq. 3 indicates a change of about 15 percent per degree for silicon. Thus it is advantageous to bias the diodes in constant-current mode.

Although the control element could be incorporated with any of the conventional R-C phase-shift networks, such as the Wien bridge or the 3 or 4-section ladder network, a variation of an all-pass lattice network was chosen, as shown in Fig. 1A and 1B. The transfer function for this circuit, with $R_C = R_E$, $E_{in} = E_2 = -E_1$, $X_{C1} << R$, and a current source I_S of infinite impedance is

$$\frac{E_o}{E_i} = \frac{j\omega RC - 1}{j\omega RC + 1} = \frac{[(\omega RC)^2 + 1]^{1/2}}{[(\omega RC)^2 + 1]^{1/2}} \angle 180^\circ - 2\tan^{-1}\omega RC \quad (4)$$

Thus when $\omega = 1/RC$

$$\frac{E_o}{E_i} = 1 \angle 90^\circ \quad (5)$$

With the above assumptions the circuit has unity gain at all frequencies and a phase shift that is a function of the product RC. For a constant phase shift of 90 deg through the network, the relationship $\omega = 1/RC$ must hold, and if C is held constant, the frequency at which 90 deg phase shift occurs is proportional to the reciprocal of the resistance. By cascading two of these networks with isolation, a phase shift of 180 deg is obtained at $\omega = 1/RC$. In the present application the resistance R is the controlled diode resistance, $r_{a\text{-}c}$, and therefore the frequency at which 180 deg phase shift occurs is proportional to the diode current. Figure 1A shows two diodes biased in series used as the control element. With the a-c coupling of C_2, however, the two diodes are in parallel. This arrangement is desirable, since despite the low-level signal amplitude the diode resistance is slightly nonlinear with applied signal. The use of two diodes presents a symmetrical resistance of the collector and hence reduces signal distortion.

Using the expression derived for ϕ_1 of the phase-shift network, the deviation in frequency from the predicted value due to extra phase shift in the coupling networks and additional circuits for two sections in cascade is

$$\phi_2 = 2\pi - 4\tan^{-1}\omega RC \quad (6)$$

and thus

$$\frac{d\omega}{d\phi_2} = \frac{-1 + (\omega RC)^2}{4RC} \quad (7)$$

which becomes, for $\omega = 1/RC$, $d\omega/d\phi_2 = -\omega/2$. Therefore, if the oscillator frequency is to be within 5 percent of the predicted value at a given bias current, the cumulative additional phase shift must be less than 5.7 degrees.

In deriving the transfer function of the phase shift network, simpli-

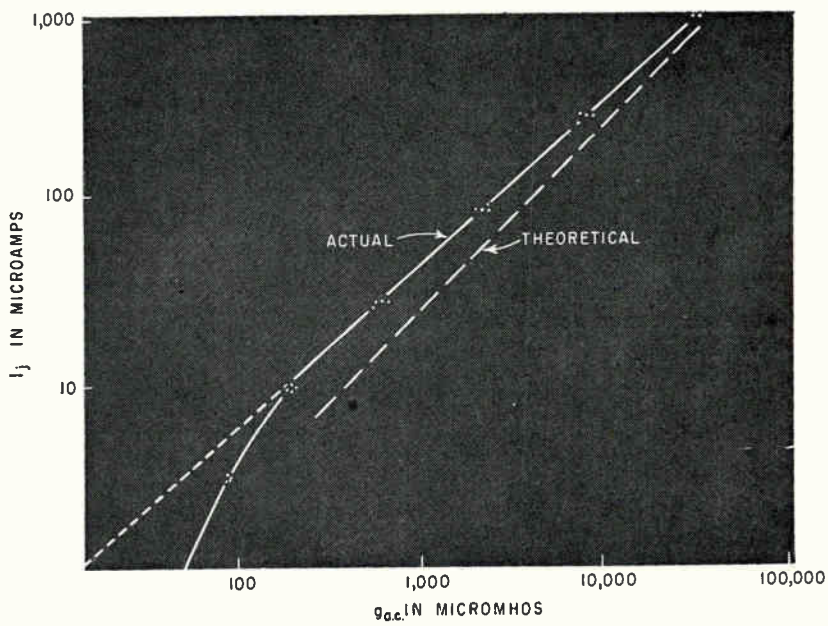

FIG. 2—Bias current plotted against junction resistance for 1N748 diodes

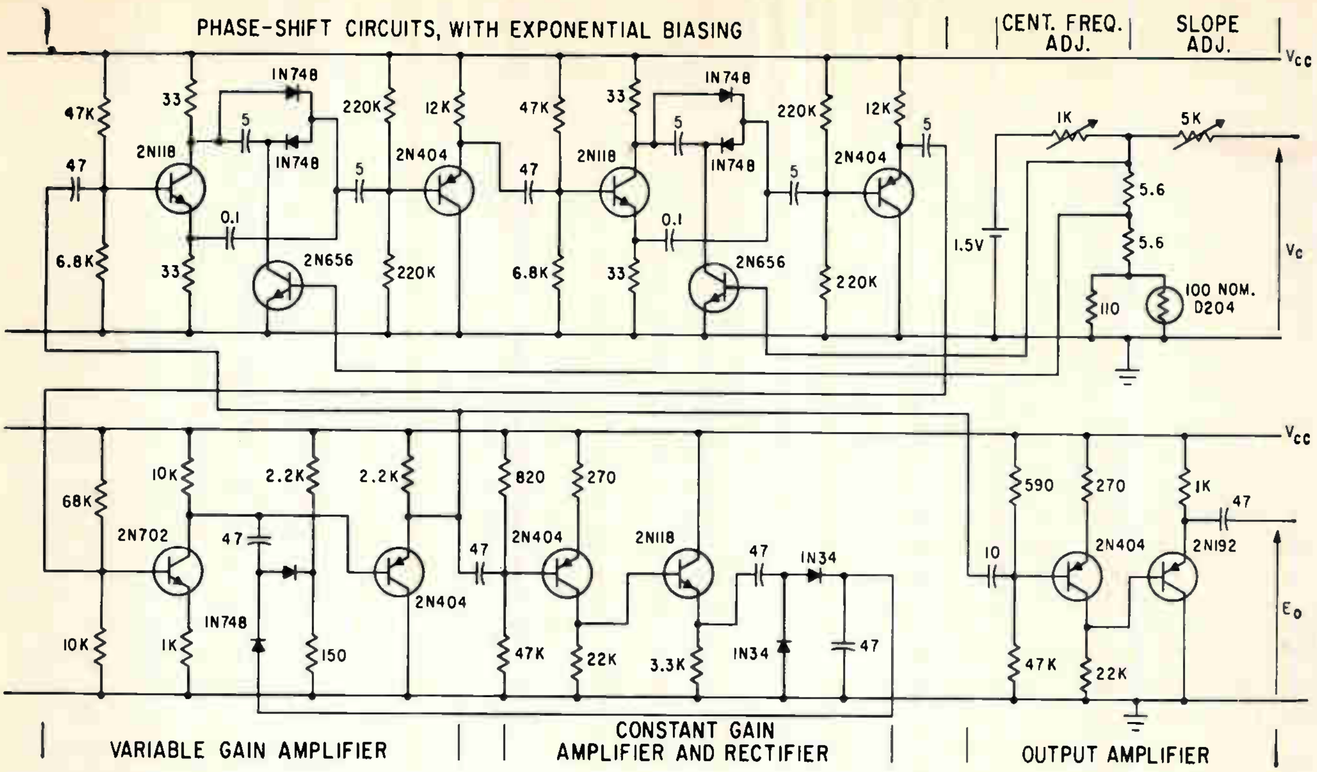

FIG. 3—Wide-range oscillator, with phase-shift circuit, upper left. Signal then goes to lower left

fying assumptions were made. The voltage gain of the phase inverter must be less than unity and hence for oscillation to occur, some additional voltage gain as well as another 180-deg phase shift must be introduced in closing the loop. The derivation also neglected the reduction of gain at high frequencies caused by the shunting effect of the internal capacitance associated with the transistors. Because capacitive coupling between sections is necessary to isolate the controlling bias current, there is also a reduction of gain at the low end of the frequency spectrum. Some form of automatic gain control is therefore necessary to keep the amplitude of oscillation constant at all frequencies.

The diode equation (Eq. 1) shows that constant current—hence constant r_{a-c}—is obtained in the presence of a d-c biasing voltage only when the amplitude of the input signal is less than kT/e. Since $kT/e = 0.025$ volt at room temperature, the a-c voltage should be much less than this for low distortion. Amplitude control is therefore necessary to maintain the diode peak-to-peak signal voltage in the low millivolt range. Without such control the oscillation would build up until the nonlinear characteristics of the amplifier or phase-shift network limited further increases in amplitude. Under the usual bias conditions, this would be a peak-to-peak voltage in volts, rather than millivolts, resulting in severe signal distortion.

The automatic gain control circuit consists of a variable-gain amplifier, a constant-gain amplifier to increase the magnitude sufficiently for rectification and control, and a rectifier that feeds back to the initial variable-gain amplifier. The load impedance and therefore the gain of the variable-gain amplifier is controlled by the rectifier output so that it provides a constant-amplitude signal. This is shown by analysis of the circuit of Fig. 1C and 1D. Assuming that $X_c << R_{La-c}$, $R_{La-c} << R_c$, $R_1 << R_{La-c}$, and $Z_o << R_{La-c}$

$$\frac{E_o}{E_{in}} \cong \frac{R_{Lac}}{R_E} \quad (8)$$

But

$$R_{Lac} = \frac{kT}{2e}\,\frac{1}{I_o + I_j} \quad (9)$$

and

$$I_j = I_o\left[\exp\left(\frac{V_{dc} - V_R}{2kT/e}\right) - 1\right] \quad (10)$$

Also, if $V_{d-c} = G\,|E_o|$ and $|E_{in}| = F\,|E_o|$ where F is some positive fraction, $0 < F < 1$, these equations may be combined to obtain

$$E_o = \frac{2kT/e\left(\ln F + \ln\frac{kT/e}{2R_E I_o}\right) + V_R}{G} \quad (11)$$

Therefore, if

$$V_R + 2kT/e\left(\ln\frac{kT/e}{2R_E I_o}\right) \quad |(2kT/e)\ln F| \quad (12)$$

then

$$|E_o| \cong \frac{V_R + 2kT/e\left(\ln\frac{kT/e}{2R_E I_o}\right)}{G} \quad (13)$$

which is independent of variations in F. Therefore, the output voltage will remain constant despite variations in the gain F, of the phase-shift circuit.

Silicon 1N748 diodes were tested to determine the relationship between diode current and the equivalent small-signal diode resistance. Silicon diodes were chosen in preference to germanium diodes because of their smaller leakage current, which increases the linear range of r_{a-c} or g_{a-c} against current at low currents.

Measurements show that the diodes are consistent in their behavior, as can be seen from Fig. 2. An extension of the linear portion of the graph verifies the effect of leakage current. Although the data points

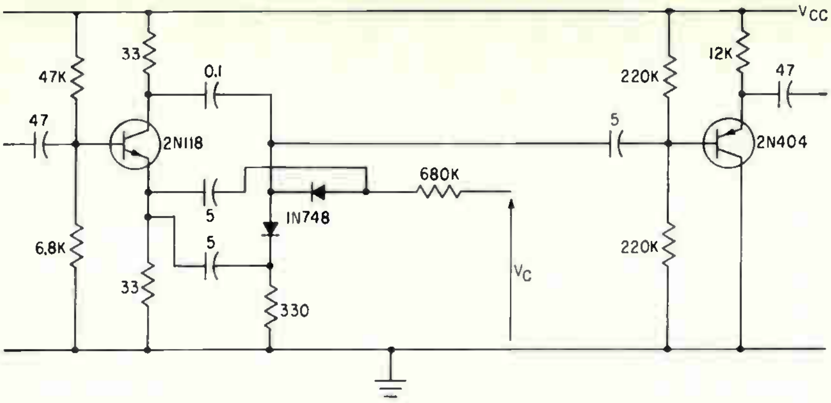

FIG. 4—Single section of phase-shift circuit with linear biasing

display a linearity on the logarithmic coordinates for about two decades of current, the slope differs considerably from the slope of 1 predicted by theory.

