A McGraw-Hill Publication 75 Cents October 12, 1962

electronics

SPECIAL *Latest trends in millimeter waves—active and passive components, equipment and systems—design approaches and problems, p 37*

Sending millimeter waves through an optical waveguide

SPECIAL CUSTOM BUILT TO YOUR SPECIFICATIONS

The bulk of UTC production is on special units designed to specific customers' needs. Illustrated below are some typical units and some unusual units as manufactured for special applications. We would be pleased to advise and quote to your special requirements.

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All types for frequencies from .1 cycle to 400 MC.

400 ∽ telemetering, 3 db at ± 7.5%, 40 db at 230 and 700 ∽, ⅝ x 1¼ x 2"

15 ∽ BP filter, 20 db at 30 ∽, 45 db at 100 ∽, phase angle at CF less than 3° from —40 to +100°C.

LP filter within 1 db to 49 KC, stable to .1 db from 0 to 85°C., 45 db at 55 KC.

LP filter less than .1 db 0 to 2.5 KC, 50 db beyond 3 KC.

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From miniature blocking oscillator to 10 megawatt.

Wound core unit .01 micro-second rise time.

Pulse current transformer 100 Amp.

Pulse output to magnatron, bifilar filament.

Precise wave shape pulse output, 2500 V. 3 Amps.

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Toroid, laminated, and cup structures from .1 cycle to 400 MC.

Tuned DO-T servo amplifier transformer, 400 ∽ .5% distortion.

Toroid for printed circuit, Q of 90 at 15 KC.

Dual toroid, Q of 75 at 10 KC, and Q of 120 at 5 KC.

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Saturable reactors, reference transformers, magnetic amplifiers, combined unit.

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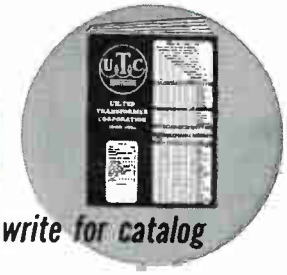

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CONTENTS continued

DEPARTMENTS

CROSSTALK

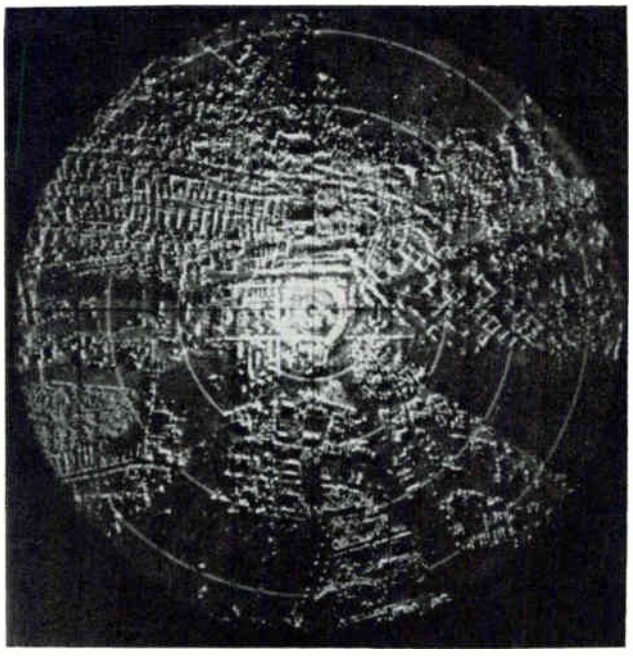
SPECTRUM SHIFTING. How would the world look if our eyes were not receptive to wavelengths of 4,000 to 8,000 angstroms, but to some other portion of the spectrum? If our eyes, instead of our ears, were tuned to the audio range, we would "see" music instead of listening to it—in stereo, sound would probably look not unlike the mountains of the moon.

Two years ago—almost to the day—Raytheon and CSF completed a joint report on efforts to develop equipment for use at millimeter wavelengths, especially frequencies of 300 Gc and higher. Indulging in a bit of drama so that the reader could visualize this "new frontier" (they did use the term before the inaugural) they asked him to imagine that he had millimeter sensors instead of eyes:

"Under these conditions, the landscape would indeed look very strange. In the first place, there would be little reflected sunlight, although the sun itself would be seen. The moon would disappear, a few stars would be visible, and perhaps there would even be new stars where none were visible before. All water and metal surfaces would appear as highly polished mirrors. Even dirty and painted metals would reflect. Trees and foliage would look gray. Earth, rocks, and building materials would literally glow. We would have to devise a new material for our windows, as glass would be only slighty more transparent than the walls. Thin materials, such as clothing, would be awkwardly transparent. It would be a waste of time to paint buildings and billboards, as all paints would have the same color. If the marvelous adaptivity of the body were still functioning we would probably have inverted vision, because what we are normally accustomed to seeing as dark would now be bright, and vice versa. The sky would look, to these eyes, as a bright glowing blanket."

Some idea of what the world would look like from an airplane is shown in the photograph. This is a view of the Shibura area of Tokyo Bay, made with Oki Electric's 8.6-mm radar. Part of the harbor is seen in the lower left, the curving line across the upper half of the picture is a railroad with a freight yard at the upper left, and even grasslands are clearly visible.

So much for the dramatic aspects of the millimeter region. If what you want is some hard-



core technical information on work being done in the field, you'll have to turn to Associate Editor Shergalis' 10-page report beginning on p 37.

FAILURE AND RELIABILITY. The requirements for components an order of magnitude more reliable than components produced in the past—reaching failure rates measured in thousandths of a percent per thousand hours for Minuteman parts—has resulted in a reexamination of failure analysis.

Testing components to see how many in a group will fail within a certain time, or testing components to destruction and determining why they failed is no longer satisfactory in many cases. The number of failures that will occur in a group of high-reliability components within a practical test period may be so insignificant that no conclusive evidence is found.

The new approach is to determine in advance, through analysis of failure mechanisms, why components are likely to fail. Precautions may then be taken to make components less prone to failure.

What failure analysts are doing now is compiling a body of information on failure causes from inspections, case histories, research, analysis and detective work (see p 28 and p 68 this week). They are working toward the accumulation of sufficient knowledge to enable failure causes to be determined on theoretical as well as an empirical basis.

COMMENT

Electron Beam Welding

I would like to draw your attention to the item, Electron Beam Welding in Inert Gasses, which appears in the Sept. 21 issue (p 76).

In the last sentence, the phrase, "for materials with higher depth-to-width ratios, voltages from 100 to 150 Kv are feasible," has no meaning. I suspect your reporter wanted to convey the following message: "Joints with higher depth-to-width ratios are feasible only with acceleration voltages in the 100-150 Kv range."

Although this statement will clearly express the thoughts of your reporter, it also may tend to mislead the reader. Depth-to-width ratio in electron beam welding in vacuum and inert atmosphere is dependent basically on beam power density and the thermal conductivity of the material to be welded. While it is true that on the average, high-voltage systems tend to deliver higher power densities, recent low-voltage systems have made most substantial strides in this direction.

ROBERT BAKISH
Electronics and Alloys Inc.
Ridgefield, New Jersey

The Maple Leaf Forever

Thank you for such a colorful display of the Canadian provincial and territorial coats of arms, on your cover for September 28. It makes an interesting change. I imagine that many of your Canadian readers (and others) have cut off that cover and hung it up.

CARL COLA
Buffalo, New York

Sealing Transistors

May I congratulate you for the excellent handling of the Hughes Microseal transistor story, Transistor's Leads Are Its Hermetic Seals (*Production Techniques*, p 56, Aug. 24).

The cover photograph certainly shows the unique nature of this transistor product and the article is accurate and will do much to further this development.

We appreciate your fine handling of this complex subject. We feel that such articles will go far toward the continuance of the fine record that ELECTRONICS has in the industry. We are proud to be a part of such coverage.

H. S. EVANDER
Hughes Aircraft Company
Newport Beach, California

Soviet Space Flight

Your *Crosstalk* editorial of July 20 (p 3) states, "The Soviets' inferiority complex has been alleviated in the field of space, where they have obviously done well."

By this statement you unscientifically accepted their claims as to how well they really have done. Proof of their claimed manned space flights has never been satisfactory. There is as good reason to suppose the Soviets never made the manned space flights they claim.

Thus, their alleged diminished suspicion, and reluctance to cooperate with the outside may, in fact, be attributable simply to a compulsive desire to catch up with us.

RICHARD PARKER
Marblehead, Mass.

Oceanology

For those who think science is mixed up in this country, here's a real confused item from the Soviet Union:

Look on page 11 of the April 15 issue of *Soviet-Bloc Research In Geophysics, Astronomy and Space*, published by the U. S. Joint Publications Research Service in Washington. The outstanding Soviet oceanographer, Academician V. V. Shuleykin, in the *Izvestiya Akademii Nauk SSSR, Seriya Geofizicheskaya*, criticizes an article in another journal, pointing out that there is no such science as "oceanology," and that articles dealing with the sea represent work in the field of *oceanography*.

Two pages later appears an abstract about tectonic maps for aiding mineral prospecting, prepared by the Geological Institute of the Academy of Sciences of the USSR: "The tectonic map of Eurasia shows the structure of the floor of the surrounding seas; this part of the work was done by the Institute of Oceanology."

ARTHUR MCLAY
Hollywood, California

VY T.M.

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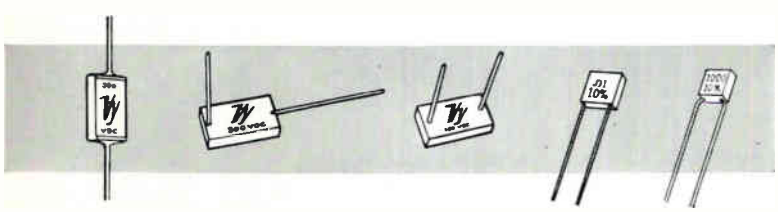

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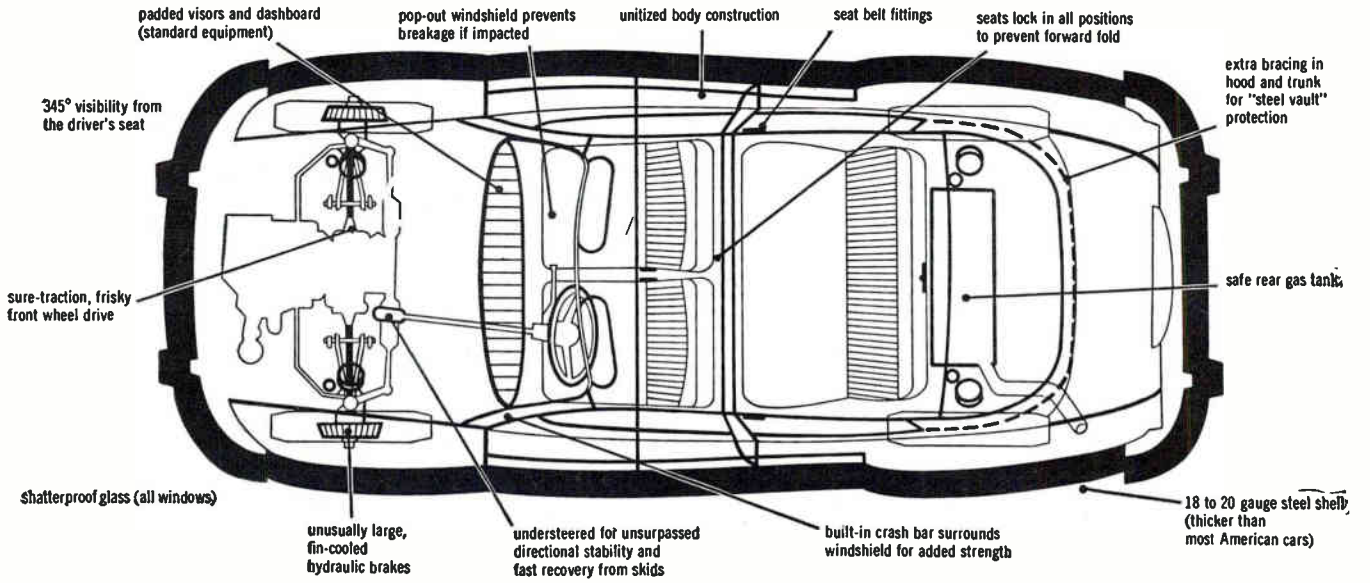
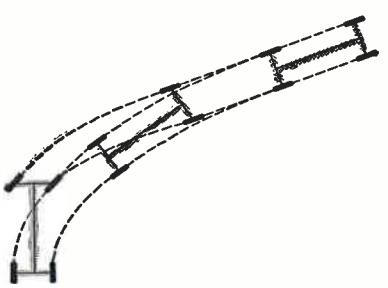


Take a critical look at SAAB safety

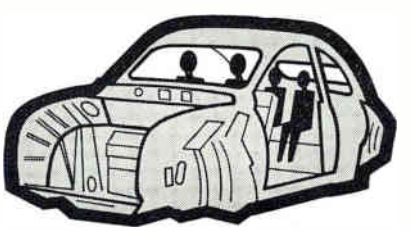
Aircraft reliability and performance standards are blended with an entirely new approach to over-all automotive design in the Swedish SAAB 96. This car was built to be better and safer, not different . . . built by one of Europe's leading aircraft manufacturers . . . built for those who enjoy mechanical excellence, technical uniqueness, and extraordinary craftsmanship.

A critical look at *all* the facts and specifications will prove that SAAB is unquestionably one of the world's best engineered cars.

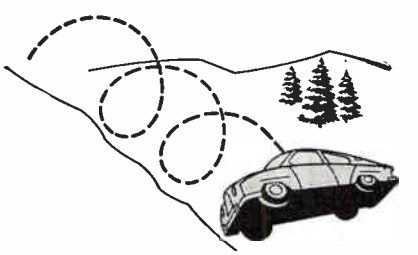
*Engine, transmission (3- or 4-speed gear box available), and differential have a written warranty for 2 years or 24,000 miles.



SAAB FRONT WHEEL DRIVE, carefully calculated understeering, low center of gravity, and advanced suspension design work together to optimize roadholding ability and safety in motion. Self-centering action of directly driven front wheels (see diagram) provides best possible roadholding ability at high speeds. Positive traction of front wheel drive at lower speeds makes cornering easier, dangerous skids virtually impossible. Front wheel drive pulls SAAB safely—on any road, at any speed, through ice, snow, and mud.



SAAB BODY SHELL is engineered to encase driver and passengers in a practically uncrushable steel airfoil on wheels. SAAB is unitized for exceptional rigidity. 18- to 20-gauge steel (heavier than most American cars) is used throughout. Additional steel members, ⅛ inch thick, brace trunk and engine compartments. A crash bar, usually a racing car exclusive, surrounds the windshield for tremendous extra strength—where you need it most. Result: SAAB is as safe or safer than most large cars.



SAAB HAS BEEN SAFETY TESTED the hard way. It was rolled down Scandinavian ski slopes. Its basic overall reliability has been proved in laboratory tests which simulate the roughest driving imaginable. Purpose: to make SAAB one of the safest cars you can drive. On the basis of test results, for example, SAAB provides as standard equipment such safety extras as: collapsible steering wheel, safety-padded dashboard and visors, positive locking seats, shatterproof glass, and safety belt attachments.

Arrange a test drive at your nearest SAAB dealer. Or write for more information—and the SAAB North American Road Atlas, a 64-page comprehensive travel guide valued at $1.00, but yours for only 25¢ to cover postage and handling. SAAB Motors, Inc., Dept. 310, 405 Park Avenue, New York, New York.

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ELECTRONICS NEWSLETTER

EIA Wants Two Tv Channels for Communications

PETITION filed last week with the FCC by the Electronic Industries Associations' Land Mobile Communications Section asks that uhf-tv channels 14 and 15 be assigned to two-way, land mobile radio services to relieve overcrowding in the mobile bands.

EIA pointed out that only eight broadcasting stations are using channels 14 and 15 now. Requirements for all-channel tv sets should be changed to exclude those channels, EIA asked. During an interim period, mobile radios would not use the tv frequencies within areas containing channel 14 and 15 stations.

In some areas, the petition said, 20 to 30 radio users are on the same frequency. William J. Weisz, Motorola vice president and section chairman, added that there are as many as 50 users on a frequency in the Los Angeles area. The two tv bands, he said, would provide 250 additional radio channels.

EIA argued that channel-splitting has gone about as far as possible and that the lack of additional frequencies is hampering public safety services. Weisz estimated that the number of mobile users would climb from 700,000 now to 5 million in 1978 The. number of authorized transmitters at present is 18 times those in 1948.

Mobile equipment is now available for 450 Mc, just below the tv bands, and could use channel 14 and 15 frequencies without major development. Equipment for higher frequencies is not practicable within the forseeable state of the art, EIA claimed.

Parametric Amplifier's Noise Temperature 10 K

CHICAGO—A parametric amplifier with a noise temperature of only 10 K has been successfully operated at liquid helium temperature at MIT Lincoln Laboratory, Carl Blake disclosed this week at the National Electronics Conference. He said the noise temperature is equivalent to that of masers engineered for systems applications.

The development indicates that helium-cooled paramps may be used instead of masers in many applications, he said, and in applications where masers are impracticable. Paramps are simple, rugged, broadband, recover rapidly from transient-input saturation and do not require a magnetic field.

Blake said it is reasonable to expect a receiver noise temperature of 20 K, including circulator. The paramp under test uses a commercially available gallium-arsenide diode. It operates at L band (1.3 Gc), with a K-band pump (13.5 Gc), and it is believed the paramp is capable of 15 Gc.

One of the first systems applications will be in Project Haystack (p 7, Sept. 21). The receiver front end of the orbital scatter facility will include a bank of six liquid-helium-cooled paramps.

Associative Core Memory Locates Word in 5 μsec

AKRON, OHIO—Goodyear Aircraft reports development of an associative memory composed of multi-aperture ferrite cores that perform logical operations and provide non-destructive-readout storage with a single magnetic circuit. The company says it will reduce data processing system time for sort, merge and table look-up operations.

In associative operation, a "tag field" is compared to the entire store and if the desired word is present, its address is made available in 5 μsec. If the word is not present, a negative report is given in 3 μsec. Portions of words may be masked to permit comparison of variable words. In a self-sorting memory, incoming data are assigned locations and called out by "key-field" identification. A complete table can be looked up in one cycle, the company says.

Memory organization is word-oriented linear selection. Word lengths may range up to 200 bits. Applications are anticipated in computers, data processing and information retrieval systems.

Formation of Satellite Corporation Is Started

WASHINGTON—A 13-man group of incorporators for the satellite communications corporation authorized by Congress, was named last week by President Kennedy. After they arrange financing, control will pass to a board of six directors elected by public stockholders, six by communications companies owning stock and three presidential appointees.

The incorporators include one man with a background largely in technical management, Beardsley Graham, formerly satellite research planning manager for Lockheed and

Mercury Program Nears End: 18 Orbits to Go

ABSENCE of any significant technical or physical problems during Walter Schirra's six-orbit flight last week means that NASA will probably wind up the Mercury program with the 18-orbit, 24-hour flight scheduled for early next year. Next stage in the manned flight program will be the Gemini program for two-man flights, followed by the three-man Apollo program.

Apollo orbital flights will be a preliminary to manned lunar exploration. Apollo flights are to start in 1964. NASA is readying the Saturn rocket for this program.

The lunar exploration program will use an advanced Saturn capable of orbiting 220,000 pounds or of sending 90,000 pounds into a space flight. This rocket is to be tested in 1965 and is to be ready for service in the lunar program about a year later.

now president of Spindletop Research Inc. The others are: Edgar F. Kaiser, David M. Kennedy, Sidney J. Weinberg, John T. Connor, George L. Killion, businessmen; Philip L. Graham, publisher; Bruce G. Sundlun, A. B. L. Litschgi, Sam Harris, George J. Feldman, Leonard H. Marks, lawyers, and Leonard Woodcock, union officer. Marks was an FCC lawyer in the 1940's.

To Build 50-Kilogauss Superconducting Magnet

BOSTON—A 50-kilogauss superconducting magnet of niobium-zirconium with an inside diameter of 10 inches will be built by Avco-Everett Research Laboratory under a $147,775 contract from Argonne National Laboratory. Argonne will use it in a bubble chamber for nuclear physics experiments. A 5-inch experimental coil under development at the lab recently achieved 34 kilogauss.

Instruments Report Plane Altitude in Digital Form

THREE new automatic instruments were shown by Kollsman Instruments at the Air Traffic Control Association meeting in Las Vegas last week. One system will digitally encode an aircraft's altitude and automatically report it to ATC centers for display. The second system automatically corrects altitude readings in transonic and supersonic planes. The third, for use in ATC centers, provides a digital indication of the altimeter setting number, for relaying to aircraft using barometric altimeters.

Metals Fatigue Slower In Space Environment

BOSTON—After 20 months of studying fatigue life of metals for the Air Force, National Research Corp. reports that fatigue life is extended 400 to 700 percent in a vacuum simulating space conditions.

Test data is restricted so far to electropolished 1100-H14 aluminum, but the company said the principles apply to other metals. The results suggest that space equipment could use lighter structures than equipment operating in the atmosphere.

Metal fatigue, NRC said, results when small cracks caused by vibration propagate and cause a rupture. In vacuum, the absence of oxides causes the cracks to tend to weld shut, as demonstrated by studies NRC made for NASA (p 76, April 27).

If a protective coating could be applied to metals cleaned in a vacuum, fatigue life of metals on earth might be greatly extended, the company added.

Japan Isn't Liberalizing Computer and Tv Imports

TOKYO—Digital computers, color-tv sets and atomic reactors are among 262 items whose import is still restricted under the government's trade liberalization program.

The goal of 90-percent liberalization (based on 1959 importing) fell two percent short on the original target date, October 1. The new target date is April, 1963.

The program is expected to have little immediate impact on the Japanese economy. In addition to exempting certain items, Japanese defenses against a flood of imports include new tariffs and taxes, basing the 90 percent on 1959 import levels, which were lower than at present, and a "buy Japanese" campaign. A tight money policy also restricts a rise in imports.

An emergency tariff council has been formed with power to adjust duties on products when domestic industry is hurt excessively.

Orbiting Observatory to Study Interstellar Gas

EQUIPMENT to carry out Princeton University's experiment in the Orbiting Astronomical Observatory program (p 22, Feb. 23) will be built by Sylvania under a $3.5 million NASA contract.

The equipment is to perform ultraviolet analyses of interstellar gas and dust clouds, process the data and store it in digital form for transmission to earth. The equipment is to lock onto its targets with an accuracy of 0.1 second of arc.