The consequences of the nonlinear relationship between conductance and bias current on the control of frequency depends on the control desired. Since the oscillating frequency is proportional to g_{a-c}, the frequency will bear this same power relationship to the control voltage when a current proportional to control voltage is used to bias the diodes. If, however, an exponential current source is used, such as a grounded emitter transistor, the power relationship serves only to vary the slope of the resulting V_b against frequency curve. For the grounded-emitter configuration, the base-voltage collector current characteristic can be approximated by

$$I_c \cong K_1 \exp (K_2 V_b) \quad (14)$$

where K_1 and K_2 are constants. But $I_c = I_j$, for this biasing scheme, and if $g_{a-c} = A\, I^B{}_j$ where A and B are constants, then

$$\left(\frac{g_{a-c}}{A}\right)^{1/B} = \ln K_1 + K_2 V_b \quad (15)$$

Then, since K_1 is a constant,

$$V_b \cong \frac{1}{K_2 B} \ln \left(\frac{g_{a-c}}{A\, K_1'}\right) \quad (16)$$

The basic form of the relationship is independent of B, and since frequency is proportional to g_{a-c}, the linear relationship between V_b and ln (frequency) still exists. This is a decisive advantage over the linear mode of biasing. For the transistors used, the proportionality between V_b and ln (I_c) holds for collector currents less than 100 microamp, but deviates from this relation at higher currents. Thus, for I_c greater than 100 microamp, it takes a larger V_b to produce a given I_c than would be predicted by the low current slope. This effect is due to the ohmic resistance of the base region. At collector current levels below 100 microamp, corresponding to bias currents less than 5 microamp, the effect of a base resistance of 200 ohms would produce a deviation of less than a millivolt, which for our application would be negligible. The 2N656 transistors were chosen as the current source in the oscillator because of their small base resistance and consequently small deviation from the desired relationship between V_b and ln (I_c).

The over-all schematic, Fig. 3, shows that emitter followers isolate amplifiers to prevent loading effects by succeeding stages. Capacitive coupling between the phase shift network and the emitter follower blocks the d-c biasing current so that the bias current is determined by the current source. The equal emitter and collector resistors are small in value to reduce the output impedance of the phase inverter. For a given range of variable resistance, the value of C will determine the corresponding range of frequency for which the phase shift is 180 degrees according to the relation $\omega = 1/r_{a-c}C$. For a desired range of frequency, C should be chosen to correspond to the optimum range of resistance. This optimum range of resistance is limited at the high end by the nonlinearity that occurs when the control current approaches the value of the leakage current. When a transistor is used as the control current source, the low end of the useful resistance control range is limited by the deviation of the transistor from an ideal exponential current source at higher currents.

Figure 5A shows a plot of the base voltage to produce a phase shift of 180 degrees against ln (frequency) for the phase shift circuit shown in Fig. 3. For this frequency range, the magnitude of phase shift due to capacitance coupling at low frequencies and transistor capacitance coupling at high frequencies is negligible, and the deviation from the linear portion of the graph at the low and high ends are due to the control limitations.

For the amplitude control circuit of Fig. 1D the output voltage will be approximately constant, inde-

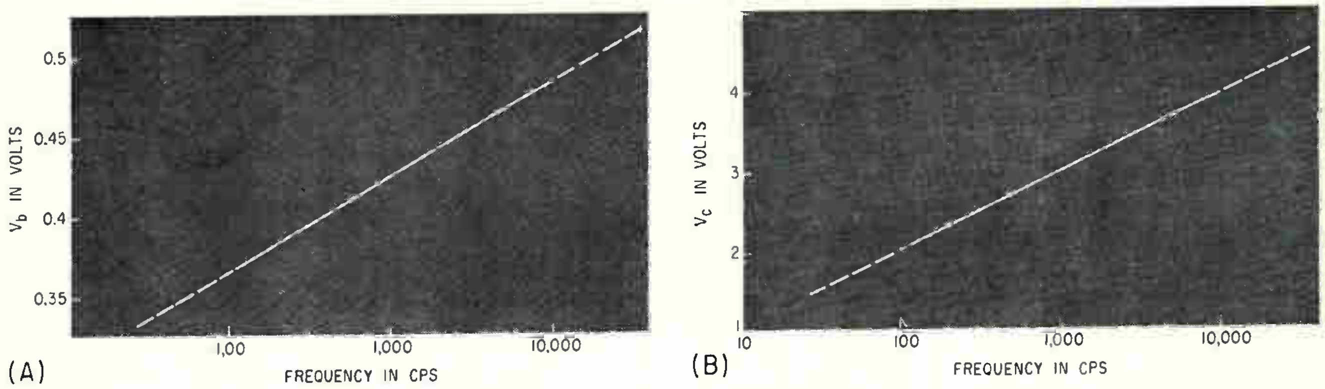

FIG. 5—Base voltage to produce a 180-deg phase shift plotted against frequency, (A); control voltage against oscillator frequency, (B), using exponential biasing

pendent of variations of gain of the phase shift network if Eq. (12) is satisfied. The magnitude of the output voltage will then be determined by V_R, R_E, the theoretical leakage current of the diodes D_1 and D_2, the gain constant G and the temperature of the diodes. For the values of components shown in Fig. 3, the predicted value of E_o is 0.0395 volt peak to peak, close to the measured value of 41 millivolts peak to peak. The effect of temperature on the amplitude is quite small for the values chosen, causing an increase in amplitude of about 2 percent for a 10 deg C increase in temperature. Substitution of the constants listed in Eq. (11) shows that the predicted variation in E_o is less than 7 percent for a change in the gain of the phase-shift section from 1 to 0.1.

The time constant of the voltage doubler type rectifier must be much greater than the period of the lowest frequency of oscillation to provide adequate filtering and d-c amplitude-control bias. Thus if the oscillator is to be frequency modulated by an a-c signal, the frequency of this modulating signal must be much less than the reciprocal of the rectifier time constant if amplitude modulation is to be minimized.

A series of tests to determine over-all performance were performed on the oscillator with exponential biasing as shown in Fig. 3. Figure 4 shows the modification in phase-shift circuits when linear biasing is used. The results of these tests are shown graphically in Fig. 5B through 7.

Figure 5B shows that the frequency of oscillation is variable over a range of 2 decades with about 5 percent deviation from a

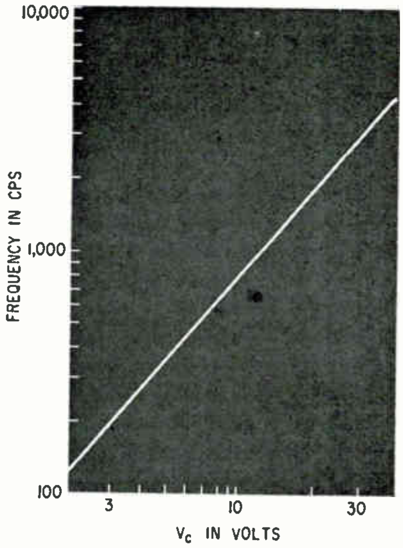

FIG. 6—Oscillator frequency vs control voltage, linear biasing

linear V_c versus ln (frequency) relationship. The deviation at frequencies above and below this range are due to the control limitations.

Figure 6 shows the data obtained for oscillator frequency against control voltage for the linear biasing network of Fig. 4. The measured slope of these data points is approximately 1.16. This is a direct consequence of $g_{a\text{-}c}$ being proportional to the bias current raised to a power slightly different from unity. A range of more than two decades can be obtained with linear biasing.

The amplitude of the output voltage is constant to within about 2 percent for the frequency range of 100 to 10,000 cps as may be seen in Fig. 7A. This data was obtained using a d-c control voltage. At the upper and lower extremes of oscillation of 77,000 and 1.3 cps, the amplitude is about 1.1 volts peak to peak.

The total harmonic distortion of the output waveform at various frequencies from 100 to 10,000 cps was measured. For this range of frequencies, the distortion is low, the highest measurement being 3.2 percent.

Because of the strong dependence of the transistor collector current on temperature for constant base to emitter voltage, the frequency of the uncompensated oscillator is sensitive to ambient temperature. For the circuit of Fig. 3 without the thermistor compensation in the base to emitter circuit, the oscillator frequency increases by a factor of about 3 for a 10 deg C rise in ambient temperature. Figure 7B shows the temperature dependence of the thermistor compensated oscillator.

The linear biased oscillator with no compensation revealed an almost linear temperature dependence with a slope of about 2 percent per 10 deg C rise in temperature.

The oscillator displays a remarkable stability with respect to changes in supply voltage. Although the oscillator was designed for a V_{cc} of 15 volts, the supply voltage can vary over about a two to one range and the oscillator frequency will remain constant to within 2 percent at the lower frequencies and to within 10 percent at the higher frequencies. A two-volt deviation from 15 volts in supply voltage produces a frequency change of less than 1 percent at all frequencies from 100 to 10,000 cps.

For the case of the exponential biasing mode, a center frequency and slope adjustment are provided, as may be seen in Fig. 3. The use of a mercury cell provides a center frequency control that is independent of supply-voltage variations. The slope can be adjusted to yield 2 decades of frequency range with a change in control voltage as small as 0.2 volt or as great as 10 volts.

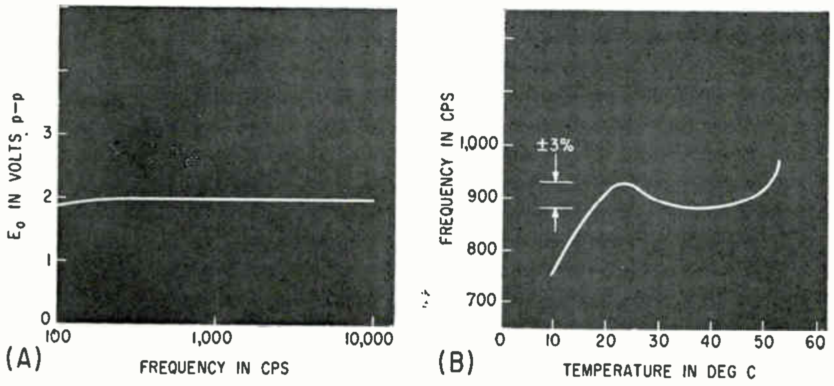

FIG. 7—Amplitude of output voltage is almost linear with oscillator frequency, (A); oscillator frequency against temperature for exponential biasing, (B)

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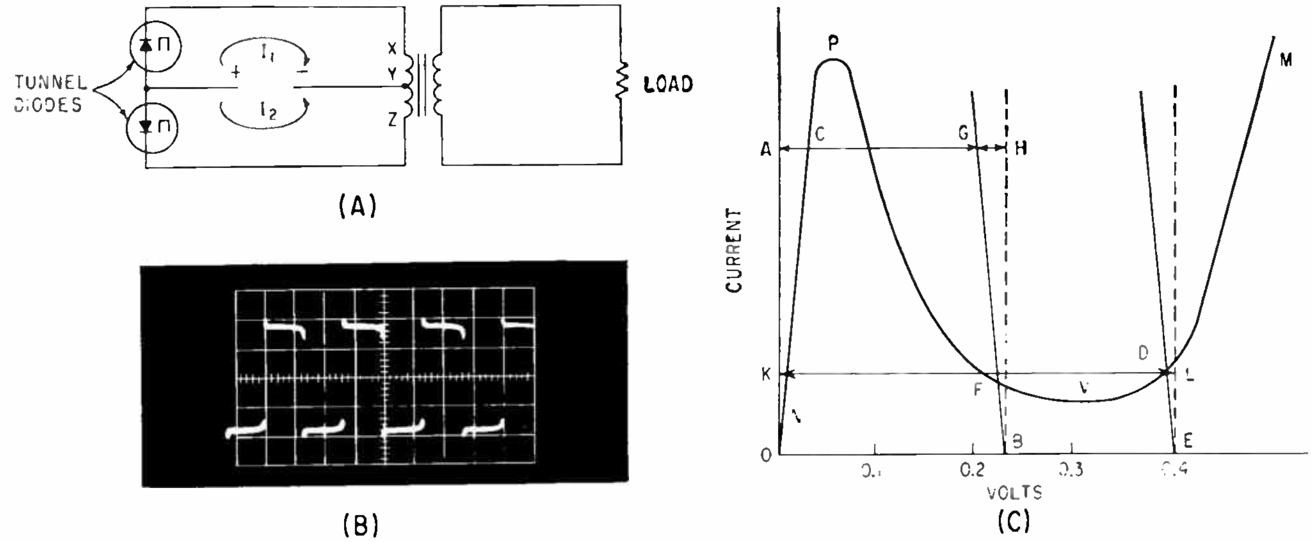

FIG. 1—Operation of square wave generator (A) to obtain typical output wave (B) is understood by analyzing the circuit's operating characteristic curve (C)

Generating Square Waves

Two tunnel diodes, a transformer and a power source produce high-quality square-wave output for low-frequency applications

By JOSEPH M. MARZOLF,
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A TUNNEL DIODE oscillator circuit, developed at the U. S. Naval Research Laboratory, was primarily intended to convert power sources of less than a volt, to higher, more practical voltage levels. However, the operating characteristic of this oscillator, and the high quality a-c square-wave output obtained, make this circuit useful as a low-frequency square-wave signal generator.

A typical circuit consists of two tunnel diodes and a square-loop magnetic core transformer, Fig. 1A. Typical output wave shape is shown in Fig. 1B. Operation of the circuit depends upon the tunnel diode characteristic, exemplified by the curve plotted for a germanium diode, Fig. 1C.

Several circuits have been constructed using tunnel diodes with peak current ratings from 1 ma to 10 amperes, and designed for various frequencies. The circuits are advantageous where thermoelectric generators are power sources. Such generators are low-voltage high-current sources and, as such, are ideally suited as power supplies.

To understand how the circuit in Fig. 1A operates, assume that the input terminal voltage is *OB* (Fig. 1C), and the slope of the load line is such that this line intersects the tunnel diode characteristic curve at point *F*, somewhere within the negative resistance region, that is, between the peak and valley points.

When the input voltage is applied to the terminals in Fig. 1A, currents I_1 and I_2 will flow in the directions shown. If both loops including the diode characteristics were identical, the currents would be identical at all times and the circuit would not oscillate.

However, in a circuit this condition is impossible, since the loop impedances and diode characteristics will be slightly different. So assume that I_1 is larger than I_2 and quickly reaches its operating or dynamical equilibrium point, *C*, in Fig. 1C. When operating at this point, *AC* represents the voltage across the diode, *CG* represents the voltage induced in the primary winding by the changing flux in the core and represents the induced component of the load voltage referred to the primary circuit, and *GH* represents the ir drop of the primary circuit. The sum of these three voltages equals input voltage *OB*.

The changing flux in the core induces a voltage in the lower half of the primary winding also equal to *CG*. However, polarity adds to the input voltage in determining the voltage impressed across the lower tunnel diode. Thus, if *BE* is made equal to *CG* and the load line *DE* is drawn parallel to *BG*, the operating point for the lower loop

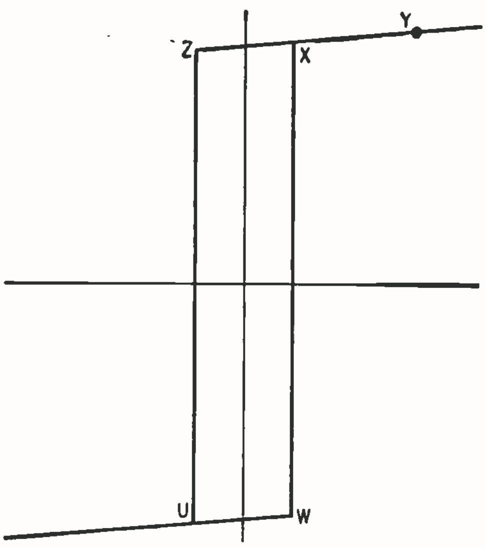
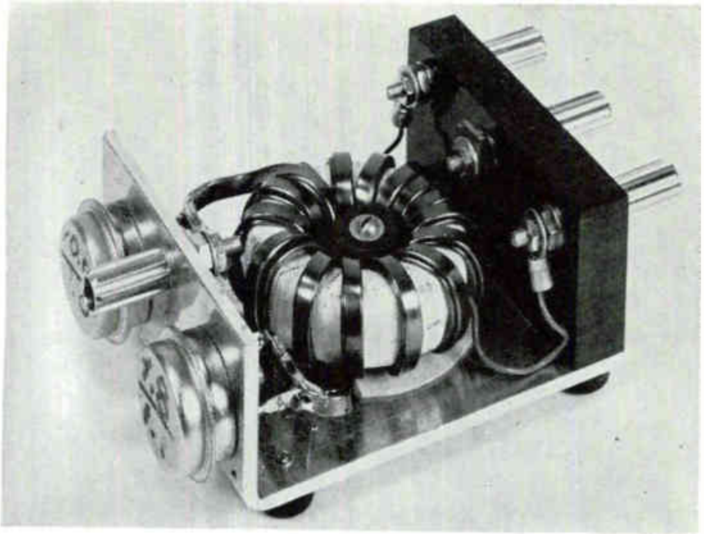


FIG. 2—Idealized hysteresis loop for the magnetic core



Square-wave generator using tunnel diodes having a peak current rating of approximately 10 amperes

With Tunnel Diodes and Cores

is established at point *D*. Thus, in the lower loop, *KO* is the current, *KD* represents the voltage across the diode and *DL* represents the ir drop in the primary loop. The sum of *KD* and *DL* equals the sum of the input voltage *OB* and the induced voltage *BE*.

Thus the parameters of the circuit constrain operation so that while the core flux changes from *W* to *X* in Fig. 2, the induced voltage *CG* remains constant. Both the magnetizing current and the load current remain constant.

When the core saturates (point *X* of Fig. 2), suddenly the induced voltages *CG* and *BE* decrease rapidly. The only way this can happen with the operating points remaining on the diode characteristic curve is for the difference between I_1 and I_2 to increase rapidly. This can only be accomplished by I_1 increasing and I_2 decreasing. Thus *C* moves toward *P*, and *D* moves toward *V*. Also the operating point for the transformer core moves from *X* to *Y*.

When the peak and valley points are reached, $(I_1 - I_2)$ no longer increases because of the tunnel diode characteristics, and an unstable condition occurs. Rapid transient conditions cause the operating point for the upper loop to shift from *P* to *M*, and the lower loop to shift from *V* to *N*. Operation at these points requires that the induced voltage in the windings be reversed, which is accomplished by a rapid decrease in $(I_1 - I_2)$. Thus I_1 must decrease and I_2 must increase very rapidly, causing the operating point of the upper loop to move from *M* to *D* and the lower loop to move from *N* to *C*. During this time the transformer core operating point moves from *Y* to *Z* in Fig. 2. When point *Z* is reached, the flux decreases from *Z* to *U* establishing a stable condition similar to the period while traversing the distance *WX* with the exception that the induced voltages in the windings are now reversed. This condition with the operating point for the lower loop at *C* and the upper loop at *D* will continue until the core saturates in the negative direction. At this time the circuit quickly switches to the initial conditions and completes one cycle of operation, which will now be repeated. Since the switching transient takes place rapidly, the load voltage is an a-c square wave.

Frequency output of the circuit depends upon the size and material of the core, the number of turns on the primary windings, and the input voltage. These are related by

$$E = N \frac{2BA}{t} 10^{-8}$$

where *E* is the voltage across the coil in volts; *N* is the number of turns on each half of the primary windings; *B* is the maximum flux density of the given core material in gausses; *A* is the cross-sectional area of the core in square centimeters; and *t* is the time duration of one half cycle in seconds.

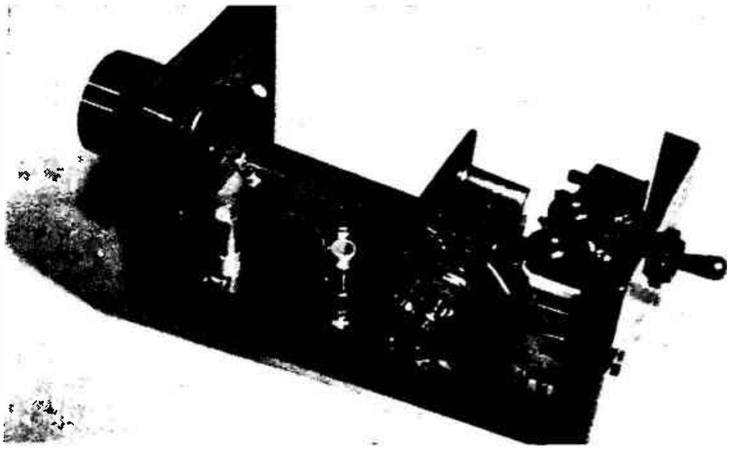
Power output of the circuit depends upon the peak currents of the tunnel diodes, since the input voltage is limited to approximately 0.25 volt (for germanium). At present, tunnel diodes can be made in the ampere range, but no theoretical peak current limit exists. Apparently the peak current is a function of cross-sectional area only.

Improved fabrication techniques should produce the large-area uniform junctions for higher peak currents.

The impedance of the primary circuit, including the input generator, must be low for the circuit to oscillate in the mode explained. However, considerable latitude is permitted in the secondary circuit, because of the normally high voltage step-up of transformer.

DIODE AMPLIFIER HAS TEN-

Wide-band amplifier uses diode biased with r-f to produce 30 to 40-db gain. Input impedance is greater than 10^{10} ohms with frequency response of 3 cps to 200 Kc within 3 db



Author adjusts amplifier (↓); close up of prototype amplifier and pump source shows component layout (↑)

By DENES ROVETI,
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RECOVERING and measuring the output of high impedance sources having a wide bandwidth is simplified by a solid-state amplifier with high input impedance. The amplifier, of the parametric type, has an input impedance of 10^{10} to 10^{11} ohms and serves as a buffer amplifier or impedance transformer at low energy levels. In the amplifier, the total energy of a silicon diode is varied by the input signal to obtain power gains of 20 to 40 db.

Low-energy pulse experiments and electrostatic field variation measurements led to the development of the amplifier. Requirements included an input impedance in the order 10^{11} ohms, minimum input shunting capacitance, bandwidth ranging from less than 1 cps to several hundred kilocycles and input power levels as low as 10^{-16} watts. Present transistor feedback techniques make these requirements difficult to achieve.

The inherently high input impedance of the resonant slope amplifier[1,2] suggested an approach to obtaining the performance. But first the time constant of the input circuit must be optimized to improve low-frequency response and input impedance. This necessitates elimination of d-c biasing which, in turn, causes additional response limitations and stability problems at higher input impedance levels since the biasing is usually established in series or in parallel with the source impedance.