In Brief . . .

CANADA'S topside ionospheric sounder, Alouette (p 8, Sept. 28), and the U.S. space weather sattellite (p 8, Oct. 5) have been launched.

SIX BANKS, in Buffalo, Rochester, Albany, Syracuse, Utica and Binghamton, N.Y., are cooperatively setting up three data-processing centers, will lease IBM equipment for $950,000 a year.

FIRST DIRECTOR of MIT's Center for Materials Science and Engineering (p 100, June 29), will be R. A. Smith, British physicist.

CBS LABS will develop computer-oriented composing and printout devices for Merganthaler Linotype Co. under a long-term pact.

ITEK CORP. has sold its Electro-Products division, specializing in crystal products, to Midland Manufacturing. Roanwell Corp. has bought Teltronics, an instrument manufacturer.

WATERMAN PRODUCTS' crt operation in Philadelphia has been acquired by Nathan, B.S. and K. B. Lifson, principals in Continental-Wirt Electronics.

INFRARED DETECTOR for the Army's Mauler missile will be developed by Infrared Industries under a $364,000 contract.

USS BAINBRIDGE, Navy's first nuclear-powered, guided-missile destroyer, was launched last week in Boston.

IN A DATA transmission experiment last week, Telstar relayed the equivalent of 1.46 million English words a minute. Rate was 875,000 bits a second.

SYLVANIA has received an additional award of $16 million for Minuteman's ground command and control system, bringing total to $18 million.

MAGNAVOX received a $2.6-million contract from Navy for airborne radar. Jordan Electronics received a $1.7-million order for guidance power supplies for the Army's Sergeant missile.

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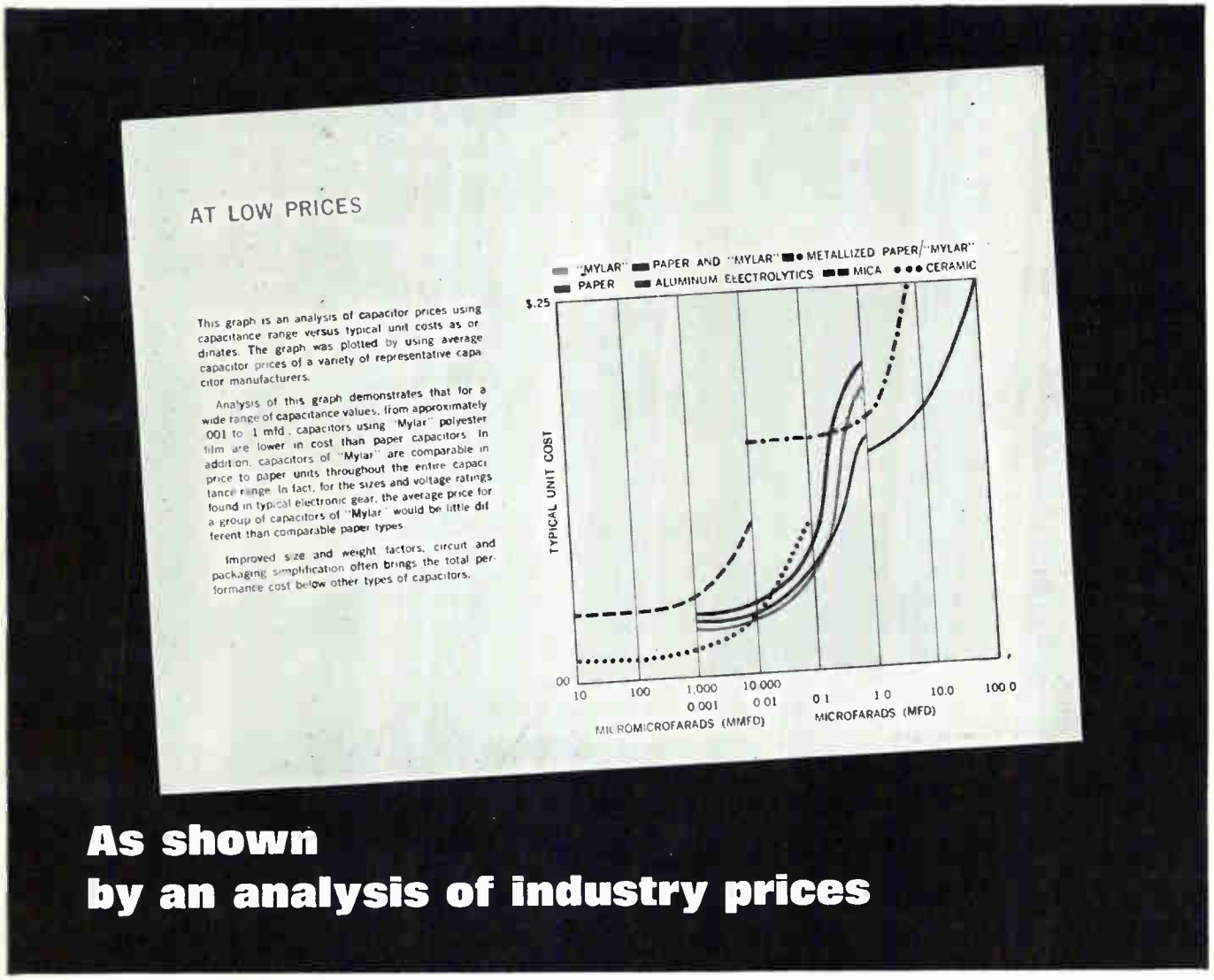
Capacitors of MYLAR® often cost no more than paper—sometimes cost less



As shown by an analysis of industry prices

A recent industry survey made by Du Pont showed that most design engineers did not consider capacitors of "Mylar"* in the same low price range as paper. Yet a study of manufacturers' average prices, as reported in our capacitor booklet, points out THAT OVER A RANGE OF SIMILAR CAPACITANCES AND RATINGS—UNITS MADE WITH "MYLAR" COMPARE CLOSELY IN PRICE WITH THOSE OF PAPER.

This means, at no greater cost, you get the extra reliability of "Mylar"—superior dielectric strength, moisture resistance, and thermal stability over a wide range of temperatures. And you can design more compact components with the reduced capacitor size permitted by "Mylar".

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WASHINGTON OUTLOOK

ONE AGENCY MAY DO ALL NAVY BUYING

PLAN TO SET UP a single Navy agency to handle all hardware R&D and production contracting is under serious consideration. The agency would be patterned after Army Materiel and Air Force Systems Commands and would absorb the Bureaus of Ships, Naval Weapons, and Supplies and Accounts. The plan is being studied as part of a full-scale management review ordered by the Secretary of the Navy last April. Creation of such an agency would be in line with the trend under Defense Secretary McNamara to consolidate procurement functions and to centralize policy-making. A single Navy materiel agency would simplify industry access to Navy contracting authorities.

REASON: TOO MANY HITCHES IN SYSTEMS INTEGRATION

BEHIND THE PROPOSAL to set up the agency are complaints about the lack of system integration in Navy weapon system development. One Navy official tells ELECTRONICS that serious problems in mating the Tartar, Terrier, and Talos antiaircraft missile systems with the vessels that carry them have raised modification costs and delayed their operational status. The problem, he says, stems from lack of planning coordination between BuShips, in charge of shipbuilding, and BuWeps (and previously the now-defunct Bureau of Ordnance), responsible for the missile systems.

The Polaris program avoided this sort of problem by combining development of the missile, its electronic systems and the submarines under a single office headed by Adm. Raborn. In effect, the new agency would extend the Polaris concept to all naval weapons development.

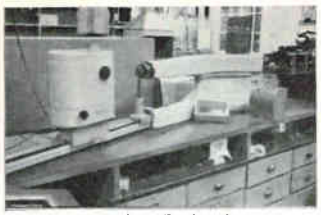
An electronics industry source here claims that Navy's lack of system integration has had serious results. He charges that if all electronics systems on a major vessel were exercised at the same time, one system would knock out or interfere with others. He complains that the Navy thinks in terms of "accommodating electronics equipment to a ship rather than of integrating the vessels into a system." Selecting shipyards, rather than electronic companies, to manage construction of missile tracking vessels is a typical deficiency, he says.

MIDWEST IS STAGING A COMEBACK IN CONTRACTING

MIDWESTERN STATES are staging a comeback in defense production, latest Pentagon figures show. Ohio, Indiana, Illinois, Michigan and Wisconsin racked up the biggest increase of any region. They won $3.2 billion in prime contracts during fiscal 1962, ending June 30, or 12.6 percent of the $25 billion total awards. In the previous year they got $2.6 billion in contracts, or 11.8 percent of the total, compared to 32.4 percent during World War II and 27.4 percent during Korea. The Midwest's comeback stems from the Pentagon's new stress on procuring conventional military hardware—the type of production that the Midwest has traditionally specialized in, but which was deemphasized until recently.

Colorado, Georgia and Utah also showed a big boost. Kansas and Texas were hurt the most with the phasing out of B-52 and B-58 bomber production. California still leads with 23.9 percent of the total but its rate of growth in defense contracting is apparently leveling off. New York, the second leading state, was down from 12 percent in the previous year to 10.7 percent, but showed a slight increase in dollar volume.


Design


Materials Evaluation


Pilot Production


Eng. Qualification Approval

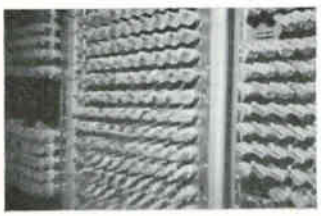

Production

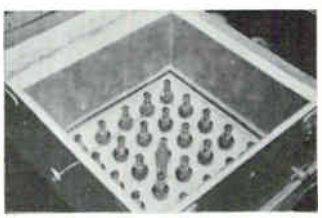

X-Ray Inspection

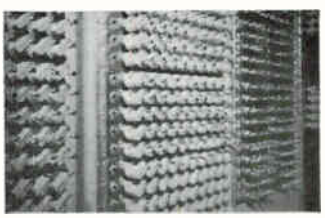

Microscopic Inspection

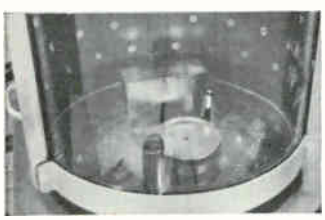

Auto. Electrical Test


Pulse Emission


Survival/Stability Life


High Temp. Life Test


Room Temp. Life Test

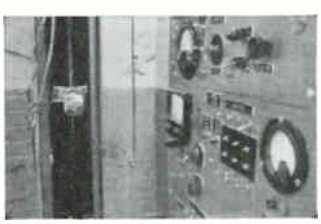

Altitude

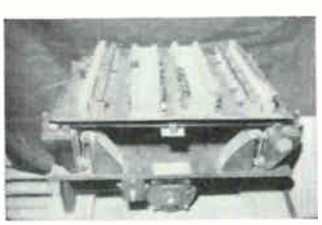

Temp. and Humidity


Shock Test


Vibration


Sweep Freq. Vibration


High G Shock


Vibration Fatigue


Reliability Evaluation

Step by Step . . . Raytheon builds reliability into every subminiature tube.

From inspection of incoming material and components, through final tests and shipping, Raytheon's unique Reliability Assurance Program produces the most reliable subminiature tubes available. Every production step is monitored and controlled by a quality and reliability group completely independent of the manufacturing groups. Their only responsibility is that every tube shipped must consistently deliver maximum reliability.

That's why one person of every eight in the Raytheon Industrial Components Division is a member of the quality and reliability group, with an average of eight years service. And, that's why every month 10,000 subminiature tubes are put through exhaustive life tests and an additional 8,000 are subjected to a variety of extremely vigorous environmental tests.

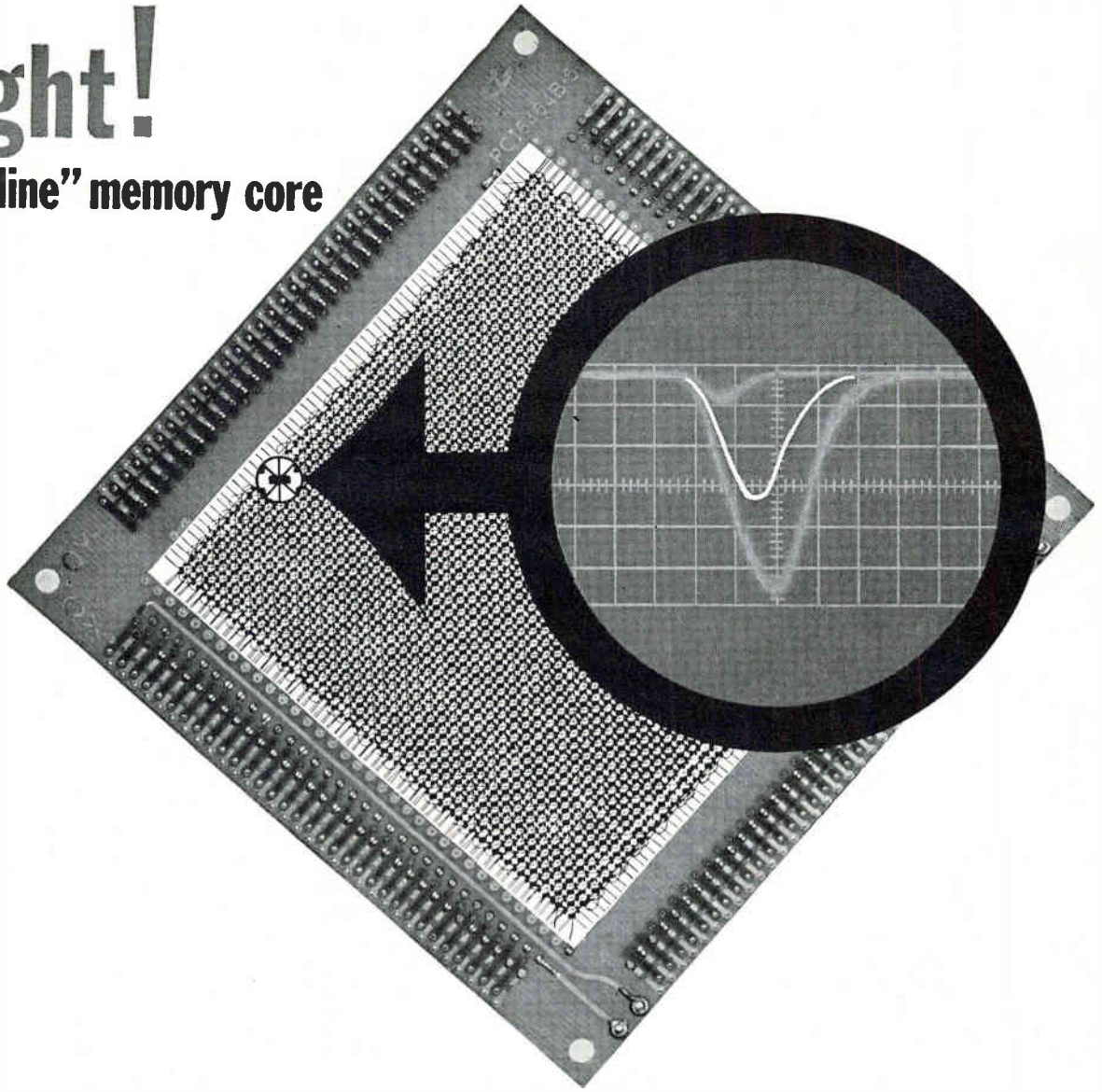
Results of Raytheon's Reliability Assurance Program can be seen in the proven successful record of consistently reliable service of these tubes in more than 25 major missiles. Because *reliability is built into* — not tested into its product, Raytheon sells more subminiature tubes than all other manufacturers combined!

For reference data on Raytheon's broad line, please write: Raytheon Company, Industrial Components Division, 55 Chapel Street, Newton 58, Massachusetts.

RAYTHEON

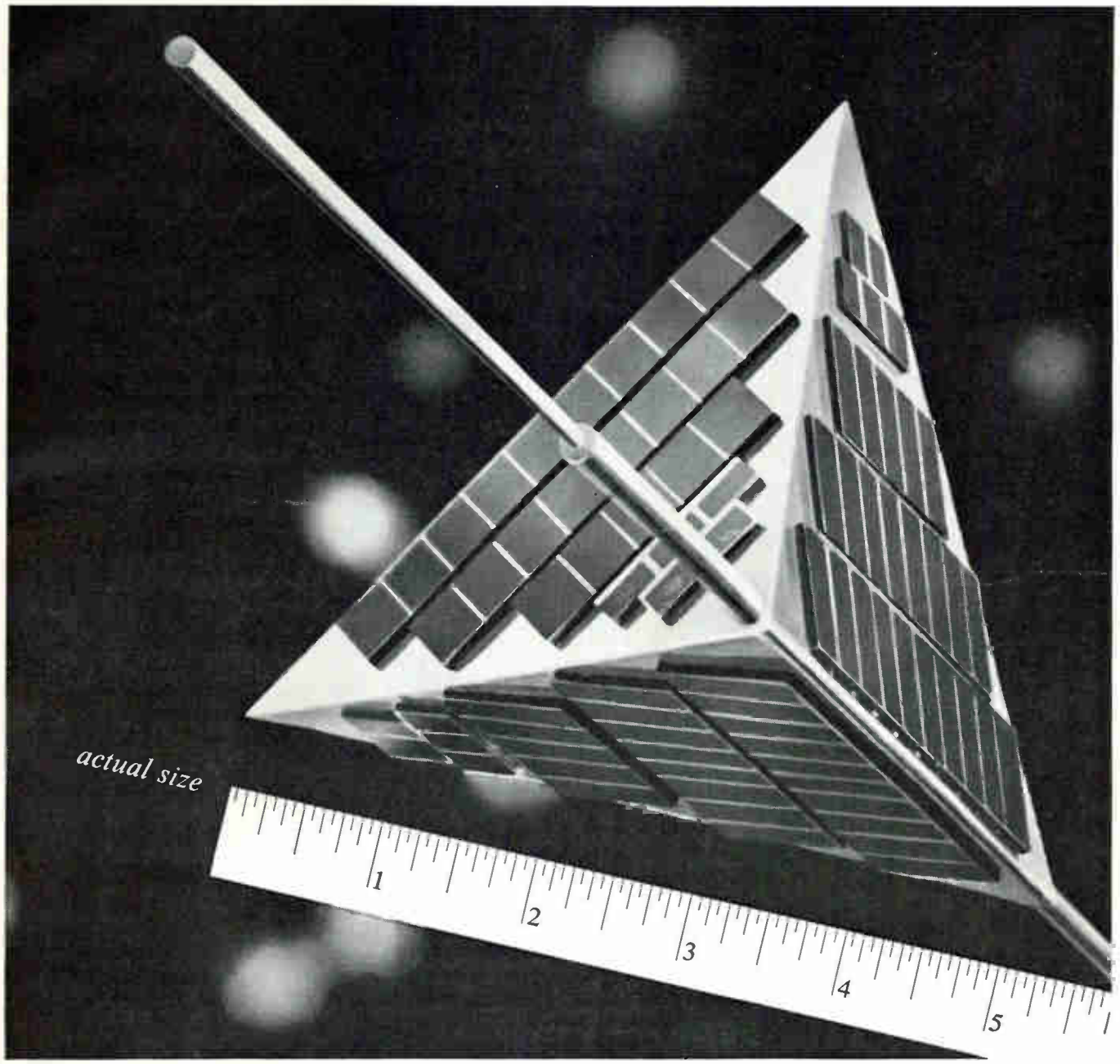
caught!

a "borderline" memory core



This memory core passed through extensive quality control tests — chemical analysis of raw materials, firing tests of mixed materials, dimensional and density tests of pressed parts. It was individually tested for high-speed operation and visually and mechanically sample-tested before being strung into a plane. At one of the final tests, however, this core failed to measure up to high IGC standards. It will be replaced and the plane checked again and again under simulated computer operation. ■ **Magnetic storage systems are our business.** Painstaking quality control plus complete, specialized testing and production facilities, assures that maximum reliability is built into every IGC memory system, stack, plane or core. This reliability can put more quality into your systems. **For complete file of engineering data on our memory products,** write or phone Indiana General Corporation, Electronics Division, Keasbey, New Jersey.

INDIANA GENERAL



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

STL is active on hardware projects such as this and as prime contractor for NASA's OGO and an entirely new series of classified spacecraft for Air Force – ARPA. We continue Systems Management for the Air Force's Atlas, Titan and Minuteman programs. These activities create immediate opportunities in: Space Physics, Radar Systems, Applied Mathematics, Space Communications, Antennas and Microwaves, Analog Computers, Computer Design, Digital Computers, Guidance and Navigation, Electromechanical Devices, Engineering Mechanics, Propulsion Systems, Materials Research. For So. California or Cape Canaveral opportunities, please write Dr. R. C. Potter, Dept. G-12, One Space Park, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

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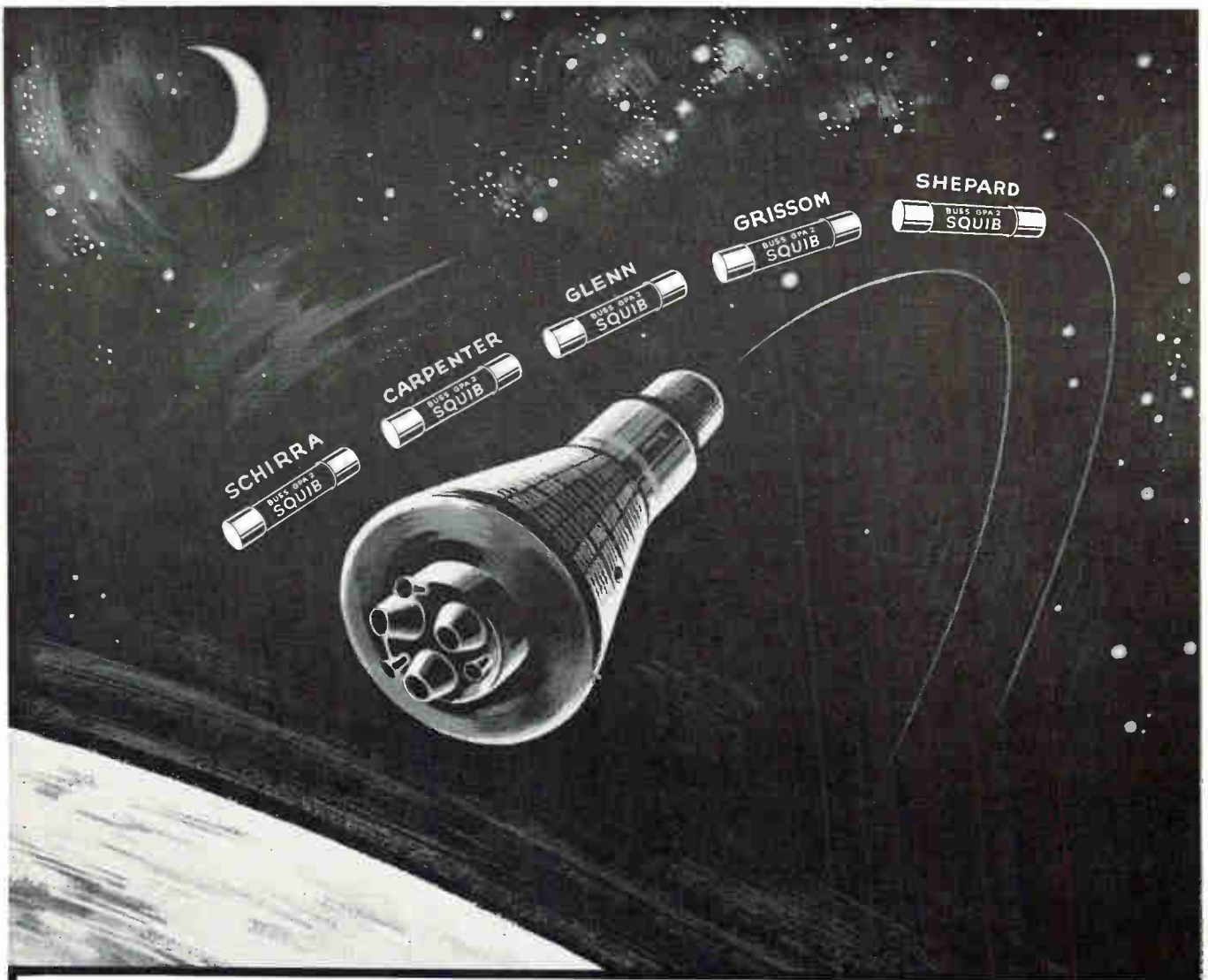

BUSS FUSES FLEW INTO SPACE WITH SCHIRRA AND ALL U. S. ASTRONAUTS—

and by proper functioning helped bring them back safely!