Using the self-biasing action of a diode excited from a-c solves the problems. This self bias with a-c drive sets the depletion layer capacitance of the diode to a fixed reference value to establish the reactance for the control element. Variation of capacitance and leakage of a typical diode used is shown in Fig. 1A.

Figure 1B shows the circuit for the resulting high-impedance parametric amplifier. Diode D_1 is the energy storage element and the crystal-controlled transistor oscillator is the pump-frequency source. A low-capacitance connector minimizes input capacitance ($C_{connector}$ = 0.02 to 0.03 pf).

Like the magnetic amplifier, this parametric amplifier is supplied from a high frequency a-c, or pulse pump source. The crystal controlled oscillator should have low internal impedance (50 ohms or less) and low spurious noise level. The low internal impedance is necessary to supply enough energy at any instant to D_1, D_2, L_1, C_3 as the input signal varies the total charge stored in the diodes. High internal impedance (R >> 50 ohms) results in harmonic distortion in the output especially at the low end of the frequency spectrum.

Regardless of the type of oscillator, a minimum spurious noise content is essential to obtain low noise level. With the oscillator in Fig. 1B, minimum noise at the output with input open is about 200 μv.

The high-frequency constant voltage and frequency source (with low R and low noise) is connected to L_1 and C_3. The Q of L_1 is around 60. With higher Q values more voltage gain can be obtained (output voltage is proportional to the steepness of the resonant curve) at the expense of stability and bandwidth. With lower Q values, voltage gain is sacrificed for wider frequency response and increased stability. Design consideration of the re-

GIGOHM INPUT IMPEDANCE

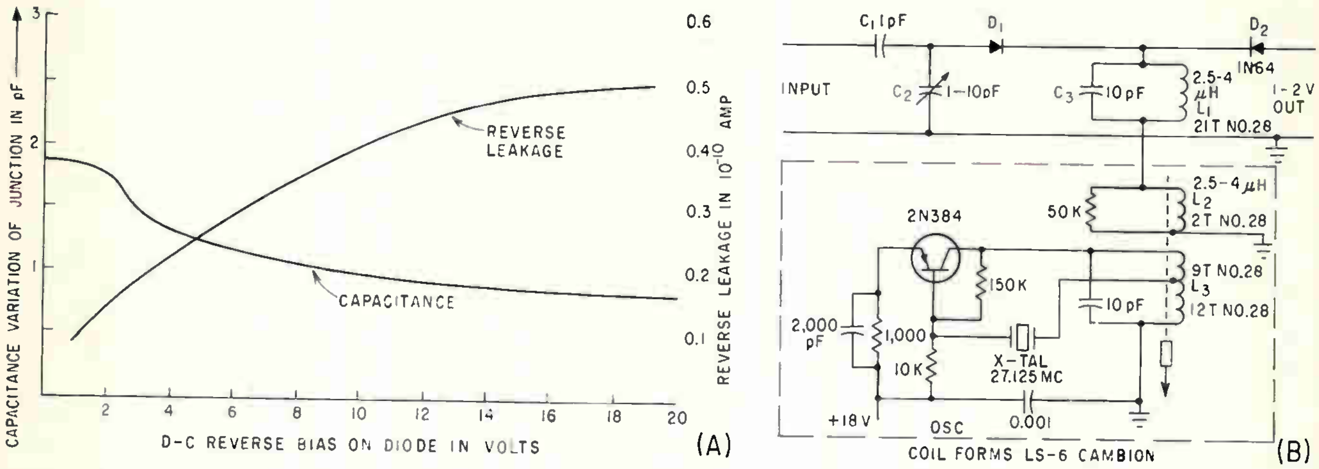

FIG. 1—Reverse bias determines capacitance and reverse leakage (A). Drain on 18v supply in (B) is 2-3 ma

quirements decide the optimum quality factor.

High side of the tank coil is connected to silicon (D_1) and germanium (D_2) diodes having high reverse leakage ratios: $R_{reverse}$ for D_1/D_2 > 20,000 under small signal a-c and reverse biased d-c conditions. This ratio is related to the maximum real-impedance-component transformation that can be obtained from the amplifier. A high ratio is desirable for optimum performance. The diodes can be connected in any polarity to the tank coil without affecting the performance of the amplifier appreciably.

At the output, value of the resistive and capacitive load component is decided by voltage gain and bandwidth requirements. Higher power gains can be obtained at lower R levels with optimum value about 100 kilohms.

The Table shows how output voltage varies with load. These values are for an input signal of 0.5 v rms at 10 cps and a power source of 27 Mc, 50 ohms, 1 v rms. For good high-frequency response, the output circuit's time constant should be low ($1/f_{max} >> R_l C_l$); for example, the load resistive component (R_l) should be 10[illegible] ohms or less with shunting capacitance C_l of 10 to 20 pf.

The input signal is applied through C_1 which can be adjusted from 0.0001 pf to a few pf to suit operating conditions. For unity voltage gain, C_1 should be approximately 5 pf. with lower input capacitance, the voltage gain is reduced proportionately (at 0.01 pf, voltage gain = 0.01/5 = 0.002 but other characteristics are not affected). This is useful for capacitance and dielectric constant measurements in a wide frequency range (1 cps to 200 Kc within 3 db).

Capacitor C_2 swamps out any change that may affect operating point on the resonant slope caused by variation in the signal source impedance. With fixed input source impedance, C_2 is not required.

Another function of the high pass input circuit (C_1, C_2) is to maintain the self-bias d-c value on D_1 in an unloaded condition so that in the dielectric and in R parallel only the loss component has to be supplied during the forward conduction cycle. When C_2 is not used and C_1 is small, a fixed capacitance of 0.1 to 1 pf is needed to build up the self bias and to affect the tank circuit's impedance while the depletion layer capacitance of D_1 is changed by the input signal.

AMPLIFIER OUTPUT

Load Resistance in Ohms	Output Voltage in mv	Power Output in Watts
10^7	100	0.1×10^{-8}
10^6	97	0.94×10^{-8}
10^5	68	4.6×10^{-8}
10^4	20	4×10^{-8}

In Figure 2 curve A shows frequency response of the parallel tuned circuit in variation of d-c self bias. Change in the amplified output voltage is indicated on curves B and C as the pump frequency is varied from 24.5 to 28.5 Mc. Input voltage is kept constant at 0.5 volt and 100 cps and the pump voltage at 1 volt rms.

Curve A displays a narrower response at high frequency and a wider band on the low end than expected on the basis of linear circuit elements. Measured Q of the parallel resonant circuit C_3 and L_1 was 65 at 27 ±1 Mc, giving a bandwidth of 415 Kc assuming linear elements.

Actual asymmetrical bandwidth is 500 Kc with 100 Kc on the high side and 400 Kc on the low end. The wider bandwidth results from loaded Q (1 megohm at output) and from the loss components of the diodes. Displacement of the resonance curve symmetry and the broad response at the low frequency side is attributed to the nonlinear, resonant effects in the diodes.

Output voltage variation with pump frequency is shown on curve C below resonance, and on curve B above resonance. Experimental results indicate the voltage gain of the amplifier is proportional to the slope of the resonance curve. At the resonant frequency, slope of the resonant curve is zero and the output, therefore, is also zero. As the frequency deviation from the resonance point increases, an optimum steepness is reached on both sides of the envelope giving two maximum voltage outputs. These maximum output points occur at the 3-db points. Below the 3-db points, the output voltage slope response is close to the envelope response slope.

For small input signals (under 2 v) there are four distinct operating regions for the amplifier: below or above resonance; below or above the 3 db points. On any one of these regions the operating point can be chosen by adjusting L_1, C_3 or the pump frequency.

For high linearity in a wide input signal range (500 μv to 1 v rms) operating point on curve *B* above the 3-db point gives the optimum performance. With a pump source frequency stability of 50 parts per million, output voltage drift will not exceed more than 1 percent.

In Fig. 3, the dynamic operating condition of the amplifier is clarified by expanding the section of the envelope response curve between the resonant frequency and the upper 3 db point. Inductance L_1 and the lumped C (C_3, D_1, D_2, C_2, C_1) resonates at 27 Mc as before, and the variable frequency oscillator is adjusted to 27.086 Mc to shift the operating point P_1 of the amplifier to the linear part of the slope. The equivalent input circuit is also shown.

For an input signal of 100 cps, R_{11} of the diode is much greater than its capacitive reactance and R_{11} can be neglected. Inspection of the equivalent high pass capacitive divider indicates that $\frac{1}{3}$ of the input signal is across the junction capacitance and is superimposed on the d-c self bias. Using Fig. 1A, this input voltage component can be used to find ΔC.

Figure 3 shows how the incremental capacitance change, with an input voltage of 0.5 v rms (0.5/3 across junction) causes 5 to 6 Kc frequency deviation. This Δ f produces 0.282 v peak to peak at the output while the output signal is traced by the changing operating point P_1.

For good low-frequency response and for minimum signal loading, D_1 must have low capacitance and low reverse leakage. However, this is difficult to obtain as there is no one process that yields, at one time, low capacitance and low leakage. Usually, low capacitive diodes are made by variations of the diffusion process while low leakage units are made by the alloy process.

The high conductive silicon diode presently used in this amplifier has these typical characteristics:

$$\left.\begin{array}{l} I_{reverse} = 0.00005 \text{ to} \\ 0.00002\ \mu a \\ C = 0.5 \text{ to } 3 \text{ pf} \end{array}\right\} \text{at } -9.1 \text{ v}$$

These diodes, not generally available, are produced to specification.

Typical applications of the amplifier include detecting the variation of charge density patterns in electrostatic display devices (these charge densities are converted into fluorescent light), detection of slowly changing electrostatic fields through air or other dielectric medium, and analyzing stresses of vibrating elements to record variations in the amplitude and frequency without loading or touching the vibrating member in a wide frequency spectrum.

Other practical applications include measuring voltages and observing wave shapes of insulated wires by placing an alligator clip or probe (with a shield to eliminate 60 cycles) on the insulated wire and tracing any circuit from a few cycles to several hundred kilocycles without making actual contact.

The amplifier has the following specifications: minimum input impedance of 10^{10} ohms at the low frequency end (plus input connector capacitance), frequency response of 3 cps to 200 Kc within 3 db, output impedance of approximately 1 megohm and 3 to 10 pf, voltage gain of 0.1 to 0.5, power gain of 20 to 40 db, output voltage of 0.5 volts maximum and noise level in microvolt region (typical noise level with crystal controlled transistor oscillator is 200 μv).