When a man's life and scientific data relies on the accuracy and dependability of every component in a spacecraft,—chances with unknown or improperly engineered components cannot be tolerated.

That's why the Space Age engineers turned to BUSS for the fuses used to protect the electrical circuits in the spacecrafts.

This is not surprising when you consider that BUSS maintains the largest staff of fuse engineers and the largest fuse testing laboratory in the world.

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Most probably, the type of fuse exactly right for your application is already available from your BUSS distributor—but should you have a special problem, you can save engineering time by letting BUSS fuse engineers help you solve it. Our engineering department is always at your service.

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Varian Associates' family of pulsed driver traveling wave tubes is the most complete in the microwave industry. These state-of-the-art tubes are available in power ranges from 5 kW to 50 kW, to satisfy requirements of modern radar systems. Tube construction employs contra-wound helix or ring-bar circuits to permit efficient operation.

Varian's driver TWT family covers a wide range of varying operational requirements. All have wide bandwidth and flat gain characteristics. Most are periodic permanent magnet focused, some are solenoid focused for use in phased array systems or other special applications. Varian pulsed TWT's feature high duty cycles, long pulse capability, high efficiency.

If your special radar requirements demand high-performance driver TWT's, Varian has (or can design) the tube for you. For additional information, contact Tube Division.

Tube Type	Frequency Range (Gc)	Peak Power (kW)	Average Power (watts)	Pulse Width Microseconds	Gain (db)	Focusing	Modulation
VA 134B	0.5-0.6	5	350	600	35	PPM	Grid
VA 137C	0.87-1.00	5	350	600	45	PPM	Grid
VA 133D	1.25-1.40	5	350	600	50	PPM	Grid
VA 131E	1.25-1.70	25	150	35	35	PPM	Grid
VA 131B	1.25-1.70	50	200	30	40	PPM	Grid
VA 128C	2.9-3.35	5	15	10	30	PPM	Grid
VA 139A	5.20-5.90	5	10	10	50	Solenoid	Cathode Pulsed

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Aircraft Navigation: Is Doppler

That poser will start navigation session at ECCANE this month

NINTH ANNUAL East Coast Conference on Aerospace and Navigational Electronics, Oct. 22 to 24 in Baltimore, will start off with a controversial question—are inertial navigation systems any good for aircraft?

The lead-off speaker at the Monday-morning session on navigation, Edward R. Dayton, of Lear Siegler, Inc., thinks that the more "prosaic" doppler systems are better and cheaper for aircraft use than are inertial systems.

HYBRID SYSTEMS—After comparing the relative merits of the two types of systems, Dayton proposes two hybrid systems (see illustrations).

In one, heading information would be obtained inertially, but velocity would be provided by doppler radar. Such a system, he says, would cost about $45,500, compared to $85,000 for a low-cost all-inertial system, and would be more reliable, accurate and lighter. The multisample navigation system is an alternative.

One of Dayton's main arguments against inertial navigation for aircraft is that pilots rarely need a self-contained, long-range navigation system. Flights are either short in range, or the pilot flies from fix to fix, which amounts to the same thing. Other arguments against inertial, he says, are its high equipment and support costs and the cumulative error factor.

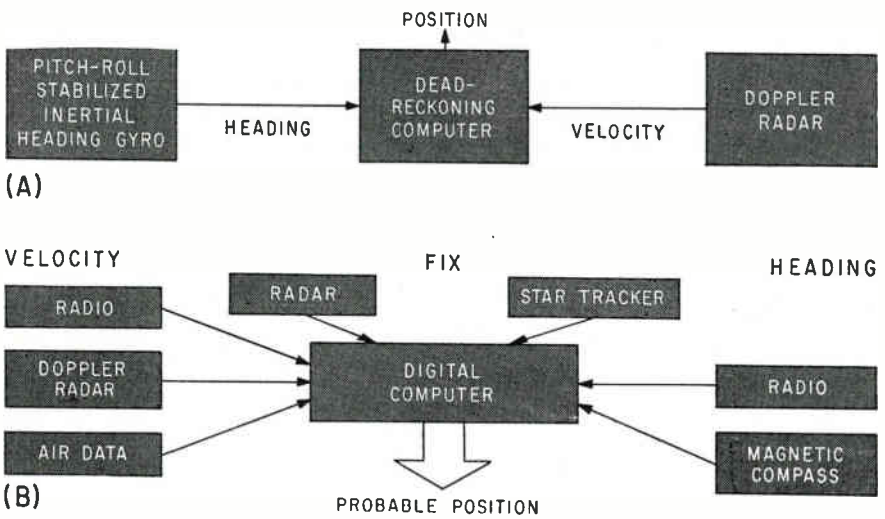
If all requirements are met, Dayton says, inertial and doppler systems both perform well. But if requirements are missed, inertial performance is "horrible" while doppler performance is still "good."

What is needed instead of inertial systems, Dayton says, is a good stable platform, costing no more than $40,000, for use as a vertical reference. It should provide heading information independent of vertical system failure, he adds.

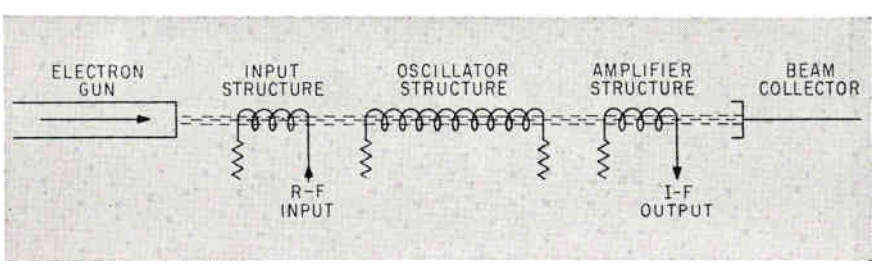
SATELLITE GUIDANCE—A self-contained system applicable to manned or unmanned space vehicles will be described by T. W. Godbey and A. W. Roeder, of General Electric. Called the Continuous Orbital Guidance System (Cogs), it consists of an attitude control system, autopilot, radar altimeter and computer. The system will during the first orbit detect and correct any deviation from the preplanned orbit. The pulsed radar altimeter measures altitude at successive instants of time while the attitude reference maintains the vehicle roughly horizontal. By taking two readings and dividing by time, the first derivative of altitude can be obtained. Further measurements will give the second derivative. By obtaining this information quickly, the system designers expect to make orbital rendezvous easier by rapidly measuring the orbital characteristics of the chase vehicle.

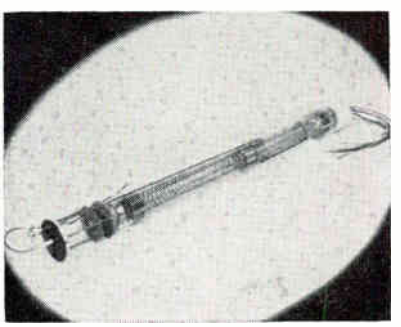
Drifts inherent in inertial guidance systems can be corrected by celestial references, according to S. S. Viglione and H. F. Wolf, of Astropower Inc. Since single star trackers may lock onto the wrong star, they propose a mosaic of photocells tied to a majority logic network, as shown, to recognize star patterns.

A. M. McCalmont, Scientific Analysis Corp. will report on a study of communications for manned space flight, based on state-of-the-art equipment readily



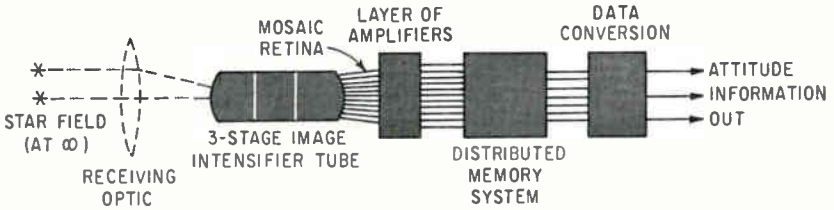
HYBRID DOPPLER *systems proposed for aircraft navigation. One would get heading information inertially (A), while the second would depend on other sensors (B)*





BACKWARD-WAVE *converter developed by ITT is an electronically swept receiver in glass envelope (right). Proposed version (sketch) would have built-in i-f amplifier and may be used in millimeter-wave region*

Or Inertial Better?



STAR FIELD *recognition system will lock onto familiar star patterns for space or aircraft guidance*

available. The results indicate that a transmitter operating in S-band (2.3 Gc) with an adaptive system in which bit rate, message format and bandwidth are varied will fulfill communications requirements for several years.

RENDEZVOUS AIDS—Fairchild-Stratos study of sensors for spacecraft rendezvous and a proposed multifunction radar design will be reported by H. E. Prew and D. B. Newman. The design integrates the antenna, receiver and transmitter modules to provide range, range rate, radial altitude and tangential velocity. Detailed in the presentation will be the functions of detecting another space vehicle, tracking, and the maneuvers necessary for vehicle to vehicle docking.

Precision radar conceived around a new technique called the delay-lock discriminator will be described by W. G. Weis and M. Evans, of Lockheed. The delay-lock discriminator is a device for measuring delay between two correlated waveforms and is related to the phase-lock loop. Besides its intended use in satellite rendezvous it has applications in radar tracking.

FASTER TIME—Problems in air traffic control can be reduced if, instead of maintaining a flight path history on the radar scope, the action can be speeded to give the operator a dynamic display, report S. Adelman and B. E. Potter, of Sperry Gyroscope. They will discuss a time-compression scheme in which path history is stored, then played back several times as fast. This allows targets to be compared both upon the geometry and the velocity of their flight paths.

BW CONVERTER—Among new microwave components to be disclosed is a backward-wave converter developed at ITT Components division. Described by R. W. Wilmarth and R. J. Blanchard, the converter is effectively an electronically swept receiver in a single vacuum envelope (see illustration). An r-f signal is fed into the tube, mixing takes place in the electron beam, and the output is at i-f. Mixing in the electron beam is superior to a crystal mixer and separate components and interconnecting r-f lines are not needed, they say. The device may be used in the millimeter range, and may include a built-in i-f amplifier.

The conference will be highlighted by three invited sessions: A review of laser principles, developments and their potential as communications devices, on Monday; a panel on microminiaturization, on Tuesday; and adaptive control for spacecraft and high-speed aircraft, on Wednesday.

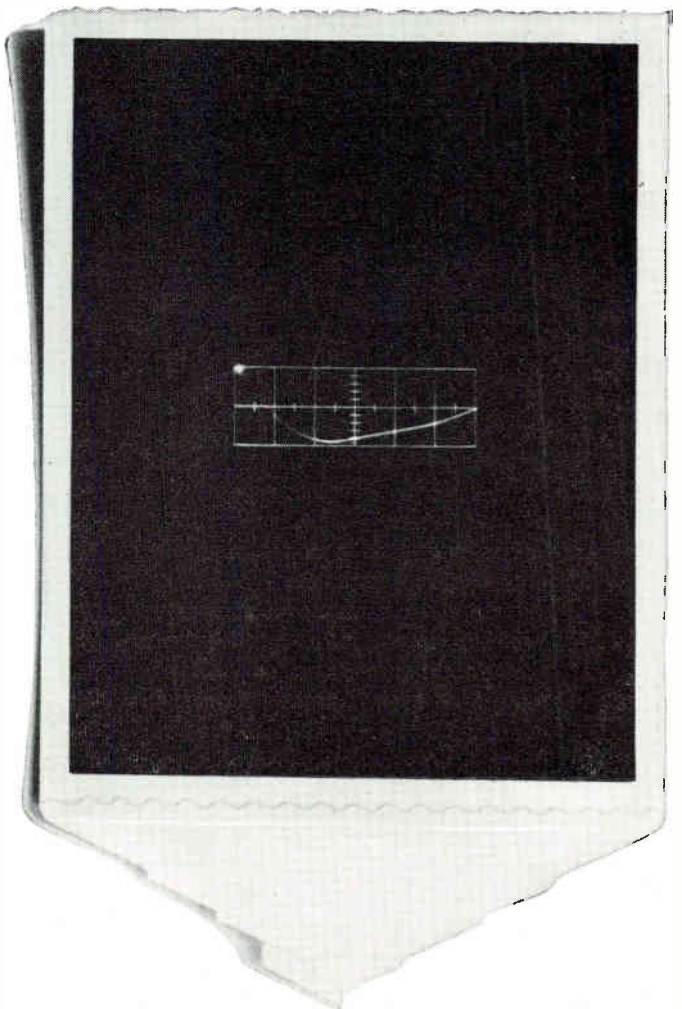
Another U. S. Radio Facility in Australia

MELBOURNE—The number of U. S. radio facilities planned or installed in Australia continues to grow.

The USAF has established its third communications research station at the RAAF base at Pearce, in southwestern Australia. Others are at Alice Springs and Laverton, near Melbourne.

Jet Propulsion Laboratory is seeking a site for a deep space tracking station. The southwest corner, with its freedom from man-made radio interference, is the likeliest site.

U. S. Navy and NASA are also planning new facilities (p 8, Sept. 21).



2 nanoseconds/cm: impossible to photograph until now

Polaroid has a new film that is so fast, it will reproduce scope traces that are almost invisible to the naked eye. The one above, a scintillation pulse, has never been photographed until now. Pulse duration was ten nanoseconds. Scope sweep speed was 2 nanoseconds/cm. *The new 10,000-speed Polaroid PolaScope Land film produced a finished usable print ten seconds after exposure.*

The maximum writing speed of the 10,000-speed film is about twice that of the Polaroid Land 3000-speed film, which is currently the standard for high speed photography. The new film not only gets "impossible" pictures, it also produces far better shots of slower pulses and steady state waveforms. Because of its high speed, less light is required; camera aperture and scope intensity can be reduced considerably, producing sharper pictures.

And besides oscillography, the PolaScope film opens up new possibilities in applications where light is at a premium, such as photomicrography and metallography. It is not suited, however, for pictorial work due to its high contrast and relatively coarse grain.

PolaScope film (designated Type 410) is packed twelve rolls to a carton. The price is about the same as the 3000-speed film.

The film can be obtained through industrial photographic dealers. For the name of the dealer nearest you, write to Technical Sales Department, Polaroid Corporation, Cambridge 39, Massachusetts.

New Polaroid Land 10,000-speed film for oscillography.

More new millimeter wave FERRITE COMPONENTS . . . This is the new TRG transistorized switch driver and circulator combination for millimeter wave radiometry. Like most TRG ferrite components, it is available nowhere else — truly a pioneering device in the true sense of that sometimes abused word. Yet, TRG offers this unique combination, as it offers all other TRG advanced components, on short delivery. You'll find the ferrite switch driver and circulator more fully described below. And please remember this: today, there is only one source for a complete line of millimeter wave components of all types, covering the entire 26.5 to 220 KMC region. That source is TRG. Whatever your problem — a component, or complete systems development — TRG has more of everything it takes, including experience, to place the answers right in the palm of your hands. Please write for Catalog 163 today.

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TECHNICAL RESEARCH GROUP, 400 Border St., East Boston 28, Mass.

The new TRG transistorized ferrite switch driver and circulator combinations are available over the entire 26 to 140 KMC region. Applications: millimeter wave radiometry, spectroscopy and radar duplexing. Representative specs: Rise Time, less than two microseconds . . . Repetition Rate, 2 pps—10,000 pps . . . Duty Cycle, 50% Automatic binary reduction of input trigger pulse.

COMPONENT	A-band 26-40 KMC	V-band 50-75 KMC	E-band 60-90 KMC	F-band 90-140 KMC	TYPICAL PERFORMANCE FOR A, V, E and F BANDS		REMARKS
FERIMAT — Tunable Isolator	A100	V100	E100	F100	A, V, E	VSWR 1.25 max. — Loss 1.5db max. — Isolation 20db min.	Tunes over full waveguide range
					F	Under development, present performance quoted on request	
Isolator	A110	V110	E110	F110	A, V, E	VSWR 1.25 — Loss 0.7db — Isolation 17db min., 25db at band center	Bandwidth: 6% A-band, 3% V and E-band, $f_o \doteq$ 1 KMC F-band
					F	VSWR 1.30 — Loss 1.0db — Isolation 16db min., 22db at band center	
On-off Switch or Variable Attenuator	A120	V120	E120	F120	A, V, E	VSWR 1.25 — Loss 1.5db — Isolation 50db	150 ma switching current, 3μ sec. rise time
					F	Under development, present performance quoted on request	
Modulator	A130	V130	E130	F130	A, V, E	4% Band — VSWR 1.25 — Loss: on 1.5db — off 30db	Normally closed — Approx. 150ma switching current, 3μ sec. rise time
					F	2% Band — VSWR 1.3 — Loss: on 1.5db — off 30 db	
Reciprocal Switch	A140	V140	E140	F140	A, V, E	3% Band — VSWR 1.25 — Loss 1db — Isolation 20db	High power — Approx. 150 ma switching current, 3μ sec. rise time
					F	Under development, present performance quoted on request	
Four Port Circulator	A160	V160	E160	F160	A, V, E	3% Band — VSWR 1.3 — Loss 1db — Isolation 20db	Utilizes two dual mode transducers and a Faraday rotator
					F	Under development, present performance quoted on request	
Switchable Circulator Switch	A162	V162	E162	F162	A, V, E	3% Band — VSWR 1.3 — Loss 1db — Isolation 20db	High power — Approx. 150ma switching current, 3μ sec rise time
					F	Under development, present performance quoted on request	
Transistorized Driver	170				Rep. Rate: — 2pps to 10,000pps, Rise Time: — Less than 1.5 μsec. with coil of 1mh or less, Duty Cycle: — 50% automatic Binary Reduction of input Trigger, Input Signal: — Plus or minus pulse or square wave, 5 volts peak		Designed for pulsing ferrite waveguide switches and modulators over 26 to 140KMC band

NOTE: TRG ferrite components can be built to operate with existing high power millimeter transmitting tubes. A custom built Model V160 circulator recently was successfully tested at 10 kw peak power.

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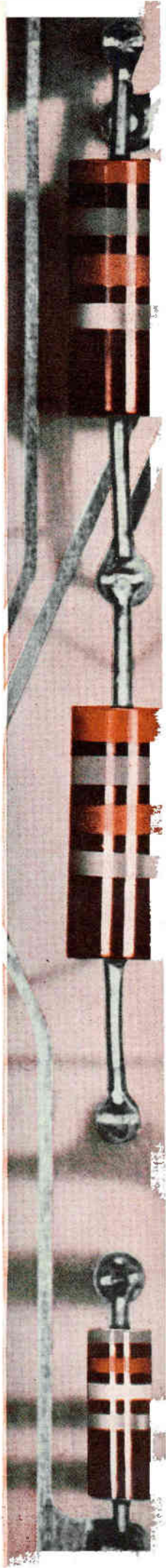

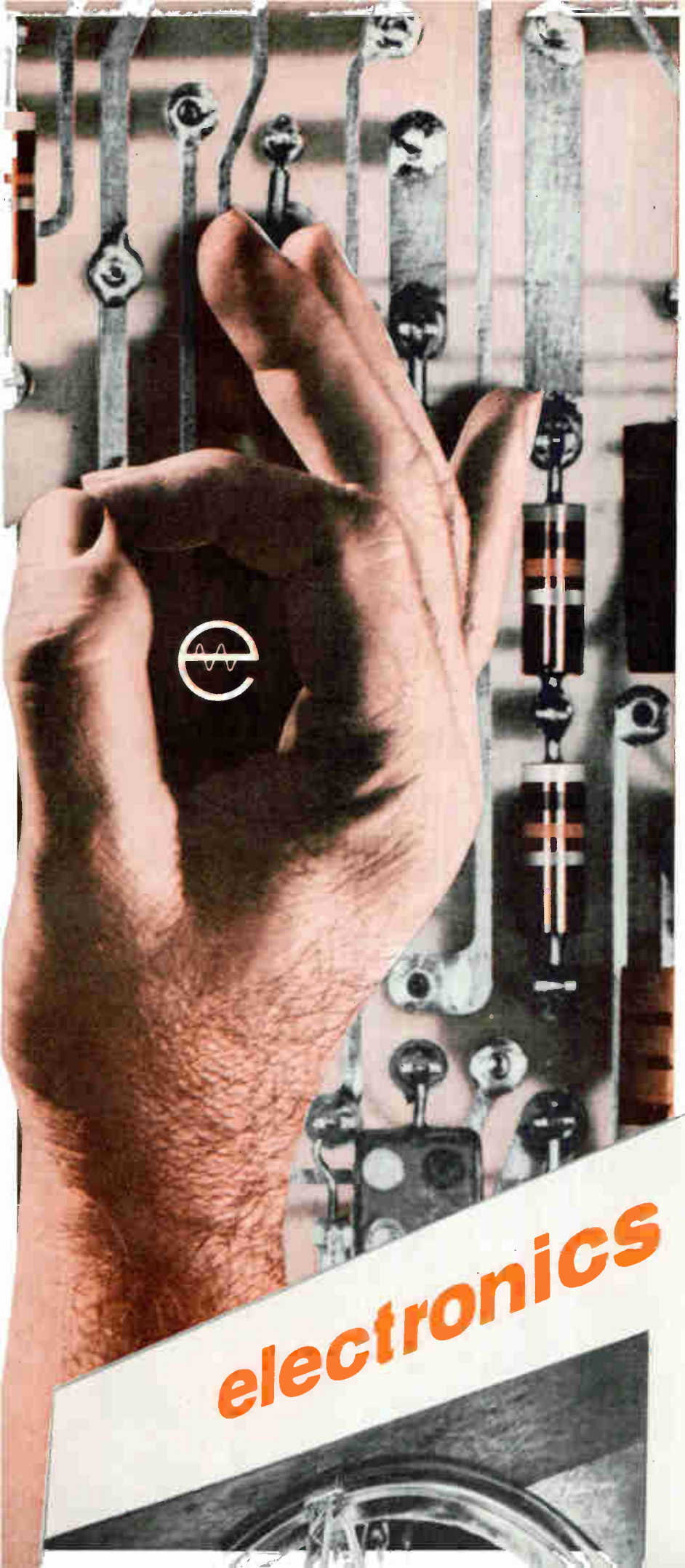

more about acceptance

In an industry where engineers can have over 50 publications for free, 57,000 of them subscribe to *electronics*. This is a 40% increase in paid subscribers since 1956. To be a paid subscriber, an electronic engineer must, at a minimum:

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57,000 electronic engineers do this.