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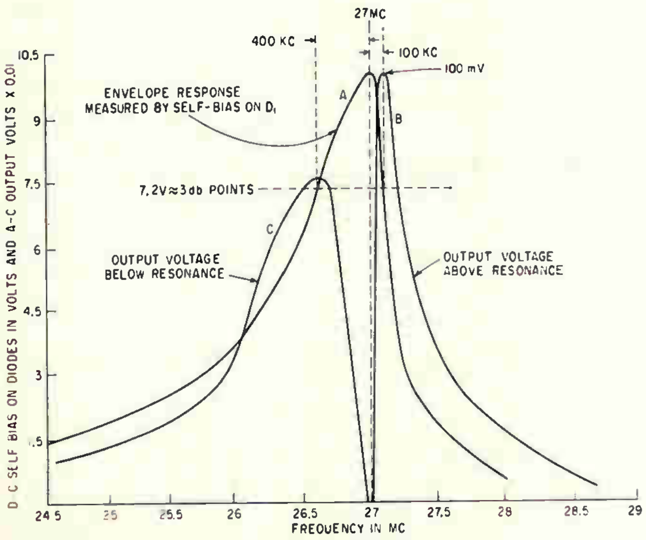


FIG. 2—Diode self bias and output voltage variation

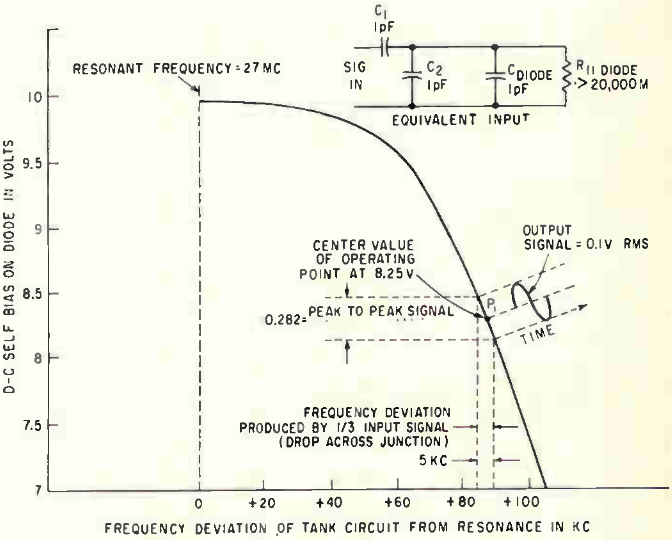


FIG. 3—Operating point is set at linear portion of curve

Disk Resistor Permits Impulse Current Studies

By F. H. INDERWIESEN,
E. J. MARTIN, JR.,
P. C. PATTON
Midwest Research Institute,
Kansas City, Mo.

DISK-TYPE current-viewing resistor has been developed for impulse current studies. Self inductance in the compact resistor is only 0.025 microhenries, and its performance is said to be significantly better than that of the coaxial resistor. The current-viewing resistor was designed at Midwest Research Institute, where it was required in development of a 2,500-joule flash photolysis and flash spectroscopy instrument.

Measuring peak current impulses of about 10^5 amperes or viewing them on an oscilloscope is required in such diverse fields as plasma physics, nuclear fusion and exploding wire studies. However commercially available current-viewing resistors are expensive and often have limited current-carrying capacity.

Although the coaxial shunt resistor[1] is often used, the shunt must be relatively long to develop a satisfactory voltage for even large currents. The coaxial shunt resistor also has limited current-carrying capacity because of the crushing force of the magnetic field on the outer conductor.

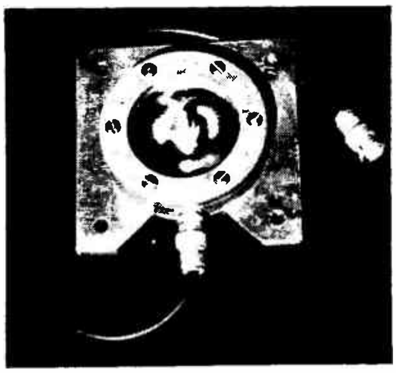
The geometrical design of the disk resistor eliminates the undesirable properties of conventional current-viewing resistors. It is relatively small, easy to make, convenient to use and accurate. The disk resistor also has high current-carrying capacity as well as low self inductance.

The resistor in the photograph provides a voltage output proportional to current supplied to a 0.5-ohm load in flash photolysis experiments. The design is a variation of the radial-plane geometry[2]. Current enters the center terminal of a thin resistive disk, flowing radially outward and leaving the disk at the circumference. The 0.005-inch thick disk is made of #302 stainless steel, which is nonmagnetic and has relatively high resistivity (about 7.2 × 10^{-5} ohm-cm).

Current enters a low-resistance connection to the center of the disk. The disk is clamped securely at the outer edge by heavy copper rings that form a low-resistance current exit electrode. A BNC connector on the base (grounded) electrode provides coaxial output to an oscilloscope or other instrument. Total d-c resistance measured with a potentiometer bridge was 0.0015 ohm for a disk with an active radius of 1 inch. (Active radius includes only the radius of the stainless steel resistive material between its inner and its outer circumferences.)

CURRENT-VIEWING RESISTOR CHARACTERISTICS

	Disk	Coaxial[1]
Resistance in ohms	0.001539	0.0018
Current circuit self inductance in henries	$0.027 \times 10^{-[illegible]}$	0.06×10^{-6}
Maximum voltage drop at terminals (L di/dt for di/dt = 5×10^{10} amp/sec)	1,250	5,300
Allowable energy in joules	not determined	11,500
Current limit in amperes imposed by magnetic force	not determined	223,000
Size in inches	1×5×5	2×2×38
Material	302 stainless steel	80% Cu, 20% Ni
Resistivity[3] in ohm-cm	7.2×10^{-5}	3.63×10^{-5}
Thickness[4] in inches	0.005	0.216
Skin depth at 1 Mc in inches	0.018	0.013



Current enters electrode at center of disk and leaves from copper rings at outer circumference

Since for practical purposes current flows only in the radial direction, the resultant magnetic flux is essentially parallel to the plane of the disk. Thus magnetic forces on the disk resulting from interaction of disk current and magnetic field are small even for large currents, and there is little danger of disk rupture. Current-carrying capacity is limited by thermal rather than mechanical properties of the disk. The factors that result in small magnetic forces also result in low self inductance. For an active radius of 1 inch in a nonmagnetic disk, self inductance is 0.025 × 10^{-6} henries.

The relatively small size and the geometry permit short leads for connection to the load. In some cases, leads can even be an integral part of the load. For longer leads, a coaxial line can be used with the current-viewing resistor forming part of the line termination. The compactness and geometry of the disk resistor also result in low inductive and capacitive coupling.

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McGraw-Hill Publication,
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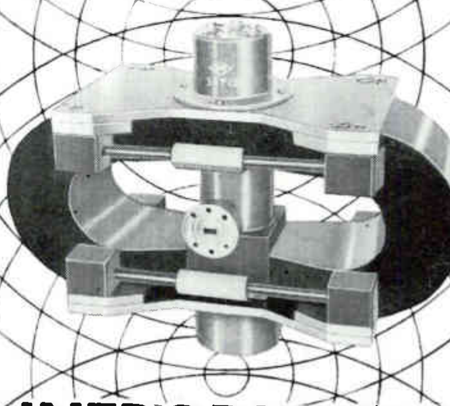

INTRODUCING LADDERTRON

A NEW TUNABLE HIGH POWER CW MM-WAVE KLYSTRON

LADDERTRON, a single cavity, multi-gap klystron, employs a strip beam system, that permits LOWER BEAM VOLTAGE CW OPERATION FOR VERY HIGH POWER USE. The frequency of the LADDERTRON is mechanically tunable over a range of 1,000 Mc, and the control electrode modulation enables the electronic tuning in a range of 40 Mc.

The 2 models now in production are the 35F10 with a frequency of 35 K Mc and an output of 5 watts, and the 50F10 with a frequency of 50 K Mc and an output of 5 watts.

Model No.	35F10	50F10
Output Power	5W	5W
Center Frequency	34,000 Mc	50,000 Mc
Mechanical Tuning Range	±750 Mc	±1,000 Mc
Resonator Voltage	1,850V	2,140V
Cathode Current	110 mA	120 mA
Electrical Tuning Range	40 M c/s	40 M c/s
Water Cooling	0.5 ℓ/min.	0.5 ℓ/min.

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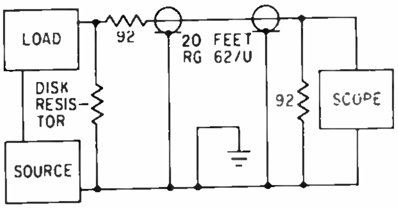
and, as a consequence, the disk-type current-viewing resistor provides good isolation and shielding of the potential circuit from the current circuit.

The circuit in the figure was used to study characteristics of 2,500-joule flash discharges, which is a typical application of the current-viewing resistor. The load is a gas discharge lamp used for photolysis excitation.

To transmit voltages pulses developed across the disk resistor to an oscilloscope, 20 feet of RG 62/U coaxial cable is used. The resistor on the ground side keeps potential on the cable low. The cable is terminated at the oscilloscope in its 92-ohm characteristic impedance, and another 92-ohm resistor is connected in series with the coaxial cable input for matching (to damp reflections that might result from imperfect termination at the oscilloscope). The components selected for each of the two 92-ohm resistors are noninductive metallized film resistors.

The 2:1 voltage division resulting from using two 92-ohm resistors gives an overall factor of 1,333 amperes per volt at the oscilloscope terminals. With an input limit at the oscilloscope of 500 volts peak, the circuit can theoretically be used for viewing current pulses having peak values of up to 666,500 amperes.

Measurements and calculations indicate that performance of the disk resistor compares favorably with other current-viewing resistors. Characteristics are compared with those of a coaxial shunt resistor in the table. The disk resistor is



Typical circuit uses disk resistor to view current pulses

superior in size, current-carrying capacity and low self inductance. Mathematical analyses have not yet been made of skin effect on impedance or mutual inductance between the current and the potential circuits. However there is no detectable deterioration of output pulses compared to input pulses of known amplitudes and rise times under one microsecond when viewed on an oscilloscope.

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Square-Rooting Circuit Is Stabilized

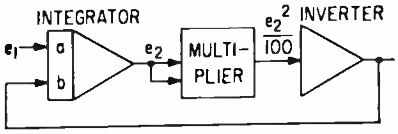
By A. MOSES,
Las Cruces, N. M.

STABILITY of circuits used in analog computers for obtaining square roots can be improved by incorporating an integrator in the loop.

A multiplier is often used to obtain the square root of an analog input voltage.[1] Integrators are used to obtain solutions to simultaneous linear equations.[2] When the usual method of obtaining a square root is unstable, a combination of these two techniques is especially valuable.

In the arrangement in the figure, $-de_2/dt = ae_1 - bce_2^2/100$. Following the initial transient condition, the steady-state solution exists when $de_2/dt = 0$. Therefore $e_2 = 10\,(ae_1/bc)^{\frac{1}{2}}$. By making $bc = 100a$, $e_2 = e_1^{\frac{1}{2}}$.

If desired, the constant bc can be in increased by using gain c in the inverter.

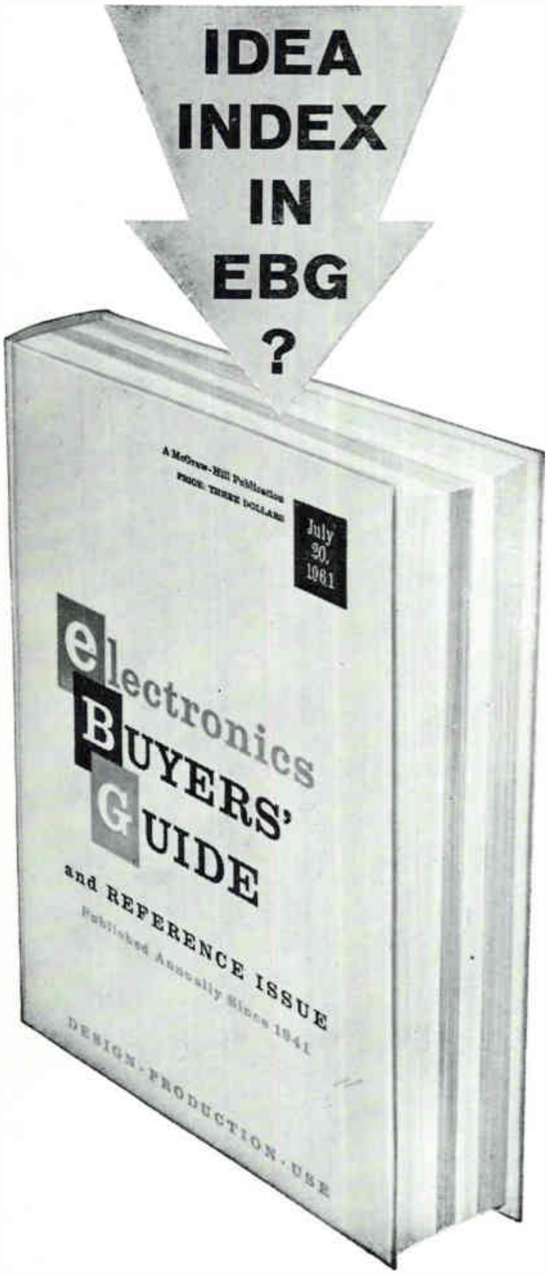


Square-root circuit for analog computers includes integrator

REFERENCES

(1) S. Seely, "Electron Tube Circuits," p 154, McGraw-Hill Book Co., Inc., N. Y., 1950.
(2) G. A. Korn and T. M. Korn, "Electronic Analog Computers," p 66, McGraw-Hill Book Co., Inc., N. Y., 1956.