In Electronics, like any other industry, a man with something important to say wants to say it in what he thinks is his industry's most important publication. Although *electronics* is basically a staff-written magazine (28 full-time editors), no other magazine can match its roster of industry contributors. *electronics* currently has hundreds of contributed articles awaiting evaluation.

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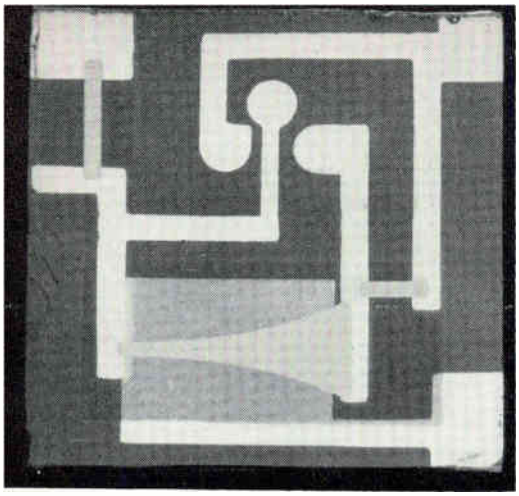
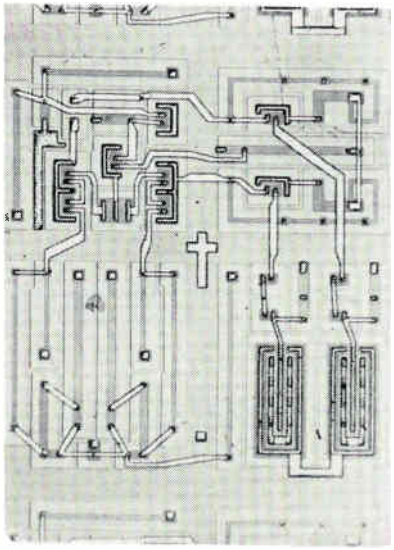
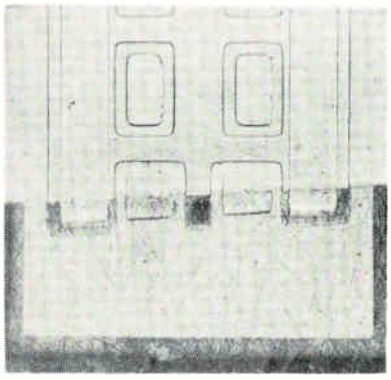


TAPERED *form in lower half of Melpar's modulator-oscillator circuit is a three-layer distributed-RC network*



SERVO AMPLIFIER *developed by Norden is fabricated in four separate parts on silicon chip (above). Microphotograph below shows power transistor junction contours in beveled and stained edge of crystal*



Navy to Push Microelectronics Development Programs

Thin-film versions of airborne and ship gear are being readied

By NILO LINDGREN
Assistant Editor

WASHINGTON, D. C.—"Microelectronics offers us a solution to our problems, and this is the way we are going to go!"

Thus concluding a packed two-day Navy Laboratory Microelectronics Conference last week, Col. A. C. Lowell, Avionics Division, Bureau of Naval Weapons, affirmed that microelectronics is moving rapidly into the system-implementation stage of development.

Lowell detailed a BuWeps program for the orderly incorporation of microelectronics into military systems, called Meetat (Maximum Improvement in Electronic Effectiveness Through Advanced Techniques).

Aimed at utilizing the full potential of the microelectronics technology, Meetat phases include converting present aircraft equipment into microcircuit forms, and the eventual development of fully integrated systems of functional, throwaway modules.

For instance, Sperry's completely digital Loran C navigational system in microelectronic form will weigh 20 pounds instead of 100 pounds in the present system.

Another program for shipboard electronics, Prise (Program for Integrated Shipboard Electronics) still being planned, was revealed by G. Neumann, of Electronics Support Branch, Bureau of Ships. It aims at equipments in standard packages.

Neumann stated that 60 to 80 percent of present shipboard equipment could use off-the-shelf Prise packs. Prise packages are to be specified to contractors by functional and performance requirements only. Although packs would be standardized, any techniques could be used in making the packs.

FILM COMPUTERS—IBM is to complete next year a 250-cubic-inch fixed-point, stored-program, general-purpose digital computer with a memory of 1,000 13-bit words. One of the earliest applications of thin-film techniques to airborne equipment, it will be part of a weapon-delivery system.

The computer is built up of about 100 pluggable, integrated-film panels on 1.865 × 2.5-inch substrates, holding about 32 basic circuits each, as illustrated on p 26. A universal interconnection pattern provides different logic functions with a single deposition sequence and identical masking. All transistors on a panel are simultaneously attached by solder reflow.

The basic circuit is transistor-resistor logic using the NOR function. Resistors are flash-evaporated chromium-silicon monoxide, lands and conductors are deposited copper on chromium, and insulation and dielectrics are silicon monoxide.

Another BuWeps system, described by S. Gordon, of Johns Hopkins University, will be a thin-film digital decoder for a missile system. It will employ some 225 transistors, 500 diodes, 600 resistors and 60 capacitors. Three or four units are to be built by continuous, compatible fabrication procedures. The contract is to be let shortly.

Still another system, a 200-module digital computer, has been fab-

ricated by Lear Siegler and will be tested in a satellite later this year.

500-C FILMS—Radiation-resistant integrated circuits operable to temperatures of 500 C are the aim of a thin-film program at Melpar, reported by C. Feldman and H. E. Culver. One development is a thin-film modulator-oscillator using rhenium for resistors, germanium, SiO_2 and gold on fused silica.

An unusual feature is a three-layer (germanium/silicon dioxide/gold) active-inactive device (see photo). Its bottom layer is a resistor, a tapered germanium film with an exponential geometry that forms one plate of a thin-film capacitor. Thus, the unit is a distributed-RC network. A voltage on the metal plate opposite the germanium film causes a change in the surface states of the germanium and its resistance. With transistors as amplifier elements, f-m oscillators have operated at several hundred Kc to over 1 Mc.

Another Melpar development, coming out of studies of pyrolytically deposited silicon film, has been the formation of large, pure crystallites on fused silica substrates. E. G. Bylander has made a tunnel diode from a crystallite, using thermocompression-bonded contacts.

SERVO AMPLIFIER—A 1.5-watt molecular servo amplifier was reported by M. W. Aarons, of Norden.

The design chosen was a morphological arrangement dissecting the circuit symmetrically into four separate circuits, as shown. Interconnections are deposited on the passivated surface. Six amplifiers are fabricated simultaneously on a ¾-inch wafer of single-crystal silicon 4 mils thick.

Aarons stressed the significance of the successful topological inversion of the power-transistor structure, to obtain extremely low saturation resistance. He also said that amplifiers up to 25 watts could be obtained by varying output stage design and heat sinking.

ADVANCED RESEARCH—Longer-range, speculative research at Stanford University was discussed by Prof. J. G. Linvill. D. J. Dumin recently demonstrated a superconductive trapped flux multilevel

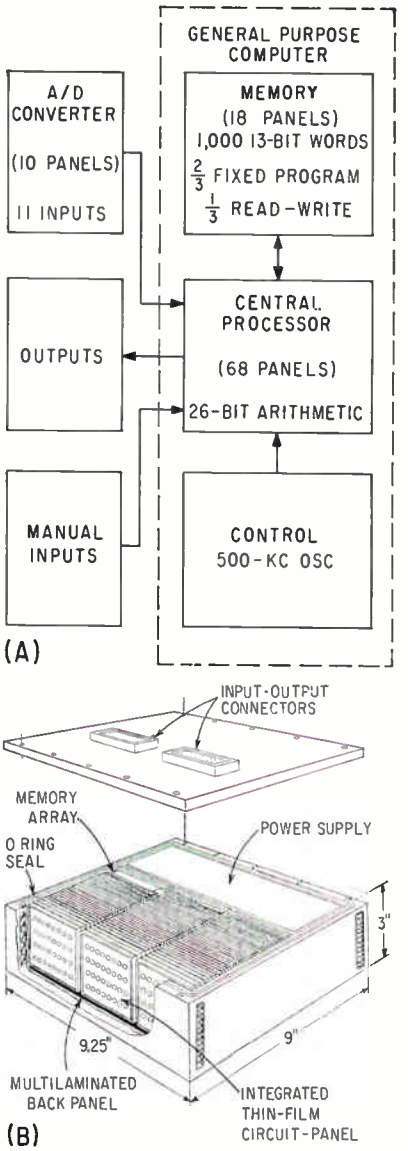
memory in which the memory levels exhibit quantum spacings. Development of a superconductive memory utilizing the ultimate fineness of steps of a magnetic memory might be possible, Linvill said.

G. J. Selvin outlined Sylvania's program to develop thin-film active components. BuShips is supporting development of vacuum-deposited thin-film silicon semiconductor devices. Selvin said that if all goes well, thin-film transistors would be in production in 1964.

The Navy is pushing research in such areas as bioelectronics and self-organizing systems. R. H. Wilcox, of ONR, said that not enough work was being done in making systems requiring large numbers of components highly redundant or self-diagnosing and self-healing. Another neglected area, ONR feels, is the development of adequate theories for microelectronic device operation and phenomena. Most present devices have been developed empirically.

J. M. Lee, of BuWeps said that good, sound data is still needed on the transient effect of nuclear radiation on thin films.

H. Parker, asst. head, Navy's Industrial Readiness Branch, said that the Navy would not allow itself to be limited to any one firm's microelectronics production capability or techniques. In awarding contracts, he said, there would be strong resistance to being constricted by the long-term proprietary considerations that any single firm might wish to exercise.



THIN-FILM COMPUTER *being developed by IBM. The computer (A) will be composed of about 100 panels (B) each carrying about 32 basic circuits*

Radio Telescope Finds Magnetic Fields

LONDON—Existence of magnetic fields in space has been proven by scientists of the Commonwealth Scientific and Industrial Research Organization using the 210-inch steerable radio telescope at Sydney, Australia. They discovered linearly polarized radiation from the source centaurus A at frequencies of 3 Gc and 1.41 Gc. Frequency variation caused Faraday rotation.

The observed Faraday rotation was nearly two orders of magnitude greater than could be ascribed to ionospheric effects and did not vary with diurnal rhythm. There is evidence that the magnetic field is largely uniform in the outer part of the galaxy (about twenty million light years from earth) for about 500 light years.

The discovery reinforces the steady state theory of the universe, because only if matter were created in the universe and then agglomerated to form stars would large magnetic fields be found, it was reported.

MASER COOLING

In the "business end" of this Air Products cryostat is a maser operating at 2.5°K (—455.2°F). The cryostat is a part of an Air Products closed-cycle helium refrigerator developed for the Bell Telephone Laboratories under contract with the Army Ordnance Missile Command.

The completely self-contained refrigeration system provides maser cooling without need for external supply of cryogenic liquids that boil away in open-cycle systems.

Components have been miniaturized to make possible the installation of the complete maser cooling system on an antenna. For example, Air Products developed compressors better than an order of magnitude smaller than previously available non-contaminating compression equipment. Moreover, the components can operate through all antenna orientations.

Today, Air Products manufactures a complete line of single- and multi-fluid cryogenic refrigerators. Applications range from the creation of ultra-low temperature environments for space chamber "cryopumping"...to cryogenic cooling of masers, parametric amplifiers, infrared detectors, superconducting magnets, and computor memory planes.

Whatever your requirements for cryogenic cooling, it pays to contact Air Products first.

ADVANCED PRODUCTS DEPARTMENT • DEFENSE AND SPACE DIVISION

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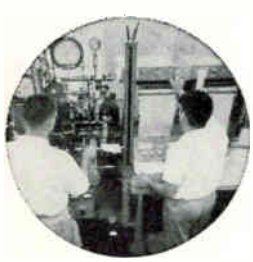
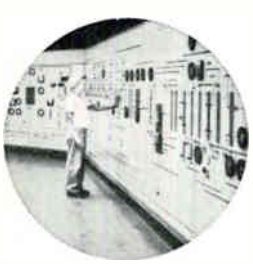
Allentown, Pennsylvania



RESEARCH AND DEVELOPMENT

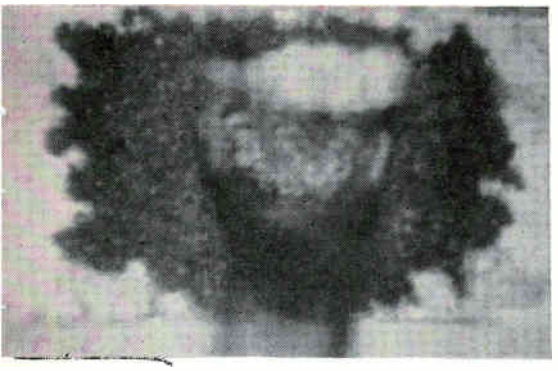
SYSTEMS ENGINEERING

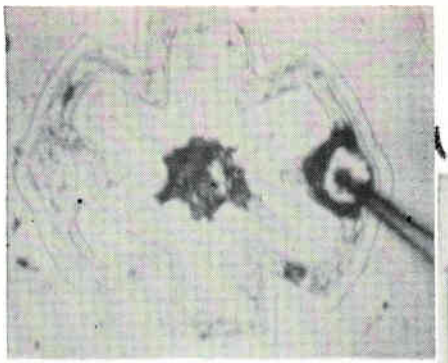
DESIGN AND FABRICATION

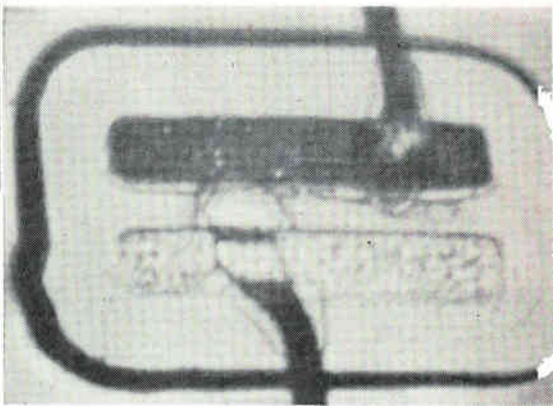


CONSTRUCTION AND OPERATIONS

MANAGEMENT







EXAMPLES *of "purple plague" corrosion resulting from improper connections*

Failure Analysis: Key to Better Reliability

Analysts aim at understanding basic failure mechanisms

CHICAGO—Trend toward thoroughgoing analysis of causes of component failures as a preventative measure was explored two weeks ago at Armour Research Foundation's first symposium on the physics of failure in electronics.

Developing components of predetermined reliability will require know-how reaching back to the microscopic materials level, said Harry Davis, assistant secretary of the Air Force, in a paper read for him.

Noting that the Air Force systems reliability program now costs $30 million, Davis said that diagnosing failures after the fact is too costly and too late. By then the parts are obsolete. Davis called for the evolution of theories and methods that would allow extrapolation of failure rates from one component or environment to others in the future.

APPROACHES — Statistical approaches to failure have already told about as much as they can, said Robert Kirkman, of Space Technology Labs, and more precise definitions—including such generally overlooked factors as human errors, foreign inclusions and loose parts—are needed.

J. Vaccaro, of Rome Air Development Center, proposed the creation of a failure institute at which fundamental physical and chemical behavior could be related to basic materials parameters. RADC's eight-year reliability program for isolating basic characteristics of materials and their interrelationships is aimed at eliminating the need for overdesign, redundancy and backup equipment.

C. H. Zierdt, of General Electric, questioned whether it was economically possible to take precautions against all the hundreds of possible failure causes. He described a diagnostic method, used in failure analysis and process control for the Minuteman 703 transistor, that reduced 30 possible failure modes to 6 and reduced total mechanisms to 11.

Armour Research Foundation speakers proposed the development of component-state equations that would allow computers to predict lifetimes. The computer could develop reliability numbers from input stating likely conditions, stresses and strengths, and time to failure.

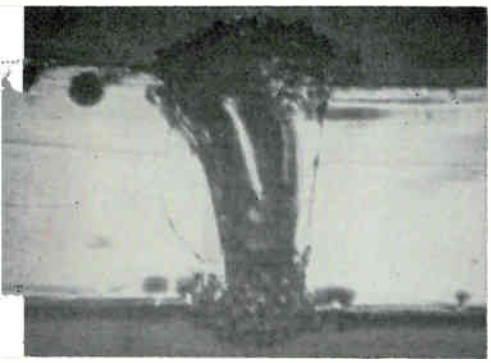
CASE HISTORIES—R. C. Phillips, of Univac showed how case histories reveal failures rooted in fundamental physical deficiencies, improper choice of materials, mechanical design, fabrication techniques or manufacturing processes. Slides of "purple plague" corrosion on semiconductor devices illustrated faulty gold-aluminum connections. Defects resulting from human error included overalloying vapor-deposited aluminum, shorts and missing switch ribbons.

R. Scarlett, of Shockley Transistor, demonstrated how instabilities trigger second breakdown in transistors with hot spots "hogging all the current". Local heat concentrations become great enough to keep the device going with the base current shut off.

Localized alloying or diffusion resulting from lateral instabilities impose failure limits on power transistors, he said. Thermal instabilities may be triggered below normal threshold, by applying localized heat at sensitive regions that probably contain defects.

Hans Queisser, also of Shockley, demonstrated how dislocations introduced during manufacturing and diffusions enhance diffusion of impurity atoms to trigger second breakdown. Enhancement of diffusions along dislocation fronts can lead to serious doping inhomogeneities in devices, he said, resulting in failures such as emitter-collector shorts or weak spots in base layers.

Preferential precipitation of foreign metals along dislocations



DOPING *inhomogeneity resulted in this emitter-collector short*

ILURE *caused by over-alloying vapor-deposited aluminum (left)*

cause undesirable softness of *pn* junctions. Dislocation effects, combined with surrounding impurity atmospheres, then influence operating properties and reliability.

Current noise measurement as a failure analysis tool for film resistors (ELECTRONICS, p 100, Nov. 10, 1961) was discussed by John Curtis, Corning Glass Works. Units with unusually high noise show defects visible under a microscope, he said. A discrete noise level divided maverick performers from normals. Although not all noisy resistors were poor performers, all resistors tending to be abnormal were noisy.

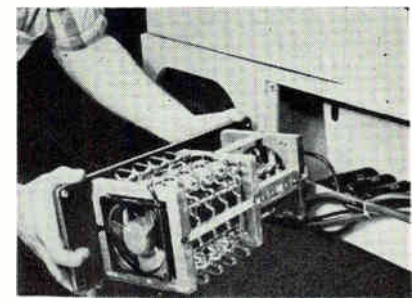
India Is Expanding Its Telecommunications Nets

INTERNATIONAL Development Association has given India a development credit equivalent to $42 million, the United Nations has announced. The funds will be used by the Indian Post and Telegraphs Department to purchase telephone and telegraph equipment as part of a $282.5-million expansion plan.

The United Nations is also contributing $985,400 and the Indian government $2 million to assist the Indian Central Scientific Instruments Organization to improve instrument development and production in India.

Transistors Save Truck Batteries

Drive control system cuts power consumption up to 73 percent



PULSE WIDTH *modulating switch fits into side of lift truck*

STATIC POWER transistors, used instead of conventional contactors and resistors in the electrical drive control system of lift trucks, enable power savings up to 73 percent, reports Allis-Chalmers Manufacturing Company.

A pulse-width modulation technique provides a smooth, continuously variable speed control, the company says. Paralleled power transistors are switched at a rapid rate to apply full battery voltage to the drive motor in pulses having constant frequency but variable width.

Transistor switching rate and on time (pulse width) within each switching cycle is determined by an auxiliary low-power circuit to which the speed control is connected. Although full battery voltage is applied during on times, the motor is supplied with a lower average voltage than that of the battery.

DIODES—Another feature is the use of diodes to provide an inherent current multiplication factor that reduces starting current drain of the battery by about 75 percent, the company said.

The motor is supplied with a higher average current than that of the battery through the action of a "free-wheeling" diode in the motor armature circuit. The diode permits current to continue flowing during off times. The current thus "coasts" or "free wheels" in the motor circuit, decreasing only in response to motor loss. Switching times of 50 microseconds result in relatively small variations of motor current. On-off cycle time is 8.3 milliseconds. During switch closure, motor current increases slowly due to motor inductance. After the switch opens, motor current continues to flow through the free-wheeling diode, dropping gradually due to losses in the motor. The process is repeated, resulting in an average motor current that is centered between maximum and minimum current values.

Heavy-load or high-torque conditions require greater on times. Since this corresponds to full battery voltage applied to a motor loaded to nearly stall conditions, extremely high currents flow. When currents exceed a preset value, power switch is turned off before the normal turn-off time. Similar monitoring of voltage is provided to prevent motor damage due to undervoltage operation.