SEEN THE NEW



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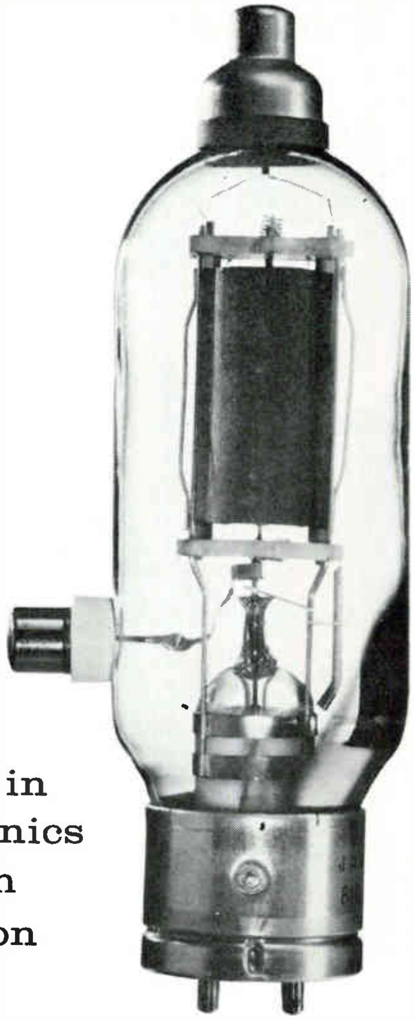

Ideas in Electronics from Norton

The electronics industry became a giant before it became a baby.

This outstanding growth has been largely due to the development of new materials — *refractory* materials with a great range of electrical properties. The prime source of these *idea refractories* is Norton Company.

For example, refractory fused alumina has high constant resistivity, to assure minimum leakage between elements in TV, radio and radar tubes. The same material is a recent innovation for transistor potting. Norton silicon carbide is an essential component in lightning arrestors and other non-linear resistors because of its variable voltage-current relationship. Silicon carbide is also finding new uses in microwave absorption, and as single crystals in high temperature rectifiers and transistors.

Fused magnesium oxide, used in most heating elements for electric ranges, has gained acceptance in such areas as advanced thermocouple design and infrared transmission.

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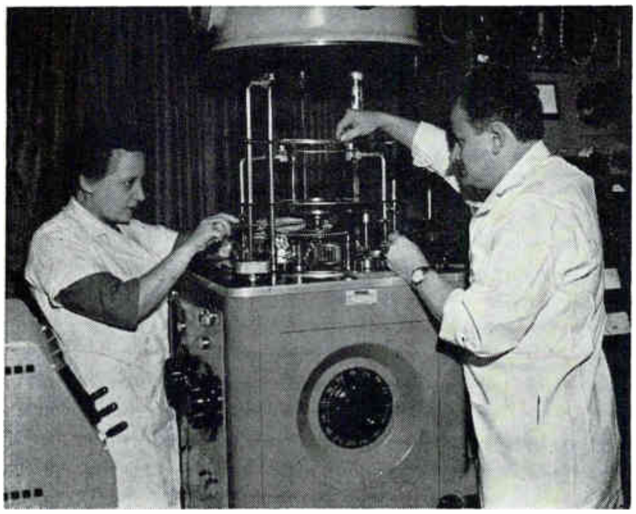


Micron-thin coatings, applied to bearings and other rolling and sliding surfaces by Erica Fliege and A. F. Kaspaul of CBS Laboratories (left) may hold important promise for aerospace components. At right, electrical and mechanical tests on slip ring assemblies coated with the dry lubricants show that operating life of these assemblies in high vacuum and high pressure systems can be extended up to 100 times

Thin Films Solve Friction Problems

VACUUM DEPOSITION techniques for laying down successive layers of vaporized metals in controlled amounts on surfaces that may be subjected to friction promise to open up applications for moving parts of electronics systems, computers, commutators, tape recorders, instruments, gyroscopes, bearing surfaces, and many other areas. And these multilayer coatings, which have a thickness of less than one-half micron, may have widespread use in other industries as the backup coats for moving and sliding surfaces.

Techniques used to develop surface coatings were derived by the Solid State Physics Branch of CBS Laboratories, a Division of Columbia Broadcasting Systems, Inc., Stamford, Conn., a group that has had extensive experience in the vacuum deposition of thin films.

Rotating Drum Anode

The development of solid lubricants at CBS began when it became evident that existing bearings and lubricants were inadequate to meet the requirements for their special Line Scan Tube, a key element in their Photoscan System for aerial reconnaissance and surveillance.

In this special flying spot scanning tube, a phosphor coated metal drum anode is rotated at 1,600 rpm within the high vacuum of the tube envelope. An average bearing life in excess of 2,500 hours was required, with extremely low starting and running torque (5-8 milli inch ounces). The unit had to withstand 400 C, and small currents—50-100 microamps at 27 Kv—had to be passed between inner and outer bearing races during operation.

The flying spot scanner had to withstand 40 G, and vibration cycles of 20 to 20,000 cps, with negligible release of gas during prolonged operation. No interferences could be tolerated with established precision.

The low torque requirement for the tube was particularly significant since the Line Scan Tube had to operate with minimum power. Most conventional oils or greases evaporated under vacuum conditions and were unacceptable for vacuum lubrication. The best available dry lubricants tested proved erratic in behavior, exhibited relatively high coefficients of friction, and their operating life fell short of the performance requirements.

Faced by these limitations, A. F. Kaspaul and Erica Fliege went ahead and developed special films. This development continued through 1961, and the perfected dry film lubricants have attracted widespread interest among friction specialists in organizations who manufacture bearings, slip ring assemblies, drive rods, gears, metal cylinders, moving and sliding parts, and other friction-bearing elements.

Satellite Applications

At the present time, CBS is investigating several lubrication problems under contracts for the National Aeronautics and Space Administration to provide long life for ball bearings, bushings and drive mechanisms. Under these contracts, dry-film lubrication techniques are being explored for the large rocket booster under development at NASA Huntsville. Another program is concerned with the development of prototype vacuum slip ring assemblies for NIMBUS, the advanced meteorological satellite. And other investigations concern the application of various solid lubricant films to magnetic tape for continuous-loop satellite recorders, as well as moving parts in computers and data processing systems.

Although none of the materials used in the thin-film lubricants are new, the techniques for preparing the multilayer coatings are new. And it was a question of how to lay down successive layers of nickel, chromium, silver, and a top layer of molybdenum disulphide in controlled amounts that would provide the proper friction-bearing surface requirements of long life, low torque, low vapor pressure, stability in gaseous atmospheres and in high vacuum, and stability in unusual environments such as radiation exposure.

Long-Life Tests

The potential held for the new vacuum bearings and dry-film lubricants were described following a Symposium on Friction Phenomena in High Vacuum recently held at the CBS Laboratories. Experiments were described in which bearings coated with the vapor-deposited films were operated as long as 3,000 hours at pressures near 10^{-9} millimeters of mercury. Conventional electroplated silver-molybdenum disulphide coatings have a life of about 280 hours. Molybdenum disulphide lubricants have a life of approximately 175 hours, and silver coatings break down after 225 hours.

Surfaces coated by the multilayer deposition process provide maximum thermal conductivity along the load-bearing surface, and the lubricants can be made electrically conductive and used on slip ring assemblies, commutators and ball bearings to pass electric current. Methods are now being developed to relubricate system components in satellite systems during outer space travel.

The half-micron film thickness of the surface coating does not interfere with the tolerances of the finest precision bearings, and minimizes plastic deformation of the lubricant which takes place under the load.

Performance tests have been made of thin-film lubricated slip rings at various temperatures and for periods of more than 300 hours at pressures of 10^{-7} millimeters of mercury. These tests indicate that the life of conventional slip rings operating in high vacuum can be extended 100 times, with no adverse effects upon torque, contact resistance, or electrical noise.

Tests also prove the compatability of the thin-film lubricants with liquid oxygen. When applied to precision instrument bearings in high temperature tests, the lubricant withstands temperatures of 450 Deg F in excess of 1,000 hours while operating at 1,650 rpm.

Within the past months, the vapor-deposited lubricants have been tested and applied by Aerojet-General, Grumman Aircraft, North American Aviation, Sandia, Baird Atomic, Bell Telephone Laboratories, United Shoe Machinery, Sperry-Gyroscope and many of the leading bearing producers—including Fafnir, New Departure, Split Bearing, New Hampshire, Industrial Tectonics, Kaydon Engineering, Marlin-Rockwell, and others.

The CBS Laboratories staff is prepared to investigate the application of the new dry film lubricants and lubricating processes to electronic and electromechanical systems.

World Standards for Electronic Components

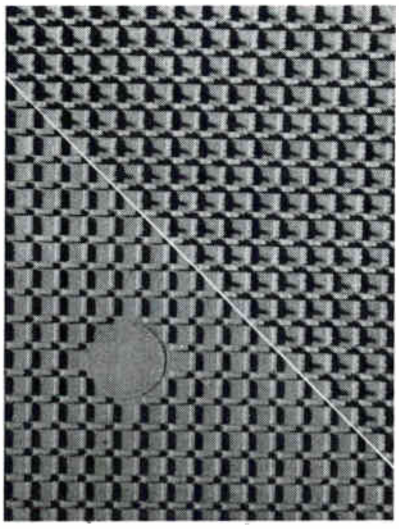
THE AIM of nearly 200 representatives from 16 countries who met in London Nov 13 was to establish international standards for sockets and accessories for electronic tubes; printed wiring; computers and data processing; environmental testing procedures for electronic components; and electromechanical components for electrical equipment.

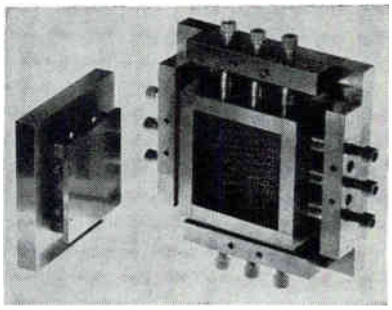
The meetings, organized by the International Electrotechnical Commission (the IEC), continued for two weeks at British Standards House. Visitors included Russians.

In all, seven IEC committees met. Their chairmen were F. Dumat of France, H. Mayr of Italy, E. F. Seaman of U.S.A., R. W. Kersey of United Kingdom, L. van Rooij of Netherlands and A. B. Credle of U.S.A. G. De Zoeten, the Dutch president of IEC was chairman at a meeting of the Advisory Committee on Electronics and Telecommunications.

Molded Jigs Reduce Core-Plane Costs

By J. S. JACKSON
J. J. MASHURA
Remington Rand Univac Div.,
Sperry Rand Corp.,
Whitpain Township, Pa.