Thermionic Waste Heat Runs Thermoelectric Unit

POWER OUTPUT of 15 watts and efficiency of 7.3 percent has been obtained from an experimental cesium thermionic-thermoelectric cascade generator. Waste heat from the thermionic unit, which fits inside the thermoelectric unit, powers the thermoelectric generator.

The thermionic unit, developed by Thermo Electron Engineering Corp. has molybdenum emitters and collectors, operates at a temperature of 1,440 C and by itself produces 12 to 13 watts at 5 percent efficiency. The thermoelectric unit, by Minnesota Mining and Manufacturing Co., uses lead-telluride elements and is rated, at 500 C, at 9.4 watts and 6.6 percent.

Better heat transfer between the units is expected to improve efficiency to 10 or 12 percent. The model used an electric heater to simulate a radioisotope source. Voltage of the thermionic output was raised to 6 volts, to match the thermoelectric unit's output, by a solid-state converter developed by 3M.

Announcing

The Gilbarco Heatless Air Dryer

In pace with the tempo of today's expanding technology, Applied Pneumatics, Inc., developed and manufactured a heatless air dryer, employing a patented adsorption process developed by Esso Research and Engineering Company. From its inception, the Applied Pneumatics Dryer was a "revolutionary" mechanism. Fractional in size to its competitors, compact and lightweight, it sold for less than one-quarter the price of other dryers.

The military, and engineers in orbital space projects, quickly recognized the advantages of the new dryer. For the past three years, virtually the entire production of Applied Pneumatics has gone into defense or space exploration projects.

Now a change has taken place. Applied Pneumatics has become a division of Gilbert & Barker Manufacturing Company. For the first time, Applied Pneumatics Air Dryers are in large scale production, available for any purpose under the Gilbarco trade name.

Gilbert & Barker has been manufacturing equipment for the petroleum industry since 1865. For the past twenty years, it has produced weapons systems for the military. Gilbarco products are used in every country in the world outside the Iron Curtain. Gilbarco's engineering and manufacturing facilities are now combined with the talent and experience of Applied Pneumatics personnel. The result is even better heatless air dryers, even lower priced, and now available in any volume.

If you need ultra-dry air in any of your operations, write:

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APPLIED PNEUMATICS DIVISION
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A few valuable sales franchises are available.

MEETINGS AHEAD

AIR FORCE SCIENCE & ENGINEERING SYMPOSIUM, AF Systems Command and Office of Aerospace Research; Houston, Texas, **Oct. 9-11.**

MAGNETOHYDRODYNAMICS CONFERENCE, Michigan State University; at the University, East Lansing, Mich., **Oct. 10-11.**

AEROSPACE ELECTRICAL/ELECTRONICS EQUIPMENT & SYSTEMS DISPLAY, Aerospace Electrical Society; Pan Pacific Auditorium, Los Angeles, **Oct. 10-12.**

URSI-IRE FALL MEETING, URSI, IRE-PGAP, et al; Ottawa, Canada, **Oct. 15-17.**

SPACE PHENOMENA & MEASUREMENTS SYMPOSIUM, IRE; Statler-Hilton Hotel, Detroit, Mich., **Oct. 15-18.**

INSTRUMENT-AUTOMATION CONFERENCE AND EXHIBIT, Instrument Society of America; Coliseum, New York City, **Oct. 15-19.**

ELECTRONIC RELIABILITY CONFERENCE, IRE-PGRQC, PGPEP, PGCP; Stevens Instit. of Tech., Hoboken, N. J., **Oct. 19.**

MOTION PICTURE AND TELEVISION ENGINEERS Convention and Equipment Exhibit, Drake Hotel, Chicago, **Oct. 21-26.**

AEROSPACE & NAVIGATION ELECTRONICS EAST COAST CONF., IRE-PGANE; Baltimore, Md., **Oct. 22-24.**

COMPUTER APPLICATIONS SYMPOSIUM, Armour Research Foundation; Morrison Hotel, Chicago, **Oct. 24-25.**

ELECTRON DEVICES MEETING, IRE-PGED; Sheraton Park Hotel, Washington, D. C., **Oct. 25-27.**

QUALITY CONTROL MIDWEST CONFERENCE, Amer. Soc. for Quality Control; Statler-Hilton Hotel, Denver, Colo., **Oct. 26-27.**

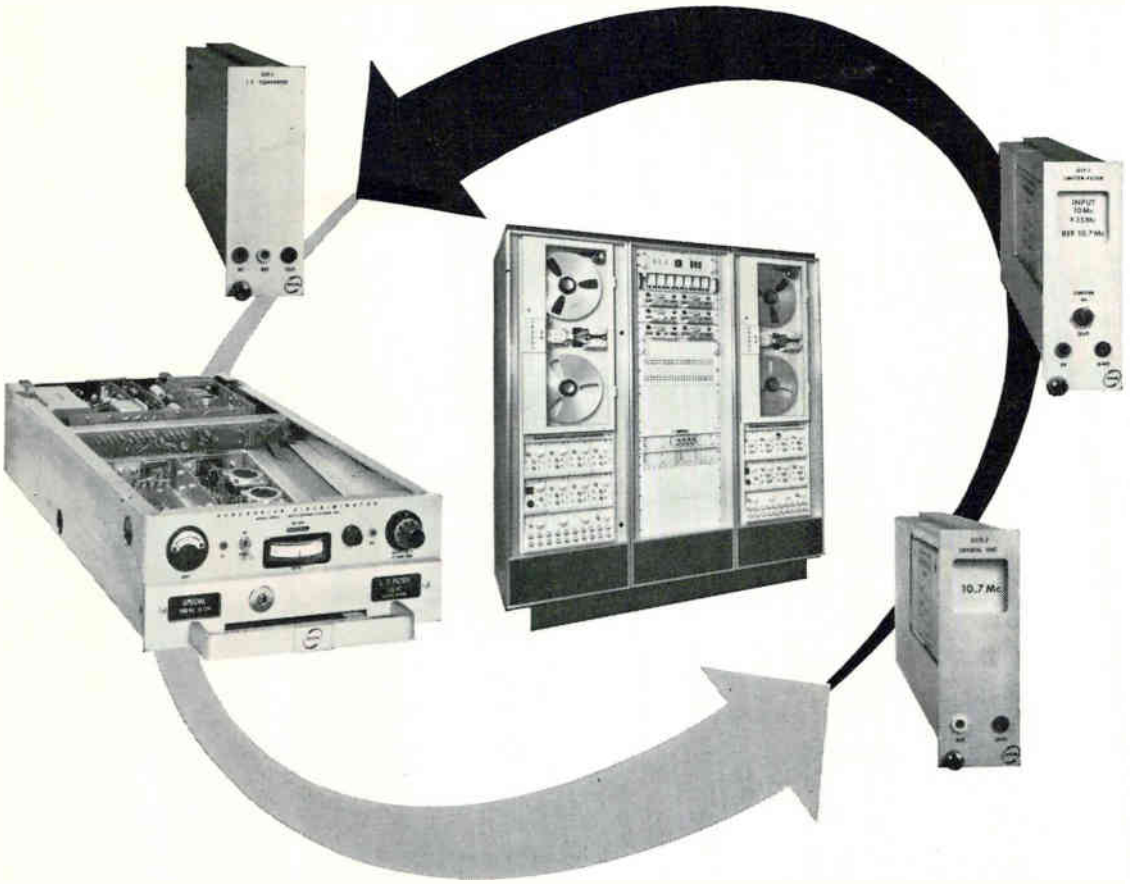
MEDICINE & BIOLOGY ELECTRONICS TECHNOLOGY CONFERENCE IRE-PGBME, AIEE, ISA; Edgewater Beach Hotel, Chicago, Ill., **Oct. 29-31.**

NORTHEAST RESEARCH AND ENGINEERING MEETING, IRE; Somerset Hotel and Commonwealth Armory, Boston, Mass., **Nov. 5-7.**

IEEE INTERNATIONAL CONVENTION, Institute of Electrical and Electronic Engineers; Coliseum and Waldorf-Astoria Hotel, New York, N. Y., **March 25-28.**

ADVANCE REPORT

SPRING JOINT COMPUTER CONFERENCE. *American Federation of Information Processing Societies; Cobo Hall, Detroit, Mich., May 21-23, 1963. Dec. 1 is the deadline for submitting complete papers not exceeding 10,000 words and 100-150 word abstracts to: P. W. Pollard, Burroughs Corporation, 6071 Second Avenue, Detroit 32, Mich. Areas of interest include: analog and hybrid systems; artificial intelligence; algorithms in business data processing; machine organization including hardware-software interplay; new logic and memory devices; data acquisition (transmission and display); information retrieval (including applications); programming.*



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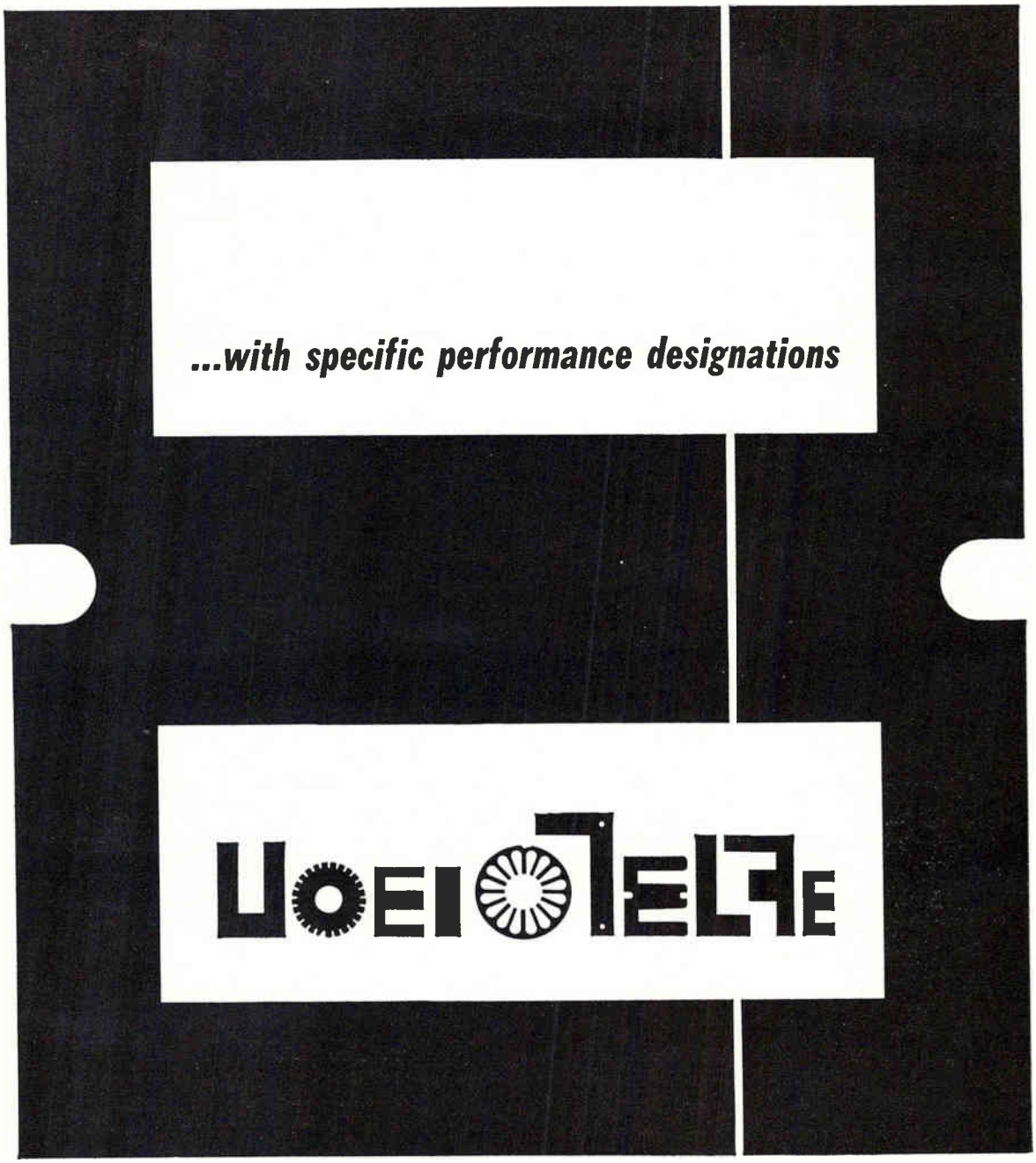

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RTV-102 is useful as an adhesive or sealant for metal fabrication. Will not sag on vertical or overhead surfaces.

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For free evaluation sample plus technical data, write on your letterhead describing your application to Section N1073, Silicone Products Department, General Electric Company, Waterford, New York.

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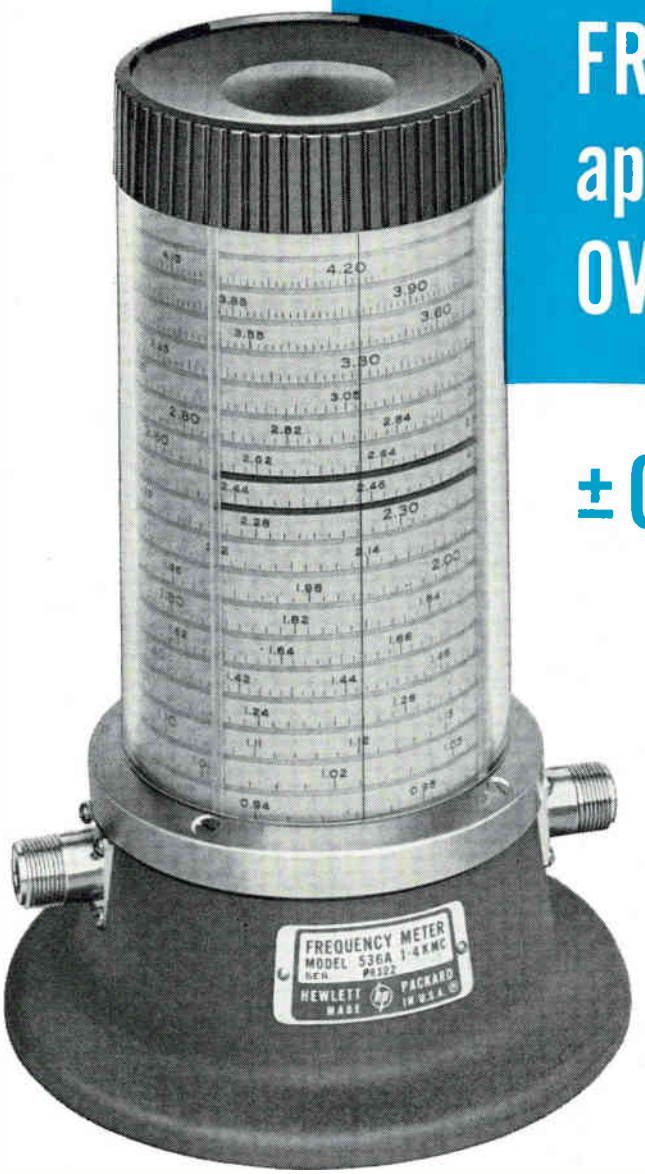
No comparable COAXIAL FREQUENCY METER approaches this OVERALL accuracy:



hp 536A Coaxial Frequency Meter

± 0.17% from 1 to 4.2 GC!

. . . because this specified accuracy includes all the variables: ± 0.02% for 0-100% relative humidity, ± 0.0016% per °C from 13 to 33°C, and 0.03% backlash! Therefore, dependable accuracy is obtained even under adverse conditions.

Further, the new hp 536A Frequency Meter gives maximum reading accuracy with its high resolution spiral dial of 180 inches calibrated in 2 MC increments. All frequency calibrations are visible, you know at a glance what portion of the band is being measured.

More, the hp 536A introduces no spurious resonances at any setting. Resonance is indicated by a dip in output power of approximately 1 db. A non-contacting plunger provides smooth tuning and long life. Call your hp representative today for a demonstration of the hp 536A or the hp 532 series waveguide frequency meters, 3.95 to 40 GC.

SPECIFICATIONS, hp 536A

Frequency range:	960 MC to 4.2 GC
Overall accuracy:	± 0.17% from 1 to 4.2 GC; ± 0.22% from 960 MC to 1 GC
Q:	Approximately 1,500
Dip at resonance:	At least 1 db from 1 to 4 GC; at least 0.6 db from 0.96 to 1 GC and from 4 to 4.2 GC
SWR off resonance:	Less than 1.2
Calibration increments:	2 MC
Connectors:	Type N female
Dimensions:	9⅛" high, 6" diameter, 13 lbs.
Price:	$500.00.

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electronics

October 12, 1962

MILLIMETER WAVEGUIDE *developed by Bell Laboratories, typical of newly developed practical components, has an estimated cutoff frequency of 500 Gc*

Millimeter Waves . . .

WHAT WE HAVE, WHAT WE NEED

Extension of conventional microwave techniques has resulted in the development of equipment in the lower millimeter region. But because of unique problems, the region above about 100 Gc is virtually untouched

By LAURENCE D. SHERGALIS, Associate Editor

MILLIMETER WAVELENGTHS, that part of the spectrum from 30 to 300 Gc, offer rich rewards in space exploration, communications, radar and investigation of many scientific phenomena. But the problems are formidable. Because the millimeter band sits astride the transition from radio to quasi-optical techniques, the scientific knowledge required to develop systems and new techniques includes disciplines beyond the scope of many engineers.

Thus, a background in many related fields is needed to help solve the problems of:

- Power generation
- Detection
- Transmission and propagation
- Design of components
- Instrumentation and measurements

These problems exist because of some of the inherent characteristics of millimeter waves. Short wavelengths require small equipment built to close tolerances. Size, while an advantage, can limit power-handling capability. Atmospherics effect millimeter wave propagation in many ways and are under constant study.

Advantages of millimeter wavelengths include:

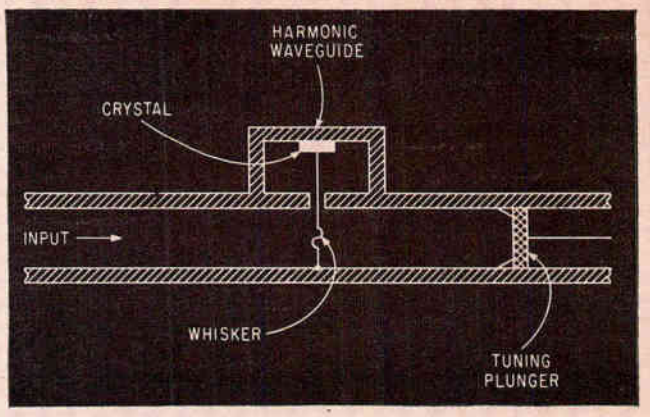
- Opening of a new expanse of the frequency spectrum
- Availability of space for wide-bandwidth systems
- Ability to concentrate large amounts of power in small beams
- Reduce interference in long-range space communications
- High resolution for radar and navigation systems
- Ability to study plasmas and other phenomena

Simple extension of microwave techniques to the millimeter region is not enough. New techniques must be invented.

POWER GENERATION—One of the most serious tech-

FORGOTTEN FRONTIER?

Is the technological barrier the only reason that millimeter equipment development seems to be slow? Not according to a comment made by a sales manager of a well-known microwave components maker who said, "There's no money in it for us. Our sales of specials in millimeter components amount to less than 1 percent of our yearly gross. Besides we don't have the manpower to do extensive development work in millimeter equipment." Other firms admit that sales are almost exclusively to low volume buyers such as laboratories and research groups. Most of the quasi-optical components needed are made by the people working on the project



DIODE MULTIPLIER *equivalent circuit shows how energy is picked up by the tungsten whisker and fed to the silicon crystal. Harmonics are fed into the smaller guide that filters out unwanted orders—Fig. 1*

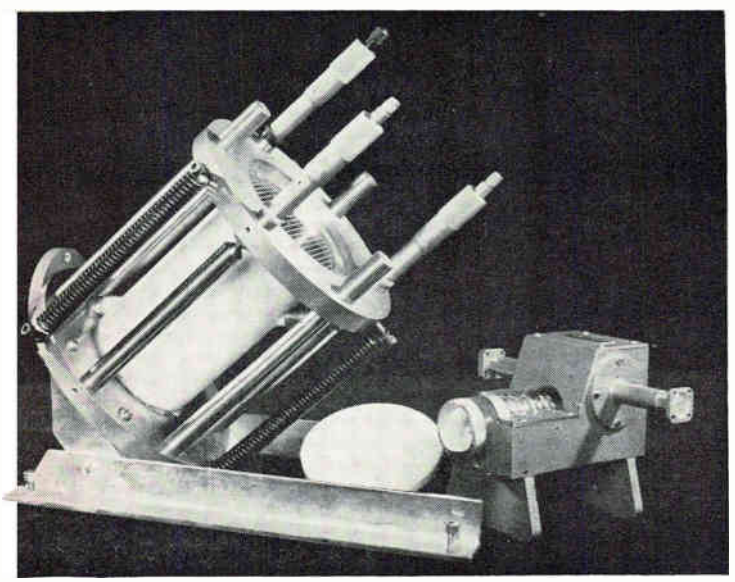
nological bottlenecks in millimeter wave systems is the development of power sources to produce one or two orders of magnitude more power than is available today.[1] Two distinct approaches are currently being studied: (1) frequency conversion, and (2) self-excited prime generators.

Frequency conversion is the most common approach and to date has been the most successful. Devices to generate millimeter power by this method are classed as active or passive. Active frequency multipliers include traveling-wave tubes and a bunched, high-energy electron beam. Both are considered nonlinear elements.

Passive frequency multipliers include semiconductor diodes, ferrites and microwave gas discharge devices. Among the semiconductor devices, varactor multipliers are becoming common. Outputs of 8 milliwatts at 50 Gc have been achieved using a multiplication of five.[2] Using a specially mounted silicon crystal in a waveguide structure, Gordy at Duke University obtained small amounts of energy at 0.5 mm.[3] He used the eighteenth harmonic of a Q-band klystron. Conversion efficiency is difficult to measure, and, little information is available. But published data seems to indicate a loss of about 15 db a harmonic.

Efficiency of nonlinear reactance harmonic generators can be high if suitable coupling circuits are used. These circuits require impedance across the diode to be high at all frequencies other than the fundamental and the desired harmonic. The design problem is difficult.

Power dissipation within the crystal structure is limited so that low efficiencies cannot be compensated by increasing power input. This is a common difficulty with semiconductor harmonic generator systems that is not present in other forms of multipliers. The cross-guide crystal multiplier, Fig. 1, is typical of this kind of device.