High pressure mold is used to form rubber negative of master jig segment. Plunger is at left

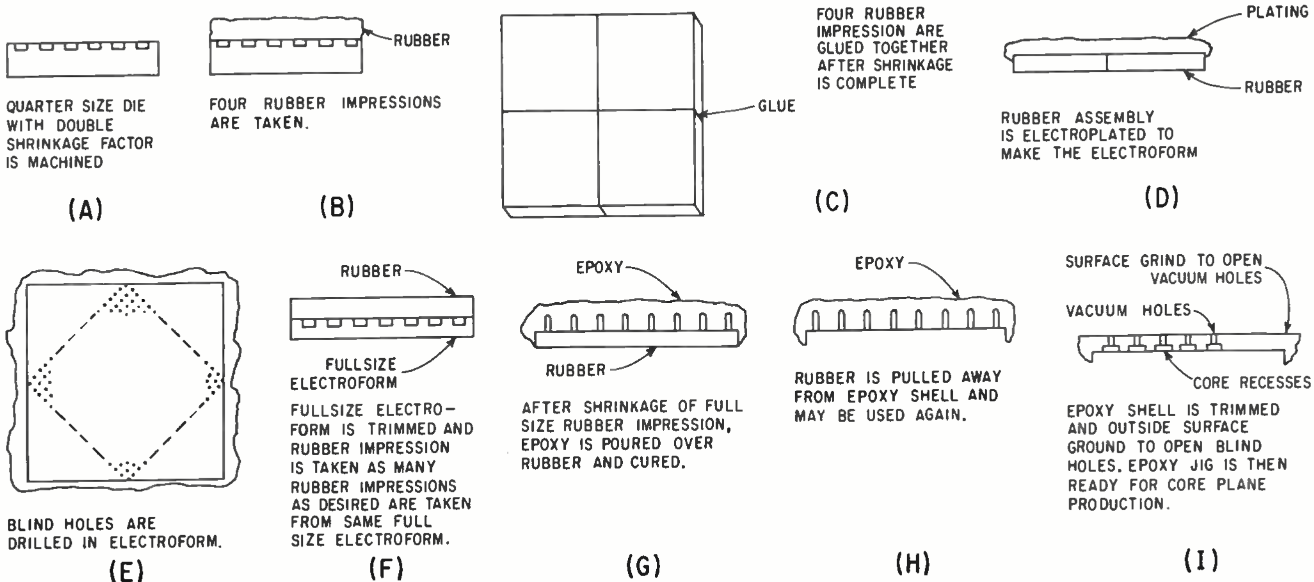
Negative of master jig is shown bottom left. Projections at upper right will form a vacuum hole in each core recess in final epoxy jig

TO MAKE JIGS AND DIES for magnetic-core plane manufacturing, Remington Rand Univac has developed a flexible molding technique. Large numbers of identical, precisely defined cavities of small depth and cross section can be made economically with the technique.

A typical storage plane includes 2,500 cores in 50 rows of 50 cores each. The plane is $3\frac{1}{8}$ inches on a side, with the cores on $\frac{1}{16}$-inch centers; the cores are 0.050 inch $\pm$0.002 inch in diameter and 0.015 $\pm$ 0.002 inch thick. Positioning the cores is accomplished in a jig. The recess for each core is made to close tolerance, not only to hold the core securely and make seating by suction effective, but to make it possible for an adhesive film to be pressed down on the core array.

Each core recess has a 0.0165-inch diameter hole through to the other side of the jig plate. After the cores are poured at random on the jig, the jig is put into a vibrating frame where a vacuum applied through the holes pulls the cores accurately into position. The adhesive film is then pressed down on the cores. When the film and cores are pulled away from the jig, the cores are ready to be wired.

Machining a complete metal plate for a jig was laborious and expensive, so the jig molding technique was developed. A quarter-size jig, available from previous work with magnetic cores, was used initially to produce negative duplicates. A silicone rubber, Dow Corning Silastic 5137 and 5138, produced faithful copies of the rectangular slots and remained flexible after curing. The negative separated easily from the master without the distortion that ordinarily would occur when a solid material is removed from so intricate a mold. To avoid off-center positioning of the pressure plate (plunger), precision locating pins were placed on each side of the mold to insure equal clearance on all four sides. The material was cured for from four to six hours at 150 F, with a postcure at room tempera-



Quarter-size master (A) is first step in producing low cost epoxy jig. Many epoxy jigs can be made from the flexible rubber mold ture. Within several days the shrinkage of the molded negative approached an asymptotic limit of about 2.3 percent.

A new quarter-size master was produced with a double or compound shrinkage factor. From this jig four rubber negatives were made and then cemented together; from this an electroformed jig was made (see figure). A silver salt and reducing agent were sprayed on the rubber, leaving about 10^{-5} inches of silver after the reduction process. A 0.0005-inch layer of nickel was deposited and then a 0.0625 to 0.125-inch layer of copper for strength and body.

Twenty-five hundred blind holes were drilled in the electroform, giving a master reproducing mold with a shrinkage factor of one. The plating process was slow and insured that treeing over or bridging did not occur. After a rubber negative is made from the electroformed master, the final full-size jig is produced by pouring an epoxy resin onto the rubber negative. The blind holes are then opened up by grinding the cured epoxy. The cost of a molded epoxy jig is approximately $100; cost of a machined jig was approximately $2,000.

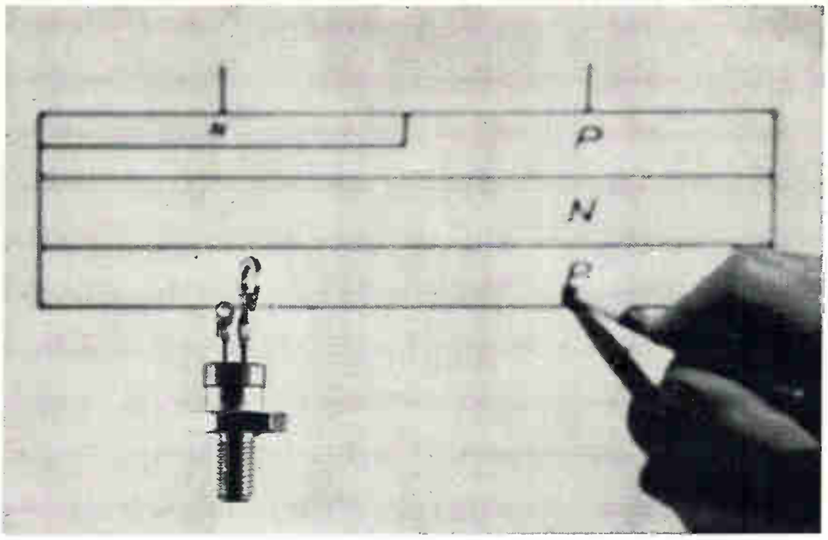
While an extra step is required to produce the electroformed mold, it can be used over and over. It is possible, however, to produce a plastic jig from a rubber negative without going through the electroform stage.

The technique has other possible applications. One would be the low-cost production of large dies for molding many small precision parts at each molding operation. Another application is the production of small precision parts having external projections. Such parts could be produced by electroforming over one of the flexible plastic negatives. The negative could be bent to permit removal of the part. Another application would be molds for making small, complex-shaped plastic parts. A die for a single part could be made, and from this master a number of flexible negatives could be produced. These negatives would be assembled into the negative for a multi-cavity die, and this large-scale negative could be electroformed to produce a many-cavity die at a much lower cost than would be possible if the entire large-scale die were produced by machining.

High Speed Diode Tester and Classifier

Diodes are loaded in bulk lots of several thousand into bowl of machine and then feed automatically through a test station. Ten tests are available, by which the diodes are classified and sorted into 16 categories. As many as 7,200 diodes an hour can be processed. Several models of the machine, manufactured by Transistor Automation Corp., Cambridge, Mass., have been designed for production, engineering and inspection

New On The Market



Silicon Controlled Rectifier

16 AMP, 500 V, ALL DIFFUSED

GENERAL INSTRUMENT CORP., 65 Gouverneur St., Newark 4, N. J. Illustrated is a triple diffused scr against a schematic showing the three junctions within the device. The smaller junction at upper left is the one previously formed by alloying and now diffused in the new device. Unit is stable at high ambient temperatures, up to 125 C; features low turn-on voltage and current requirements, and low forward voltage drop. Device is offered in standard JEDEC ratings from 2N681 (25 piv) to 2N689 (500 piv).

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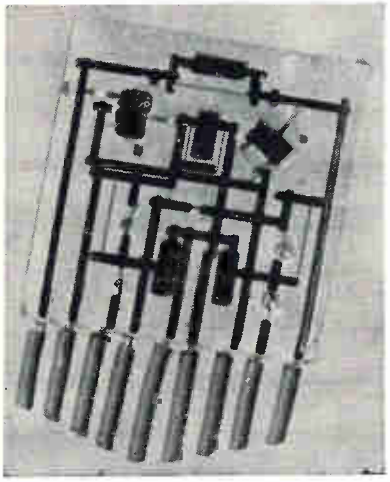

Digital Building Block

THIN FILM

ADVANCED MICROELECTRONICS, 2414 Reedie Drive, Silver Spring, Md. The FF100S, a 1 Mc digital building block, has application as a binary counter, shift register or set-reset counter. Units operate from a 6 v supply, dissipating 40 mw in a 0.165 cu in. package weighing 12 grams. The present device contains evaporated resistors and capacitors plus inserted silicon semiconductors, with 9 unidirectional copper output pins; plugs will be supplied on request.

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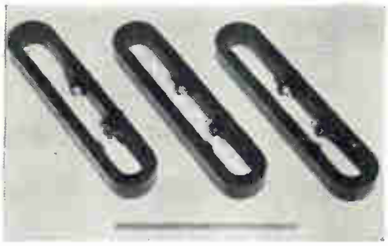

Potted Delay Lines

140 NSEC DELAY

A-T ELECTRONICS, INC., 5 Lawrence St., New Haven, Conn., announces a series of potted delay lines fabricated of coaxial cable. They can meet specifications calling for accuracy within ±0.02 nsec. Each incorporates 104 linear feet of cable in a package 18 in. long, 3$\frac{7}{8}$ in. wide and 1$\frac{3}{4}$ in. high. A 140 nsec delay is offered along with dimensional tolerances which are held to within 0.030 in. Delay tolerance is held to within $\frac{1}{10}$th nsec. At the S band, the swr is 1.3 maximum.

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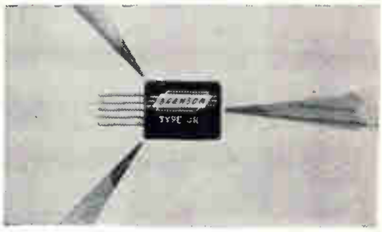


Computer Relay

TRANSISTOR SIZED

BRANSON CORP., 41 S. Jefferson Road, Whippany, N. J. Type JR relay is for p-c use in computers, data processing, airborne instruments and wherever size and weight requirements are critical. Measuring 0.2 in. by 0.4 in. by 0.5 in. and weighing only 5 grams, it offers excellent volumetric efficiency in p-c applications. It has a contact rating of 1 amp 28 v d-c and may also be used in dry circuit applications.

CIRCLE 304 ON READER SERVICE CARD

Diode Tester

AND CLASSIFIER

TRANSISTOR AUTOMATION CORP., 101 Erie St., Cambridge 39, Mass., announces a line of d-c automatic testers and classifiers for diodes. Up to 16 classifications are available. Production rate is adjustable from 2,000 to 7,000 per hr depending on tests performed and model used. Polarization: automatic electronic polarizer with open and short rejection; inverse rejection voltage adjustable from 2 to 5 v; test circuits are completely disconnected until polarization is completed and testing contacts are shorted during all set-up procedures.

CIRCLE 305 ON READER SERVICE CARD

Adapters

VERY LOW VSWR

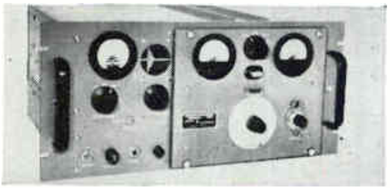
GENERAL RF FITTINGS, INC., 702 Beacon St., Boston 15, Mass., has available two new adapters for use in adapting N type systems to TM (or the reverse) or to adapt standard N slotted lines for TM applications. These TM adapters—GRFF 2298A and 2299A—feature very low vswr and are immediately available from stock.

CIRCLE 306 ON READER SERVICE CARD

Coupler Units

M. C. JONES ELECTRONICS CO., INC., a subsidiary of The Bendix Corp., Bristol, Conn. Series of MicroGuide waveguide directional couplers in L, S, and X-bands, feature flexibility in application, small size and light weight.

CIRCLE 307 ON READER SERVICE CARD



Telemetry Receiver

THREE TYPES

GENERAL ELECTRONIC LABORATORIES, INC., 8440 Second Ave., Silver Spring, Md. Three new a-m/f-m/c-w dual-conversion microwave telemetry receivers meet all IRIG standards. Standard coverages are: type 20B1, 2150-2350 Mc; type 26A1, 1700-1850 Mc; type 22C1, 1435-1535 Mc. Designed for the reception of f-m/f-m, pdm/f-m, pcm/f-m, pam/f-m and a-m data the receivers are primarily for ground station use.

CIRCLE 308 ON READER SERVICE CARD

Literature of the Week

CERAMIC CAPACITORS U.S. Capacitor Corp., 8917 Melrose Ave., Los Angeles 69, Calif. A catalog sheet contains data on a line of microminiaturized, wide temperature range ceramic capacitors. (309)

ELECTROSTATIC GENERATOR SAMES-USA, 30 Broad St., New York 4, N. Y., has available a technical data sheet describing a high stability electrostatic generator, model AKS 600-4. (310)

ECONOMY MONITOR Thermo Electric Co., Inc., Saddle Brook, N. J. Four-page Instrument Section 73 covers a ten-point electronic economy monitor. (311)

PNPN DEVICES Solid State Products, Inc., One Pingree St., Salem, Mass., announces bulletin C400, an 8-page condensed catalog on *pnpn* devices. (312)

DELAY TIMER Leesona Moos Laboratories, 90-28 Van Wyck Expressway, Jamaica 18, N. Y. Technical data sheet provides description and specifications on the Betachron model D5307 acceleration-actuated delay timer. (313)

PHOTOVOLTAIC CELLS Weston Instruments Div., Daystrom Inc., 614 Frelinghuysen Ave., Newark 14, N.J. Bulletin 03-200 covers the models 856 and 594 selenium photovoltaic cells. (314)

COMMON MODE REJECTION Video Instruments Co., Inc., 3002 Pennsylvania Ave., Santa Monica, Calif., has available a technical bulletin on common mode rejection in differential d-c amplifiers. (315)

COATED MAGNET WIRE Hudson Wire Co., Winsted, Conn., has available literature on plain enamel insulated magnet wire. (316)

COOLING MODULES Deltron Inc., 4th & Cambria Sts., Philadelphia 33, Pa. Bulletin FA 2025A describes a series of cooling modules for semiconductors. (317)

ROTARY SOLENOIDS Ledex, Inc., 123 Webster St., Dayton 2, O. Catalog C-961 contains complete technical data on eight basic sizes in rotary solenoid designs. (318)

CEC Completes Expansion Program

CONSOLIDATED ELECTRODYNAMICS CORP., subsidiary of Bell & Howell Co., has completed a $500,000 expansion program which added more than 60,000 sq ft to its Data Recorders division.

The new facility was added to an existing structure of 27,000 sq ft—one of four major buildings on the company's 17-acre site in East Pasadena, Calif. The entire 87,000 sq ft will be used by the division for manufacturing and assembly. Engineering, administrative, marketing and other functions of the division are located in adjacent buildings.

This addition and 23,000 sq ft being added to Consolidated Vacuum Corp., CEC subsidiary in Rochester, N. Y., bring CEC's total in Pasadena, Rochester, and Monrovia, Calif., to more than 647,000 sq ft.

Aspinwall Assumes Additional Post

LLOYD ASPINWALL, JR., chairman of the board and president of Filtors, Inc., Port Washington, L. I., N. Y., has been elected to the board of directors of General Battery and Ceramic Corp., Reading, Pa.

George Ritter Joins Eitel-McCullough

GEORGE H. RITTER has joined Eitel-McCullough, Inc., San Carlos, Calif., manufacturer of electron-power tubes, as plant manager of the high power microwave division.

Prior to joining Eimac, Ritter was vice president and general manager of Cetron Electronic Corp., Geneva, Ill. He previously served for more than 30 years with RCA.

General Microwave Names Lamensdorf

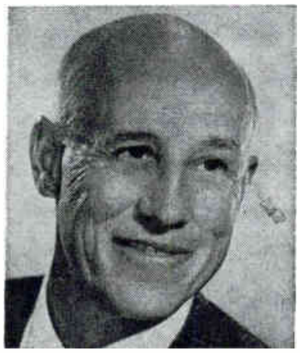
GENERAL MICROWAVE CORP., Farmingdale, N.Y., has appointed Charles Lamensdorf as project engineer. His work will involve him in the design and development of microwave components, test equipment and systems equipments.

Lamensdorf was formerly with Airborne Instruments Laboratories as a design engineer.

P. R. Mallory Appoints Edward Zdanuk

EDWARD ZDANUK has been appointed to the staff of the Laboratory for Physical Science of P. R. Mallory & Co. Inc., located near Burlington, Mass. He will specialize in the study of solid materials.

Zdanuk comes to Mallory from the research division of the Raytheon Co., where he was engaged in the study of surface chemistry.



Morgan Advances To High CSC Position

T. PHILLIPS MORGAN has been elected to the newly created post of vice president and director of operations, Consolidated Systems Corp., Monrovia, Calif.

Morgan has been director of operations for CSC since May, 1960. He is responsible for all manufacturing and quality standards of the company's four divisions—Systems, Industrial Systems, Photo-Optical, and Printed Circuits.

Northrop Promotes Two Key Executives

THOMAS V. JONES, president of Northrop Corp., Beverly Hills, Calif., has announced the promotion of two senior executives.

Thomas H. Quayle, vice president and manager of the company's Nortronics Division systems support department at Anaheim, Calif., since 1956, has been elevated to the office of corporate vice president for commercial and industrial programs.

James J. Ward, formerly assistant manager of the systems support department, has been named vice president and manager to succeed Quayle at Anaheim.

James Bittles Joins EOS

ELECTRO-OPTICAL SYSTEMS, INC., Pasadena, Calif., has hired James A. Bittles as a senior scientist in the quantum physics department. He will be engaged in a broad research program in materials for masers, lasers, and related areas.

Prior to joining EOS, Bittles was a research associate at the U. of Southern California.

PEOPLE IN BRIEF

George R. Mohler leaves Space Technology Laboratories to join the technical staff of Marshall Laboratories. Spencer-Kennedy Laboratories, Inc. adds **Jacob Shekel**, ex-Israel Minister of Defense, to its development staff. **Constantine Andricos**, formerly with W. L. Maxson Corp., named senior engineer at PRD Electronics, Inc. **Robert F. Adamsky**, previously with Laboratory for Electronics, appointed to the staff of the Laboratory for Physical Science of P. R. Mallory & Co. Inc. **James H. Gardner**, v-p of National Research Corp., is selected deputy director of defense research, Department of Defense. **Alfred G. Holtum, Jr.** is promoted to chief of the government R&D group at Andrew Corp. **Edwin R. Gamson** advances at Ampex Corp. to g-m of the Computer Products div. **Matthew Lafer**, ex-Fairchild Camera and Instrument, now chief engineer of the components div. of JFD Electronics Corp. **Joseph P. Gleason**, formerly an independent radar consultant, joins the staff of Marc Shiowitz and Associates, Inc. **Paul M. Kuefler**, from Genistron, Inc. to Genisco, Inc. as a v-p and g-m. **Gene R. Marner** moves up at Collins Radio Co. to director of research of the Cedar Rapids div. **William F. Sauers**, former president of Aircraft Radio Corp., named assistant to the president of Autonetics.

EMPLOYMENT OPPORTUNITIES

electronics

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INTERNATIONAL ELECTRIC CORP. Paramus, New Jersey	101*	5
LABORATORY FOR ELECTRONICS Boston, Massachusetts	94*	6
MICROWAVE SERVICES INTERNATIONAL INC. Denville, New Jersey	112*	7
MITRE CORPORATION Bedford, Massachusetts	48*	8
PAN AMERICAN WORLD AIRWAYS INC. Guided Missiles Range Div. Patrick AFB, Florida	34*	9
PHILCO WESTERN DEVELOPMENT LABS. Palo Alto, California	111*	10

* These Advertisements appeared in the 12/15/61 issue.

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electronics WEEKLY QUALIFICATION FORM FOR POSITIONS AVAILABLE

Personal Background

NAME ....

HOME ADDRESS ....

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

HOME TELEPHONE ....

Education

PROFESSIONAL DEGREE(S) ....

MAJOR(S) ....

UNIVERSITY ....

DATE(S) ....

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12221

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☐ Antennas	☐ Human Factors	☐ Radio—TV
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☐ Circuits	☐ Instrumentation	☐ Solid State
☐ Communications	☐ Medicine	☐ Telemetry
☐ Components	☐ Microwave	☐ Transformers
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	Technical Experience (Months)	Supervisory Experience (Months)
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RESEARCH (Applied)	......	......
SYSTEMS (New Concepts)	......	......
DEVELOPMENT (Model)	......	......
DESIGN (Product)	......	......
MANUFACTURING (Product)	......	......
FIELD (Service)	......	......
SALES (Proposals & Products)	......	......

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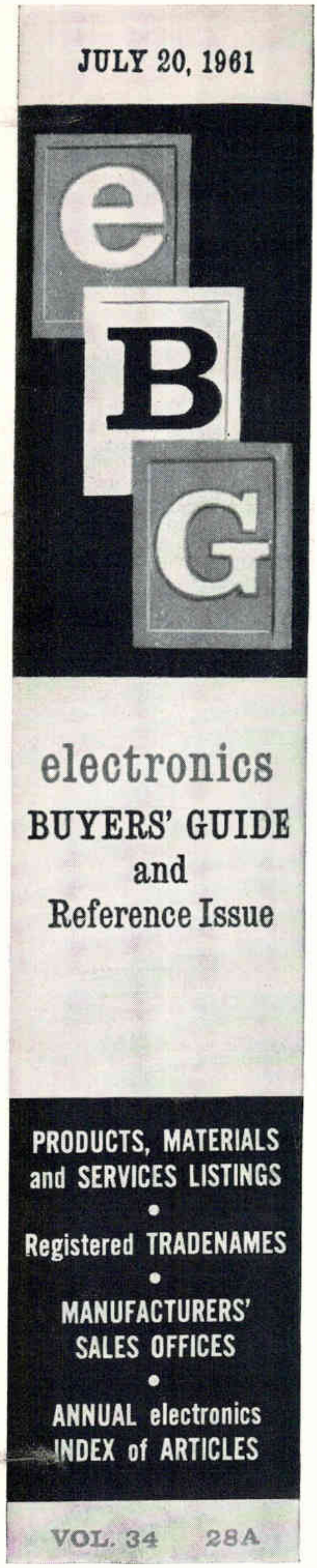

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