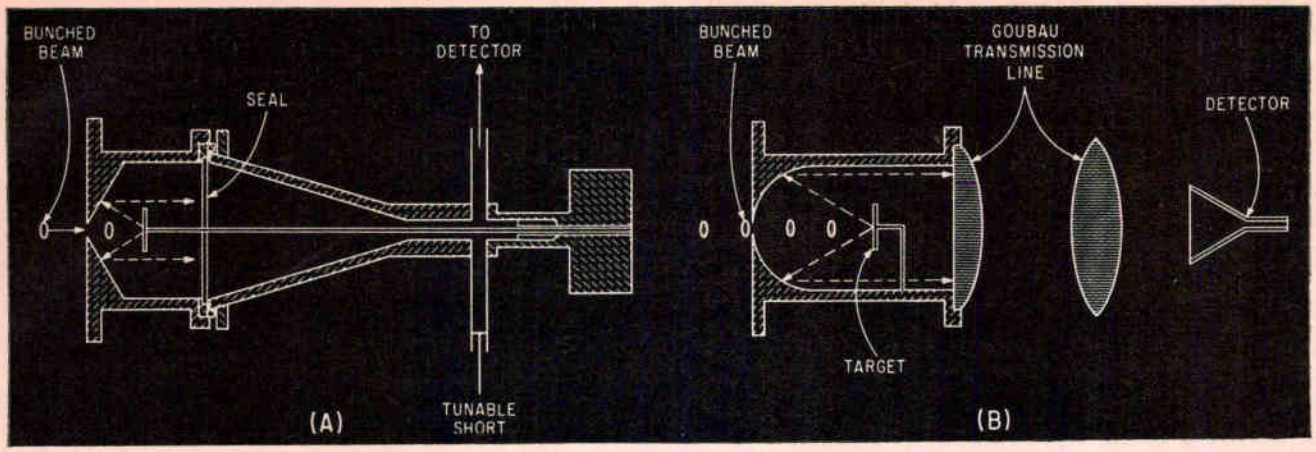


FABRY-PEROT *resonator used in 8-mm experiments at University of Illinois has end plates made in form of gratings. Gratings couple radiation out and simulate the half-silvered end plates used in optical units—Fig. 2*

FERRITE DOUBLERS — Ferrites exhibit frequency doubling characteristics and an output of 8 kilowatts at 15 mm has been obtained at 25-percent efficiency. Outputs of 60 watts at 70 Gc have been obtained and it is expected that this output can be achieved at 140 Gc.[4] Presently, outputs of peak pulse power of about 30 to 40 watts at 140 Gc are reported. Ferrites have been used in pulsed operation so far, and the possibility of their use for low-level c-w operation does not appear promising.

Nonlinearities associated with gas discharges and plasmas have been tried as harmonic generators. In 1956 coherent radiation was produced using gas discharges and resulted in generating useful amounts of 4th harmonic power. A few years later an experiment was conducted in which a gas discharge tube was placed across a junction between a waveguide carrying 3-cm exciting power and a waveguide carrying the harmonic power. A peak power of about 30 milliwatts at 3 cm was obtained. Conversion loss of 48 db for the 4th harmonic and 55 db for the 8th harmonic were obtained. The discharge gas was wet air.[2]

Studies of various types of discharge structures and effects of different discharge gases are under way. Experiments at Oxford using neon gas under pressures ranging



DECELERATION *of a bunched beam in the apparatus (A) produces bremsstrahlung radiation. Addition of dielectric Goubau transmission line (B) focuses radiation on the detector—Fig. 3*

from 5 to 40 mm Hg have resulted in an 8-mm output of 10 millwatts for a 20 Kw input.[6] This is the 12th harmonic of the source, conversion loss being 63 db.

Among the active frequency multipliers, traveling-wave tubes are widely used. Harmonic content of twt output is due to beam bunching. The helix has wide-band characteristics and couples the harmonic power out. Predictions of twt future as millimeter-wave generators indicate that a c-w output of about 10 watts at 100 Gc will be possible, using conventional delays at a voltage of about 10 Kv and a beam current of about 150 to 200 ma. Structure of the traveling-wave tube limits its power output because of its limited heat dissipating ability. But it is believed that usable power at about 300 Gc may be attained using two tubes in series, the first as a frequency doubler from a 50-Gc source and the second as a frequency tripler.[2]

MEGAVOLT ELECTRONICS—Generation of millimeter radiation using megavolt electronics techniques requires a tightly bunched electron beam at a beam voltage of about one megavolt. This technique, now under intensive investigation by the Ultramicrowave Group at the University of Illinois, depends upon the formation of a tightly bunched beam and excitation of an electromagnetic field by this beam.[6] The electromagnetic field has harmonics of the bunching frequency, and the success of the method lies in the possibility of exciting sufficiently high harmonics. For example, at a bunching frequency of 3,000 Mc, the hundredth harmonic is required for a 1-mm output. A drawback of the megavolt-electronics technique is that pulsed rather than c-w is obtained.

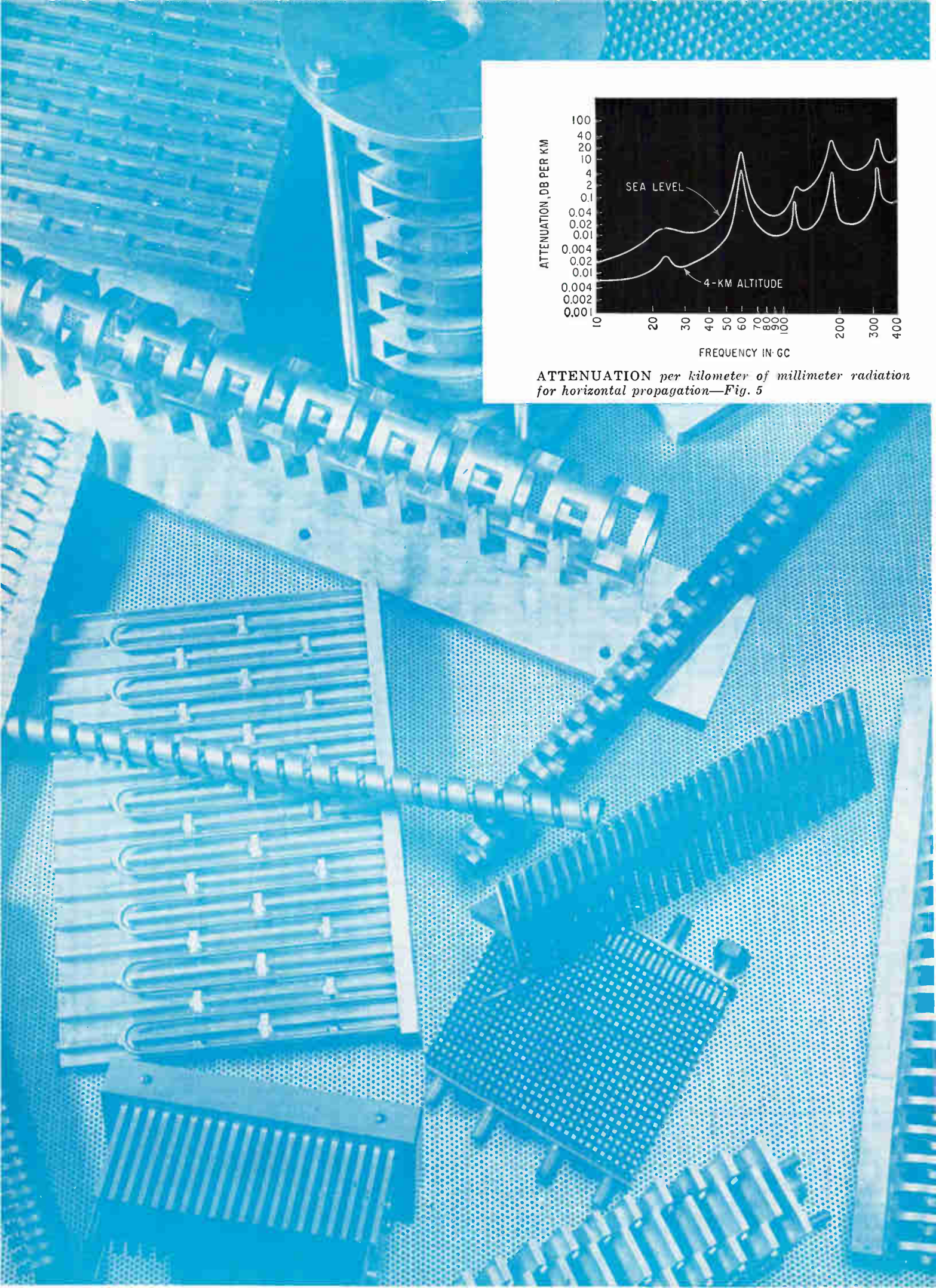
An application of the interaction of an electron beam with a plane wave is a Febry-Perot resonator, Fig. 2, in which standing waves are set up. A bunched, 1-megavolt beam generated by the rebatron, a single-cavity microwave accelerator, enters the resonator and is reflected on a copper target. One of the two plane surfaces within the interferometer is slitted to permit coupling to a waveguide system. Experimental data reveals a power of 150 milliwatts at 36.9 Gc. The apparatus is tuned by adjusting the spacing between the parallel planes. Loaded Q is about 1,500. Teflon is the dielectric used.[7]

Another method promising reasonable power at millimeter wavelengths uses the effect produced by accelerating then decelerating an electron beam. If an electron is decelerated, and the direction of motion is unchanged, radiation called bremsstrahlung is produced and is similar to the method by which X-rays are generated. An apparatus, Fig. 3A, devised by members of the Ultramicrowave Group has been able to produce coherent radiation at the 42nd harmonic of the rebatron operating frequency, that is 2.6 mm. In this scheme, optical techniques for transmission are preferred over waveguide techniques. The bunched electron beam is reflected from a metal target in a Goubau optical transmission line. A series of dielectric lenses, Fig. 3B focuses the output on the detector.[8]

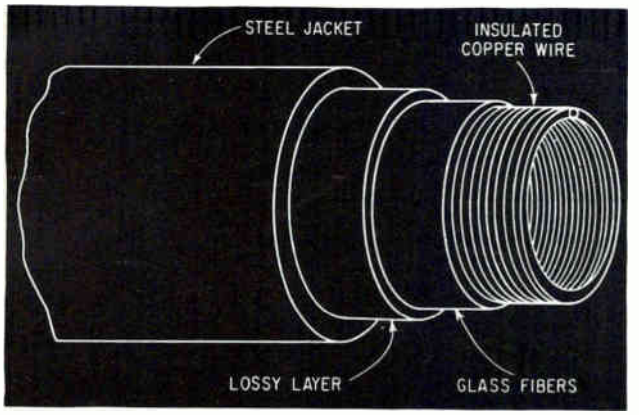
Bremsstrahlung radiation devices show promise for generation of radiation up to frequencies as high as 0.1 mm. Power in the milliwatt range should be available at these frequencies. Another advantage of this method is that physical dimensions of the components can be several orders of magnitude greater than a wavelength. Thus optical techniques can be employed.

Doppler frequency shift is promising as a generating device although practical problems become sophisticated. A long magnetic field is required. The Ultramicrowave Group has constructed a solenoid providing about 5,000 gauss over a 10-cm length, but no positive results have been reported.[8]

Conventional primary oscillators in which oscillations are self sustained comprise three common groups: magnetrons, klystrons and backward-wave oscillators. Design and operation of generators employing these devices have been adequately covered in the literature. Commercial units include O-type carcinotrons made by Compagnie generale de telegraphie Sans Fil (CSF), a high power production model provides from 100 to 1,000 watts over the range 125 to 145 Gc. A laboratory sample with a power output ranging from 1 to 14 milliwatts at 0.7 mm is also available. CSF is working on a tube to provide a reasonable output at 0.5 mm. They believe that a 0.1 mm tube is entirely feasible.[9] Because the slow wave structure is small at these frequencies and beam current density becomes high, other methods, Fig. 4, are being tried to



ATTENUATION *per kilometer of millimeter radiation for horizontal propagation—Fig. 5*



HELIX WAVEGUIDE *developed by Bell Labs. Loss characteristics of the lossy layer are varied to adapt the guide for different uses—Fig. 6*

overcome these limitations. Field emission cathodes and cold cathodes will be tried.

Sylvania, Bell Laboratories and Bendix manufacture backward-wave oscillators in the region above 50 Gc. Watkins-Johnson has reported development of a bwo with an output peak pulse power of 100 Kw and an average power of 1 Kw and tunable over the range of 94 Gc to 100.5 Gc.

Raytheon has a series of millimeter klystrons, the highest frequency being 100 to 120 Gc with a minimum power output of 20 milliwatts. Several narrow band types are available that provide about twice that power at less than half the frequency range, centering about 100 Gc for the highest frequency unit. Varian, Elliott Brothers, Litton, Amperex (Philips), E.M.I., Sperry and OKI Electric Industry Co., Ltd., Tokyo are other manufacturers of millimeter klystrons. Philips has a unit that provides power out in excess of 10 milliwatts at 140 Gc. Recent experiments demonstrated the feasibility of using a reflex klystron as an amplifier at millimeter frequencies. Using a Raytheon QKK 838 klystron, Marquette University researchers achieved a gain of 17.5 db at 73.76 Gc.[10]

Bomac, E.M.I., Elliott Brothers, Amperex, Westinghouse and Sylvania are among the suppliers of magnetrons in the millimeter region. Westinghouse has a 35 Gc magnetron with a power output of 100 Kw and weighing 6 lb. Experimental work at Columbia University reveals the possibility of magnetron outputs of 1 to 2 Kw peak at wavelengths under 3 mm. Frequency limits for magnetrons are dictated by the size of the cathode and anode. An axial beam injection method is being considered to avoid this limitation.

Many other methods of generating millimeter waves are being investigated. These include systems from which radiation is obtained from an electron traveling through a medium faster than the velocity of light through that medium (Cerenkov effect), an orbiting electron cloud (tornadotron), radiation from precessing electron spins, plasma oscillations in gases and solids, masers, and optical frequency mixing. Work on these schemes is still going on. The scope of activity in the power generation area indicates the magnitude of the problem and its importance to the system designer.

DETECTORS—Commonly used millimeter-wave detectors are the semiconductor devices. Silicon crystals have been in use for some time, but investigations into germanium and gallium arsenide show that these materials have great promise. With crystal detectors, mounting is of great importance. Two types of mounts are used—a cartridge and a crystal permanently mounted in a section of waveguide. The in-guide mount is sensitive, but is less rugged and is more difficult to adjust.

Conversion gain of a millimeter detector diode increases with d-c bias. Shot noise across the diode also increases, but the increase in gain is faster than the increase in noise. Therefore, both the noise figure of the diode and its minimum detectable signal are decreased.[11]

Commercial crystal detectors are available from several manufacturers and are capable of detecting signals up to about 140 Gc. Some include a tuning device to reduce vswr at any frequency.

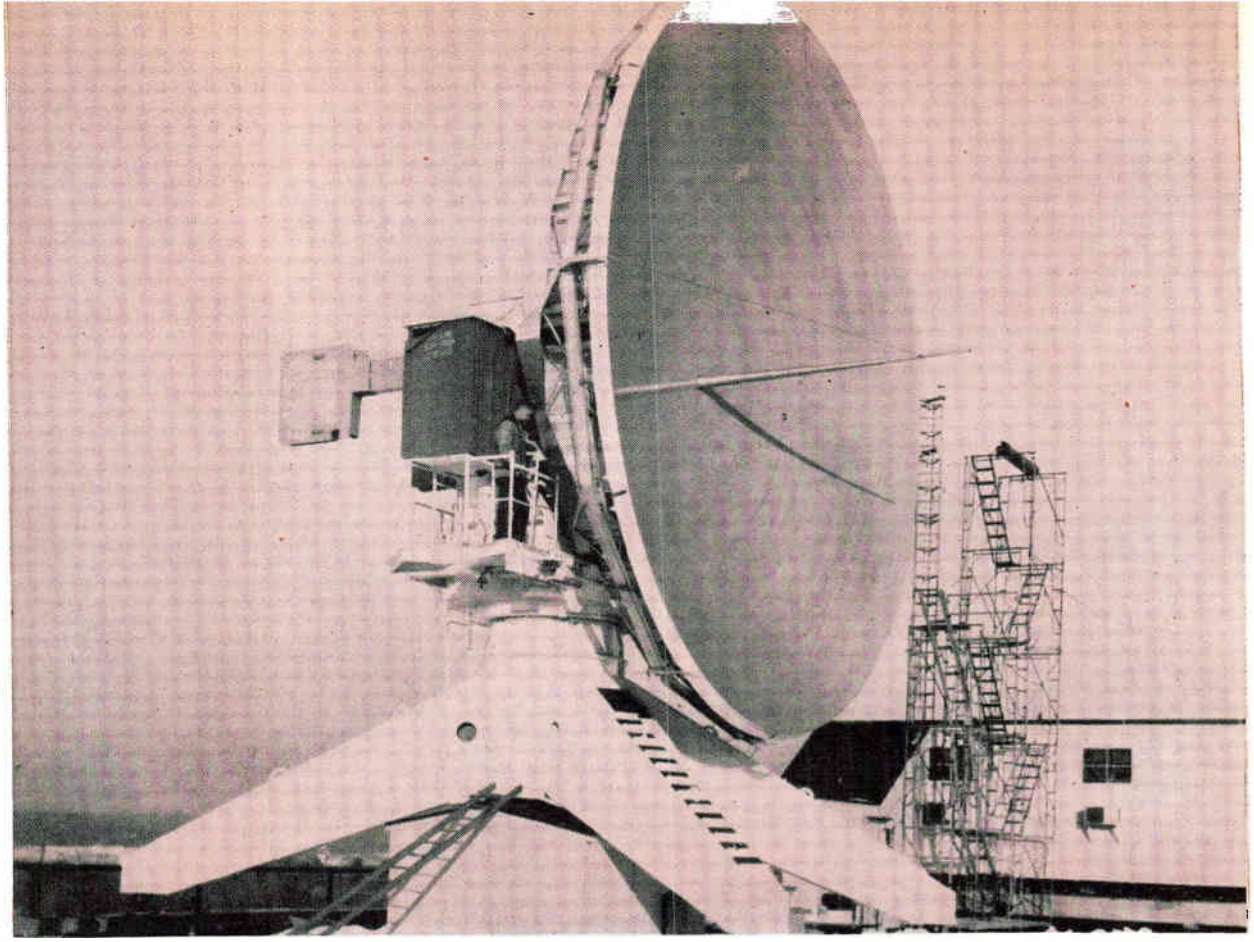
Crystal detectors are more sensitive and have shorter time constants than other detectors at the longer wavelengths. But platinum wire bolometers have been found sensitive at wavelengths below 3 mm, and usable results with a fine-wire bolometer have been reported at 1.4 mm. Evacuation of the bolometer holder and low-temperature operation will improve performance. In an experiment at 4 mm with a PRD 634 bolometer in an evacuated holder, a minimum detectable power of 4×10^{-11}-watt was calculated.[12]

A device used as an infrared detector, the Golay cell, has been found usable as a millimeter detector to wavelengths as low as 7.5 mm. It detects pressure changes in a small volume of gas that is heated by incident radiation. Sensitivity is constant well into the millimeter region. Rise time is about 15 μsec. New detection techniques are being explored, with a goal of sensitivity at least 10 to 15 db better than that now available.

TRANSMISSION AND PROPAGATION — Atmospheric attenuation of millimeter radiation is important in determining the usefulness of a system for a particular application. Certain types of radio relay service are impractical because of the vagaries of atmospheric absorption. On the other hand, the oxygen absorption effect may be used to advantage for radio systems in congested areas or for military security.

At frequencies below the millimeter band, diffraction and reflection are more significant than atmospheric absorption and scattering. At millimeter frequencies, the most important source of attenuation due to scattering is rain, snow and fog. During an average rainfall, attenuation in the range from 4 to about 12 mm is about

SLOW-WAVE *structures of various types are under study by CSF for possible application to higher powered millimeter O-type carcinotrons—Fig. 4*



SPINCASTING *used to fabricate this 28-foot dish results in a high precision surface for millimeter work—Fig. 7*

6 db per mile for each millimeter per hour of rainfall. At high rates, the attenuation may reach 15 db per mile.[13]

Attenuation due to water vapor and oxygen is more complex. Experiments reveal windows, Fig. 5, below about 20 Gc, between 30 and 50 Gc, between 75 and 100 Gc, and periodically on up to one at about 850 Gc. The popular 70-Gc frequency is not an optimum transmission frequency.

Multipath fading due to reflections is usually avoided by using narrow beamwidths. But scintillations in the signal due to atmospheric variations are observed. Duct effects and reflections from temperature inversions are possible and may be detected as a mirage.

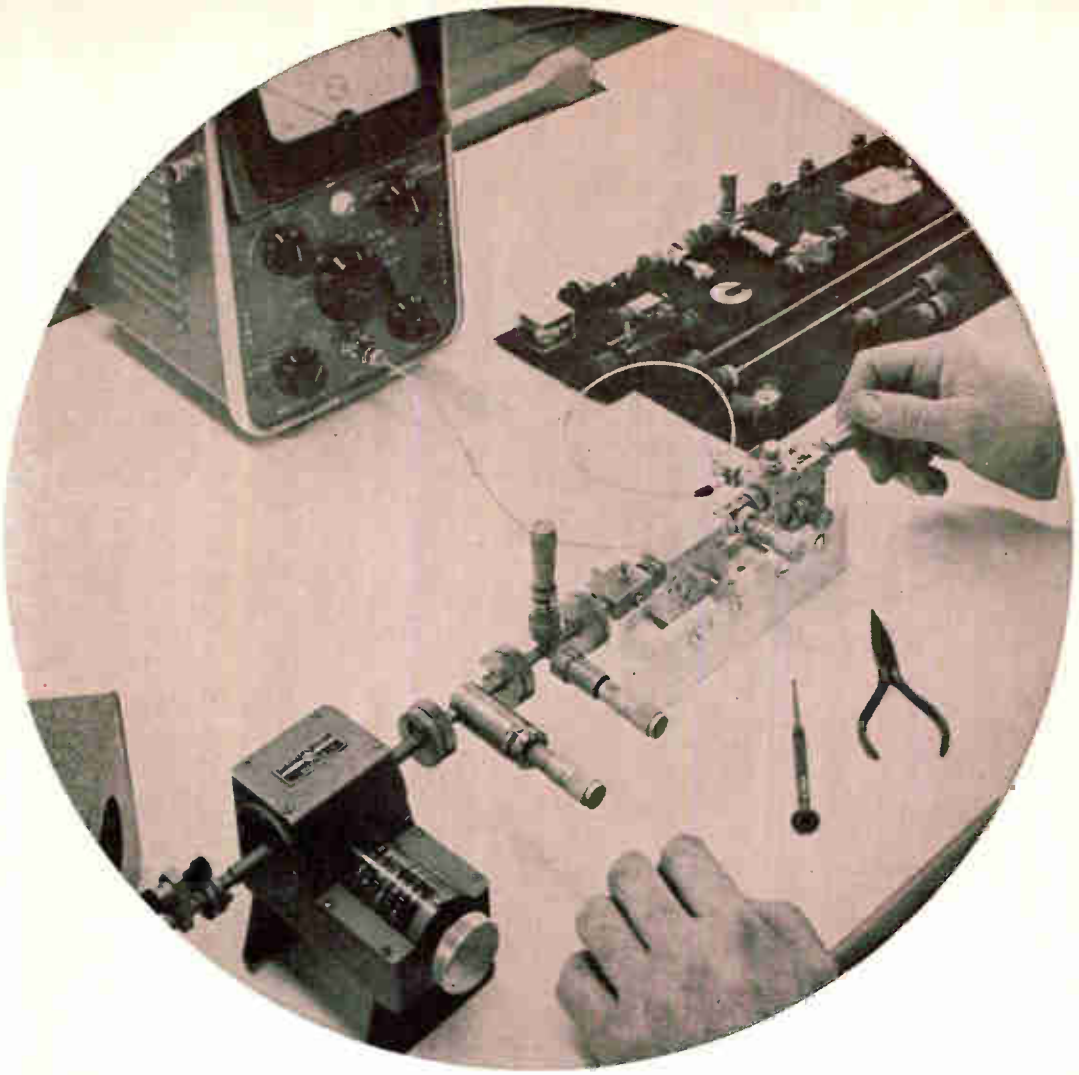
Because of their similarity to optical frequencies, millimeter waves may be guided in free space by a wide variety of dielectric lenses, antennas and feed systems. Dielectric prisms and reflectors offer interesting possibilities for transmitting millimeter energy around corners. Attenuation of such free space transmission systems is found to be less than that of conventional waveguide systems.

CIRCULAR-MODE GUIDE—Work at Bell Telephone Laboratories has overcome losses of conventional waveguide structures by employing the circular electric (TE_{01}) mode in round waveguides. Theoretical losses at millimeter frequencies in an ideal pipe are low—in the order of 2 db per mile. But it is impossible to realize a perfectly straight round tube practically. Deformities in the pipe, including joint imperfections such as offsets and tilts, cause transfer of energy from the low-loss TE_{01} mode to undesired modes. Axial straightness over a distance of about 3 feet has been difficult to measure mechanically. It has been evaluated by making electrical measurements and relating straightness deviation theory to electrical performance.

An approach to the mode conversion-reconversion problem has been tried successfully by Bell Laboratories. Taking advantage of the fact that a TE_{01} circular electric wave has an attenuation coefficient which, in a given size circular waveguide decreases as frequency is increased, Bell Labs has devised helical waveguide, Fig. 6.[14, 15, 16] It has several unique features.

Conventional rectangular waveguides are dimensioned so that only the dominant mode will propagate. But at millimeter frequencies, a waveguide large enough to give losses of 2 db per mile also permits the existence of a number of unwanted modes. Helix waveguide allows low loss for the TE_{01} mode and high loss for all other modes. Use of a highly lossy jacket between the helix and shield provide the high unwanted mode absorption. Therefore, a guide diameter of 2 inches may successfully propagate radiation up to 80 or 90 Gc. There is essentially no theoretical upper limit, but the practical limit depends upon guide imperfections and straightness. An approximate cutoff frequency of 500 Gc has been estimated.

A medium or high loss jacket between the helix and shield is used for applications requiring gentle bends in the guide. For sharp bends, the material should be low loss with a highly conducting shield. Losses in an ex-



COMPONENTS *in the 2 to 3-mm range made by FXR are used in this test of residual vswr of a slotted line—Fig. 8*

perimental section of helical guide installed at Bell Laboratories, Holmdel, N. J. installation have been measured to be about 2 to 3 db per mile in the frequency band between 35 and 90 Gc.

Helical waveguide is also being manufactured by Sumitomo in Japan under Bell licenses. and other work in this area is going on at Standard Telecommunications Laboratories, Ltd. a subsidiary of ITT in London.

Dielectric image lines may be applied to transmission of millimeter wave energy at frequencies up to about 100 Gc. Work at Johns Hopkins University has been performed on several types of lines using various dielectric materials. A tape line in which the dielectric material takes the form of a narrow tape or ribbon has also been developed. Polytechnic Institute of Brooklyn has also made some studies of dielectric lines.

ANTENNAS—Effectiveness of a parabolic antenna is proportional to the quality of its surface. Surface tolerances should be within $\frac{1}{16}$ of a wavelength. otherwise effectiveness is nulified. At millimeter wavelengths. these tolerances become difficult to maintain. especially on antennas where the effective diameter is about 1.000 wavelengths or higher.

An adaptation of an astronomy technique has been used by the Kennedy Antenna Division of Electronic Specialty Co. to fabricate large dishes to an rms surface error of less than 0.005 inch. Called Spincasting. the method was used to fabricate a 28-ft diameter antenna, Fig. 7, for Lincoln Laboratries for operation at 8.5 mm. The antenna, one of three large precision antennas in the world, has an effective diameter of 1,000 wavelengths.

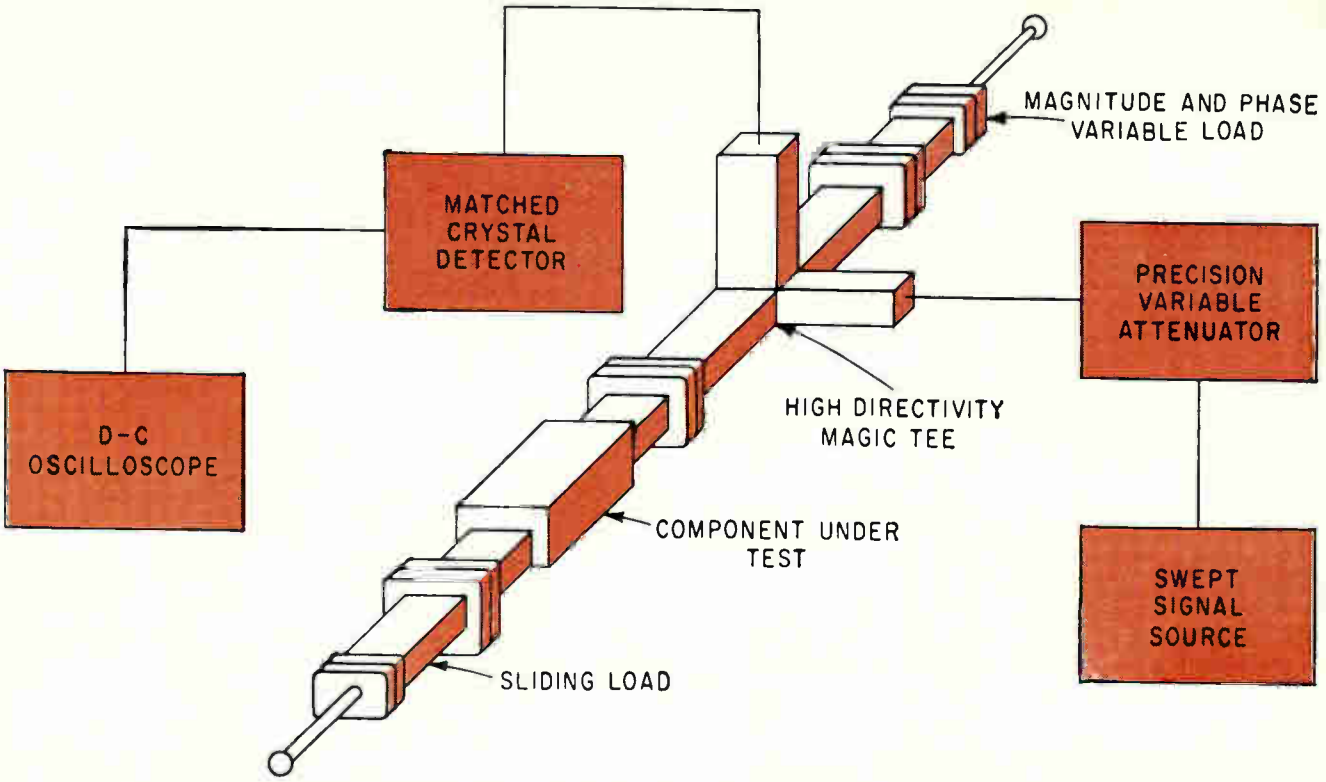
Spincasting is a process where a pool of exothermic-setting plastic is rotated in a special container at a predetermined rotational speed. A combination of gravity and centrifugal force shape the pool into a parabola. Spinning is continued until the plastic sets. Rotational speed determines the focal length of the antenna. After setting, a zinc coating is applied to the plastic by flame spraying and topped with a thin urethane film for protection against weather. Power gain of the antenna is 67.4 db and half-power beamwidth of 4.4 minutes of arc. Sidelobes are down 25 db below the main lobe.[17]

The largest of the millimeter antennas is a 72-foot reflector at the Lebedev Physical Institute in Moscow. It operates at 8.5 mm and has a gain better than 70 db.

The third of the large antennas is the 50 foot dish at the Naval Research Laboratory. It also has been operated in the 8.6 mm region. but at reduced performance.

Narrow beamwidths of these high-gain antennas require mounts capable of extreme stability and relatively unaffected by temperature such as unequal solar heating. Aiming precision of about $\frac{1}{10}$ the beamwidth is desirable. Low loss radomes are one solution to the evironment problem.

HARDWARE—Millimeter components are available from a number of manufacturers up to frequencies of about 220 Gc. These devices are usually extrapolations



VSWR MEASUREMENT *system achieves high accuracy by using a high directivity magic tee—Fig. 9*

of lower frequency units. Otherwise, the region above 100 Gc has been virtually untouched.

Machining tolerances become a large fraction of the dimensions at short wavelengths. New metallurgy techniques are being investigated. Electroforming and spark erosion are among the newer machining techniques that show promise in this development area. Ferrites, dielectrics and various types of lenses will probably become important in the development of new components. Some 2-3 mm componenets are shown in the test set-up in Fig. 8.

INSTRUMENTATION—Measurement techniques at millimeter frequencies lag the level of systems development. In fact, many researchers say that instrumentation lags systems development even at lower frequencies. Standards are yet to be developed.

Power is the basic measurement in microwave and millimeter wave technology. But power measuring devices are scarce. Some water calorimeters exist and crystals are used, mostly at the lower millimeter wavelengths. Calorimeters are difficult to set up and use and are difficult to calibrate. Crystals do not have the required sensitivity to measure the minute amounts of power at these frequencies. Thus, two major problems in this area still exist: lack of an adequately sensitive power measuring system and lack of standards.

Other millimeter parameters—Q, vswr, loss and delay are measurable using some recently developed techniques. Marelli-Lenkurt's Vecchiacchi Laboratory, Milan, Italy has designed and built equipment capable of measuring Q in the million range. This unit measures millimeter cavity and waveguide Q by establishing the relationship between the cavity's resonant frequency and its bandwidth at 3 db down from peak response. The unique part of the equipment is a flexible automatic frequency control system that maintains stability needed to measure these high values.

A precision microwave reflectometer especially applicable for vswr measurements at millimeter frequencies has been devised by Paradynamics Inc.[18] Heart of the system, Fig. 9, is a broadband 60 db directivity magic tee. Previous swept reflectometers using directional couplers did not have sufficient directivity to resolve low values of vswr. However, with directivities of 60 db, accurate vswr measurements as low as 1.01 are possible.

Frequency measurements have been made using a resonator consisting of a pair of parallel perforated plates. Developed at the National Bureau of Standards, the device measures frequency to accuracies of 0.04 percent at 6 mm. Its bandwidth permits operation over a wide frequency range.

SYSTEMS—Bell Laboratories has set up a two-mile section of helical waveguide at Holmdel, N. J. for tests that may lead to development of a complete nationwide millimeter communications network. Waveguide links could carry 100,000 two-way telegraph channels or 100 commercial quality television channels using pulse-code modulation and operating at a frequency between 40 and 90 Gc. Repeaters using twt's would be needed at intervals of about 15 to 20 miles. No timetable for development of the systems has been announced.

Sylvania's Amherst laboratories in Buffalo have set up a two-way voice communications link with transceivers, Fig. 10, at a frequency of 69.9 Gc over a distance of 6.1 kilometers.[19] Transmitter power is about 25 mw using a single Raytheon QKK 865 klystron. Pulse-position modulation is used with time division multiplexing to provide two channels. A signal-to-noise ratio of 12 db

was set up as a system requirement. The receiver is a superheterodyne using the transmitter klystron as a local oscillator. A broadband balanced mixer with an i-f output of 60 Mc feeds an i-f preamplifier and the 60-Mc i-f amplifier.

Results of tests on the system indicate that operation of the initial system was not as stable as desired, even with afc. New crystals, including the new Philco 1N2792 millimeter diodes, are to be investigated to improve receiver performance.

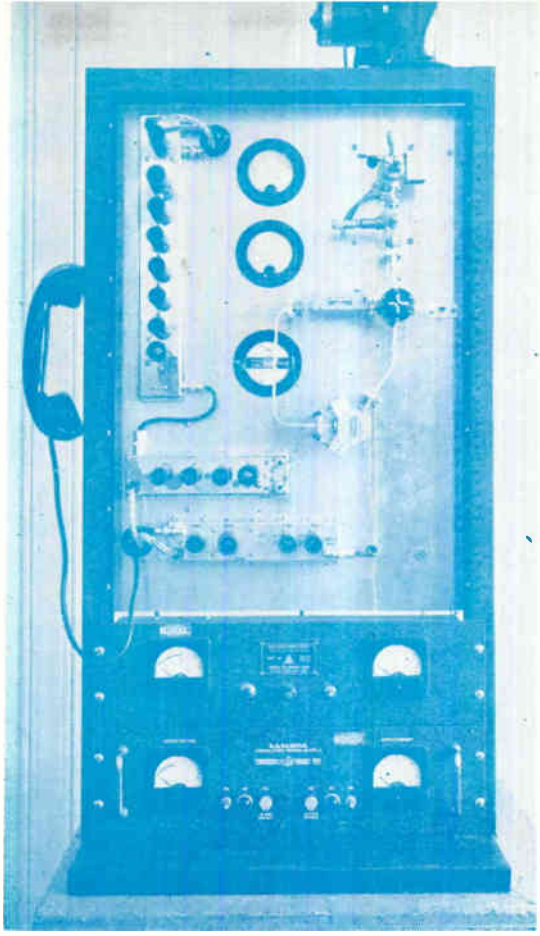
Radar experiments using the moon as a target provide an ideal testing ground for space communications. With this in mind, Lincoln Laboratory scientists have proposed an 8.6-mm radar and an associated low-noise radiometer system.[20] The antenna is the Kennedy 28-foot dish previously described. A temperature-controlled crystal oscillator at about 11.5 Mc multiplied to 35 Gc provides the stable r-f source. An Elliot Bros. type 8FKI two-cavity floating-drift-tube klystron has been selected for the 35-Gc transmitter. It has an output of about 25 watts and can be frequency or phase locked.

Using a crystal of titanium dioxide impregnated with Fe^{+++}, the maser preamplifier is of the three-level, solid-state type. Pump power is about 10 mw at 70 Gc. Liquid helium maintains the cavity and crystal at 4.2 K. Output of the maser is mixed in a conventional 12.5-db noise figure balanced mixer to get a 30-Mc i-f output. A conventional heterodyne system converts the 30 Mc signal to a frequency of 2.715 Mc. Bandwidth is maintained at 250 Kc. The complete system is shown in Fig. 11.

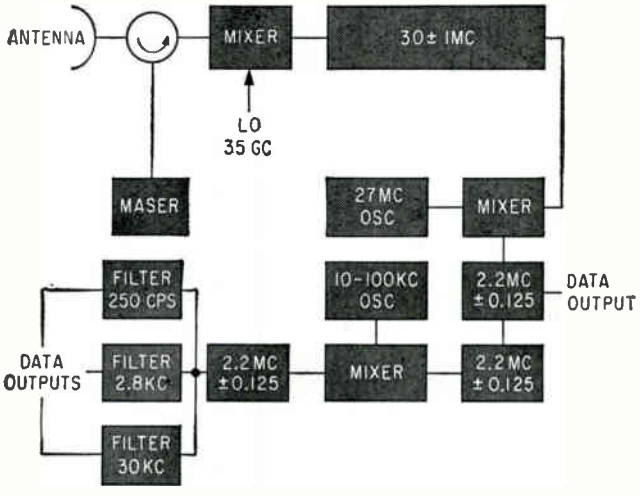
Russian moon reflection experiments have been conducted at S-band and X-band with transmitter powers of 1 and 2.5 Kw respectively. Usable signals were returned, but system performance is lower than that calculated for an 8-mm system because of wide bandwidths.

RADAR DESIGNS—Ground and air surveillance radar designers have avoided the millimeter frequencies because of water-vapor absorption problems. Airport Surface detection equipment (ASDE) now in use operates at about 12 cm. But OKI Electric Industry Co. Ltd., Tokyo has announced two radar units, one operating at 9.2 mm for radio navigation and the other operating at 8.6 mm for airport, harbor and rail yard control. Transmitter power of both units is 30 Kw peak and pulse repetition rate of 4.166 Kc. Transmitter magnetrons are OKI type 33M10 at 9.2 mm and the 35M10 at 8.6 mm. The receiver uses a balanced mixer with 1N53 crystals. Local oscillator is an OKI type 35V11 klystron and the i-f is 150 Mc. Minimum detection range is 10 meters and maximum range is 20 Km with range resolution at that distance of 30 meters. Avoidance of disturbances caused by fog and rain is obtained through the use of a combination of a low-lying cosecant-squared beam pattern and a logarithmic amplifier with a narrow dynamic range.

Water-vapor absorption characteristics of millimeter radiation are used to advantage in OKI's radar cloud detection equipment. Japan's National Meteorological Laboratory is using an OKI 8.6 mm radar with a peak power output of 32 Kw for a three-dimensional study of cloud and mist formation. Two parabolic antennas, one transmitting, the other receiving, are installed several meters apart, both pointing straight upward, Fig. 12. One reason for not using a single antenna is that t-r or atr tubes now available at this frequency are not sufficiently



TERMINAL TRANSCEIVER *for a 69.9-Gc voice link is installed at Sylvania's Amherst Laboratories to determine effects of atmospheric conditions on millimeter ground communications—Fig. 10*

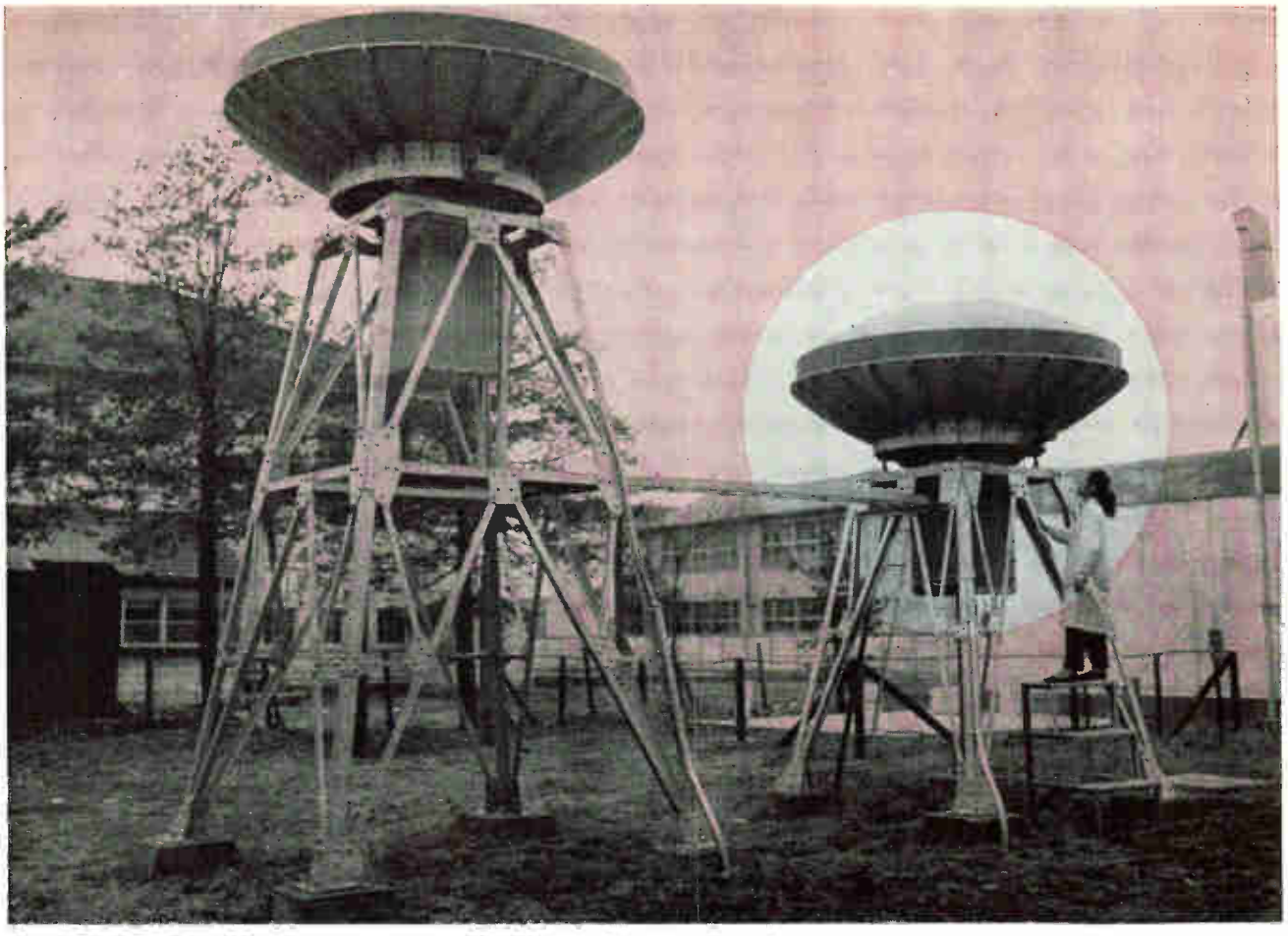


MOON RADAR *system at Lincoln Laboratories will have an 8-mm beam 0.05 degree wide and cover a circle on the moon's surface 216 miles in diameter—Fig 11*

stable nor do they have sufficient life.

The cloud-detection equipment is capable of determining cloud ceiling and depth and the status of two combined clouds. Maximum height for which the equipment is calibrated is 20 kilometers.

Other millimeter systems in use are for research into areas where more accuracy can be obtained using short wavelength radiation. At the Boulder Laboratory of the National Bureau of Standards, a system for the measurement of speed of light is being tried. It uses a Michel-



CLOUD DETECTION *radar uses two antennas to avoid losses in available t-r switches—Fig. 12*

son interferometer at a 6.2-mm wavelength. A parallel experiment in process uses a Fabry-Perot interferometer to measure dielectric properties of several materials at 48 Gc. The Q of the interferometer acting as a transmission cavity has been measured as high as 100,000 at 48 Gc.

Studies of plasmas are underway, both at NBS and at Lincoln Laboratories. Because plasma resonance is about 30 Gc, millimeter waves penetrate all but the most dense plasmas. Thus, some of this work is aimed at finding a frequency for reliable communication during space vehicle reentry.

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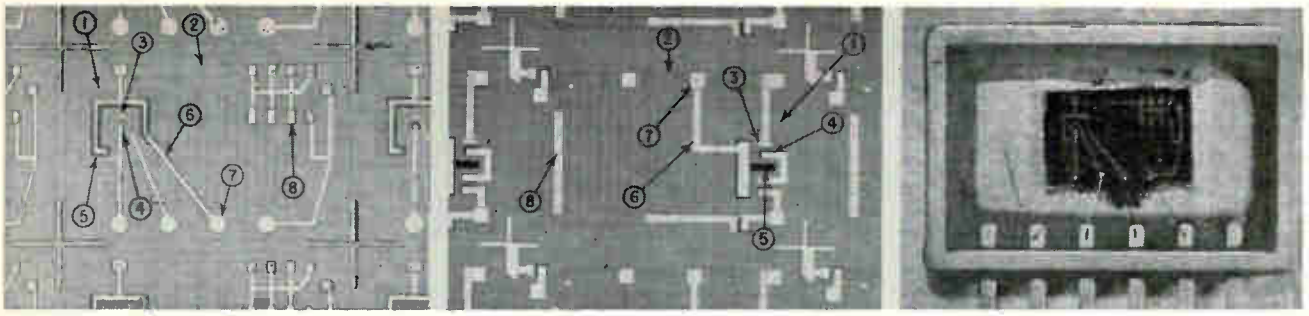


TWO BLOCKS, *common emitter (left) and Darlington Circuit (center) illustrate construction. Photo (right) shows a packaged common-emitter functional block with leads*

Latest Design Techniques For Linear Microcircuits

By L. POLLOCK and R. GUTTERIDGE, Westinghouse Electric Corp., Youngwood, Pa.

Linear functional electronic blocks are produced through solid-state diffusion and photoengraving techniques. Here the process is described in detail, illustrated with two examples

MOLECULAR ELECTRONICS seeks to use a single piece of material with predetermined electronic properties to synthesize circuit functions conventionally requiring many separate active and passive components. A monolithic structure of this type is known as a functional electronic block.

THE PROCESS—The method of producing functional blocks can be understood by considering a typical double-diffused, silicon planar *npn* transistor structure as shown in Fig. 1. The dimensions are typical of a high-frequency, small-signal transistor with a gain-bandwidth product of 300-500 Mc.

Topographic dimensions are an order of magnitude greater than the depth dimensions. It would be of no value to be able to reduce one without reducing the other to the same extent, since dimensions in the range shown will result in a device whose R-C time constants, determined by area, are approximately equal to the transit time of minority carriers across the base region, determined by depth. Two processes have been developed to achieve control of both area and depth dimensions in these ranges: selective solid-state diffusion introduces the correct impurities to the desired depth, and photoengravings select the areas to be diffused.

Selective solid-state diffusion of impurity atoms into the silicon crystal lattice is achieved by heating the material to approximately 1,200 deg C in an atmosphere containing the doping impurity. Diffusion of the elements boron and phosphorus is inhibited by a surface layer of silicon dioxide, and this property is exploited when localized *p* or *n* type regions are required. The introduction of a *p*-type region into an *n*-type substrate follows a simple sequence.

A layer of silicon dioxide is first grown over the entire surface, then removed from the areas to be diffused. Impurities are then diffused into these areas. The SiO_2 prevents their entry into other regions of the surface. During diffusion a new layer of oxide is grown over the exposed areas to be used in subsequent selective diffusions. The depth of penetration and impurity distribution within the diffused region are determined by the time and temperature of the diffusion and by the nature and concentra-

MORE MICROELECTRONICS

A few years ago, when engineers discovered that complete circuit functions could be developed on and within a single block of silicon, the art of microelectronics was hailed as a great new revolution. But claims and counterclaims often tended to outrun performance.

Meanwhile, the industry has settled down to hard-core development work and recently more concrete results have appeared—a wider choice of circuits, reliability figures, even production contracts.

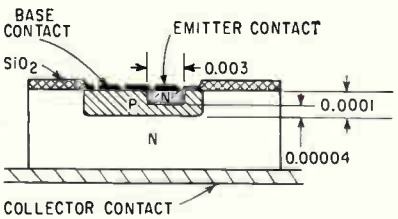
This story follows up one in our Sept. 21 issue that discussed the overall problem of translating systems requirements into an array of functional electronic blocks

Table I—PERFORMANCE DATA ON AMPLIFIERS

Common Emitter	Conventional Circuit	Functional Block
Supply	22.5 v	22.5 v
Total Current	2 ma	2 ma
Input Impedance	750 ohms	750 ohms
Output Impedance	3,000 ohms	3,000 ohms
Power Gain	30 db	30 db
Band Pass	2.5 Mc	2.5 Mc
Darlington	**Conventional Circuit**	**Functional Block**
Supply	22.5 v	22.5 v
Total Current	7 ma	7 ma
Input Impedance	26,000 ohms	21,000 ohms
Output Impedance	1,500 ohms	1,000 ohms
Power Gain	38 db	36 db
Current Gain	1,200	850
Max. Output Current	4.5 ma	4 ma
Harmonic Distortion at 3 ma out	<1%	<1%

Table II—PERFORMANCE DATA ON AN/ARC-63 RECEIVER

	Specification	Molecular Receiver
Frequency	238–248 Mc	238–248 Mc
1st i-f	28 Mc	28 Mc
2nd i-f	3 Mc	3 Mc
Sensitivity	7 μv	3–5 μv
Bandwidth	−6 db at 60 Kc	−6 db at 40 Kc
	−60 db at 180 Kc	−60 db at 110 Kc
Spurious Response		
Adjacent Channel	−80 db	−80 db
Image and Harmonic	−65 db	−50 db
AGC	±10 db for 7–500,000 μv	+6 db
Squelch Level	variable	0–100 v adjustable
Audio Power at 150 ohms	200 mw	250 mw
Response	300–6,000 cps	300–6,000 cps
Distortion	10%	8%
Input Power	24.5 w	2.6 w
Volume	148 in^3	9 in^3
Weight	5.2 lb	0.46 lb
No. of Components	219	82



DOUBLE DIFFUSED *silicon planar npn transistor structure—Fig. 1*

tion of the source of the impurity.

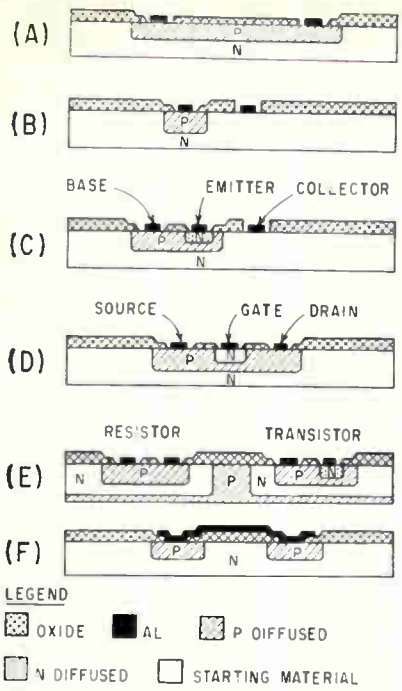
Photoengraving is ideally suited to fabrication since it is capable of reproducing fine detail while avoiding undue mechanical strain on the sample. Applications of the process to the selective removal of oxide allows precise geometric control over the diffused areas. Here the oxidized silicon is coated with a thin film of photosensitive resist, and exposed to ultraviolet light through a high resolution photographic plate bearing an image. Where the uv is able to pass through the plate, the resist is polymerized and rendered insoluble. The portion not exposed remains in monomeric form and can be removed by a solvent. The residual coating then protects against the oxide etching solution. Thus small, intricate patterns can be etched with a high degree of reproducibility from one sample to the next. This plays a large part in determining the tolerance of circuit components.

Photographic plates are prepared by reducing the original art work 100 times on micromodular cameras. The final reduction is carried out on a step-and-repeat camera to give an array of accurately indexed images. Linear dimensions on the plates are held to 1 micron to minimize the accumulative misalignment error between successive masking steps. With these multiple image plates, many devices can be fabricated on a single slice of silicon.

MAKING ELEMENTS — Through photoengraving and selective diffusion, a number of active and passive elements can be built directly on a silicon wafer (see Fig. 2).

In Fig. 2A, a resistor is formed by a single diffusion with a contact at either end. Practical values of resistors run from about 4 to 400,000 ohms and can be made with ten percent tolerances. The simple diode of Fig. 2B can perform as a rectifier, as a controlled voltage supply in the avalanche region, as a variable or fixed capacitor in the reverse bias condition and as a zener coupling element. A second diffusion is all that is necessary to make the conventional transistor of Fig. 2C or the field-effect transistor of Fig. 2D. Where it is desired, component isolation may be obtained as in Fig. 2E, which shows a transistor and a resistor formed in two regions separated by a deep diffusion. Because of the insulating oxide over the surface it is possible to interconnect contacts on the block using an evaporated film of aluminum directly on the oxide as in Fig. 2F without danger of shorting the junctions.

The elements described are sufficient to build a variety of linear circuits directly in a single chip of silicon without any external components. These circuits may be direct analogs of those made with conventional components; however, limitations on the component values or properties may require a circuit modification or a new approach to the circuit function. This is true in bias networks for small signal circuits where, because of small currents, high-value resistors are required. Since the area required for the resistance is directly proportional to the resistance, the practical upper limit on the total amount



BOTH ACTIVE AND PASSIVE *elements are built directly on a silicon wafer through photoengraving and selective diffusion techniques—Fig. 2*

of linear resistance in a circuit is about 300,000 ohms. Where the linear resistance required is in excess of this, the same function can often be performed by either a network of two or more resistors, a nonlinear circuit element such as a diode or field-effect transistor, or some combination of resistors and nonlinear elements, with a saving in total area. Significantly the cost of a functional block bears little relation to the number of separate components in the circuit, but is almost directly proportional to the area they require.

TWO BLOCKS—The first is the general-purpose single-stage common-emitter amplifier of Fig. 3A. This simple and versatile circuit can be used as a voltage or power amplifier for frequencies ranging from d-c to a few megacycles. The component values are such that the circuit can be made directly on silicon with special consideration only to active element design, isolation and stray impedance. The more specialized Darlington circuit of Fig. 3B is useful over a frequency range up to about 100 Kc, but has features such as high input impedance desirable in audio-preamplifier applications. More important, it has the gain of two stages with the dissipation of only one. Although isolation and stray impedance are not important, the bias network normally used with separate components would consume a prohibitively large area on a functional block. The circuit of Fig. 3C uses a voltage divider to reduce the bias voltage and therefore the resistance. Collector bias is used for the block circuit to gain the added voltage and thermal stability and better reproducibility. Load impedance is usually low so that little gain is lost.

The photographs show the common-emitter (at left) and Darlington (center) functional blocks. The individual operations used in constructing the finished blocks can be interpreted by studying the surface. The square path (1) is a deep *p*-type diffusion isolating the region within the square, where the transistor is formed, from the rest of the block. The darker areas, which are the resistor paths (2) and the transistor base region (3) are formed simultaneously by the diffusion of boron. The darkest areas are the emitters (4) and the collector contact area (5), which are formed simultaneously by a phosphorus diffusion. The white paths are evaporated aluminum lead-outs and interconnections (6) and lead bond terminals (7). The outlines of the contacts, which are alloyed to the silicon prior to the final evaporation, are visible under the interconnections (8).

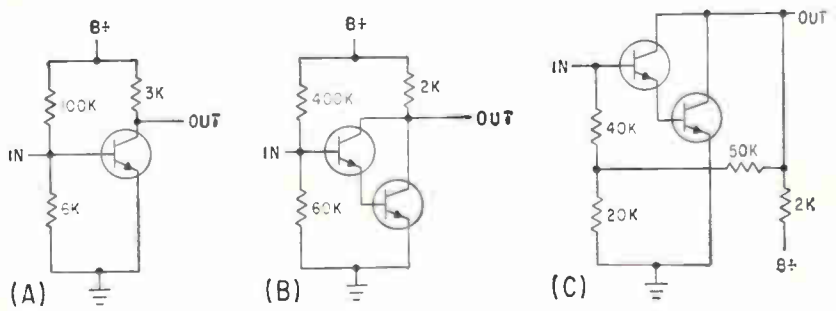
The third photograph at the right shows a packaged common-emitter functional block with the leads attached.

Table I compares the performance of typical functional blocks with that of conventional circuits.

OTHER FACTORS — Functional blocks can be designed to operate to at least the temperature normally specified for a transistor. However, this can be achieved only if the design of the entire circuit is considered, since silicon properties exhibit high temperature sensitivity and vary with impurity concentration. However, temperature properties can be accurately predicted and, due to the intimate thermal contact of components, the temperature of the entire circuit will be uniform. Thus, the temperature characteristics of silicon resistors, diodes, and field-effect transistors can be used to improve the temperature characteristics of circuits.

Reactances pose the biggest single limitation on achieving an integrated circuit. The maximum capacitance of a reverse-biased silicon junction of practical dimensions is in the range of 100 pf and pure inductance in silicon as yet has been obtained only on a laboratory scale. Where inductors or larger capacitors are needed it is still necessary to use separate components. However, solid tuned and tunable circuits are now available as piezoelectric crystals and notch filters.

To demonstrate the mutual compatibility of a wide variety of functional blocks, a molecularized version of the AN/ARC-63 emergency communications receiver was developed. This is a 243-Mc receiver using conversions to 28 and to 3 Mc. The molecular version of the receiver uses miniature circuits for the r-f amplifier and first conversion and 9 functional blocks for the remainder. These include a 25-Mc oscillator-mixer block, 3 i-f amplifiers, a detector, a Darlington audio amplifier, a power amplifier, agc and squelch amplifiers. Table II compares the performance of the molecular receiver with the AN/ARC-63 specification.

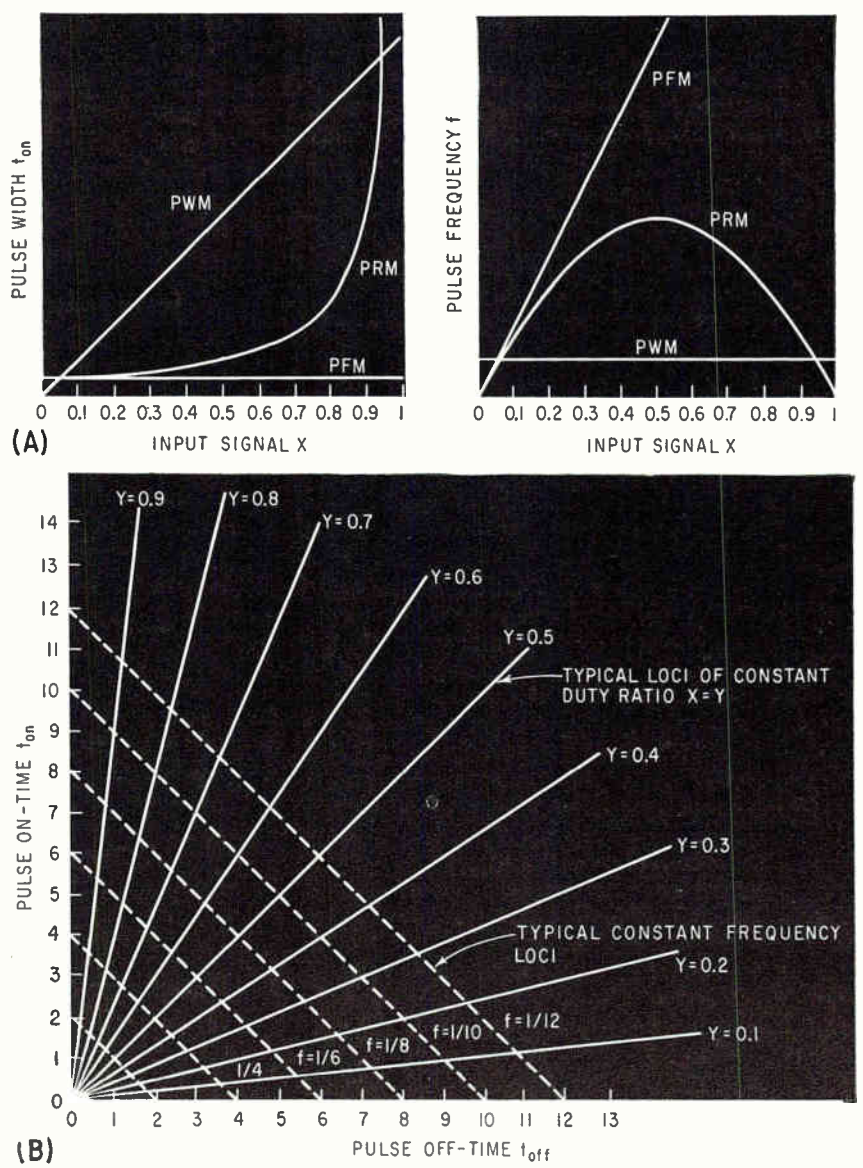


CIRCUITS *for functional blocks. Common emitter (A), conventional Darlington (B) and functional block Darlington (C)—Fig. 3*

New Pulse Modulation Method

Use of both pulse-frequency and pulse-width modulation combines the advantages of these methods. The new pulse-ratio-modulation system results in high accuracy and wide dynamic range

By R. A. SCHAEFER, Martin Marietta Corp., Baltimore, Maryland



COMPARISON *of pulse characteristics (A) based on tabulated equations; graph of on-time against off-time (B), with arbitrary scales—Fig. 1*

PULSE RATIO modulation,[1] so named because only the pulse duty ratio is linearly related to the input signal, offers advantages such as significant improvement in accuracy and dynamic range over conventional techniques. Linearity of 0.05 percent and 60 to 80 db (10^3 to 10^4) dynamic range are easily obtained. Many advantages of digital systems are also obtained.

The usual methods of pulse modulation are pulse-frequency modulation (pfm) and pulse-width modulation (pwm) A constant pulse duration is maintained by pfm while varying the frequency according to the input signal. Correspondingly, pwm holds pulse frequency constant while varying width. Pulse ratio modulation (prm) varies both frequency and width. A comparison between these modulation methods is shown in Fig. 1A.

A characteristic of a prm, pwm or pfm carrier is that complete signal information is represented by both the d-c (or average) component and the a-c component (fundamental and harmonics). This property permits amplification of the carrier with an a-c amplifier without loss of information content. It also permits demodulation back to d-c by lowpass filtering to remove the periodic components.

Except where the requirements are not too stringent, difficulties arise in use of pfm and pwm. These problems are inherent in the modulation formulas, illustrated in Fig. 1A. Both forms of modulation require that either the pulse on-time (width) or the pulse off-time approach zero at the high and low values of input signal. This is impossible to achieve, as it corresponds to infinite bandwidth. Therefore, pulse modulators and subsequent amplifiers or other devices do not operate as desired over a full range of input.

Pulse-ratio modulation avoids the problems of pwm and pfm by combining their control laws or characteristics. In prm, both the pulse

Varies Both Frequency and Width

width and the pulse frequency are simultaneously varied according to the input signal. The variations are smooth, continuous and are an inherent characteristic of the circuit.

FORMULAS—The formulas that relate pwm, pfm and prm are in the table. In all these modulation methods the pulse train duty cycle is proportional to the input signal. Duty cycle is the ratio of the pulse on-time to the total time

$$\text{Duty Ratio} = Y = t_{on}/(t_{on} + t_{off})$$

$$\text{Pulse Train Average or D-C Component} = YE_p$$

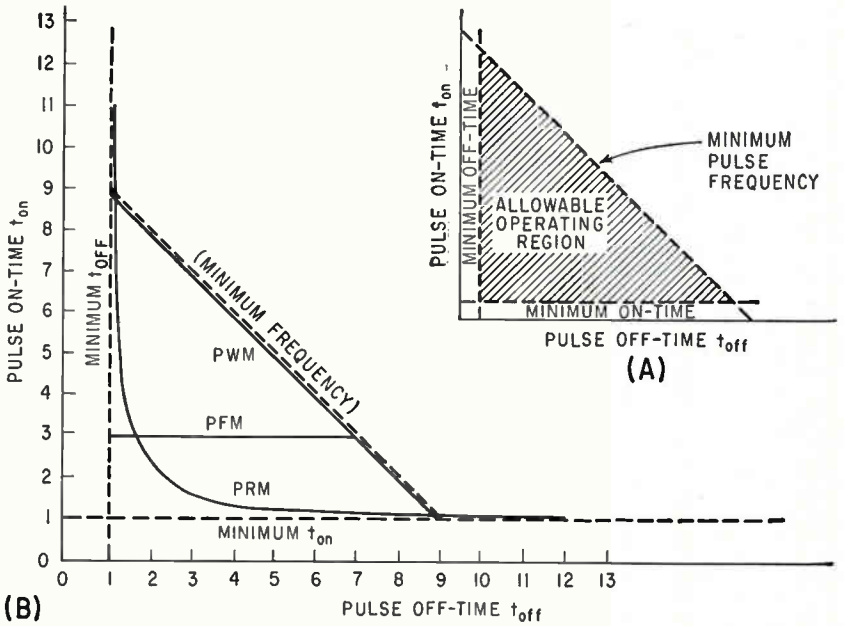
where E_p = peak pulse voltage.

Duty ratio is also equivalent to the product of the pulse width and the pulse frequency, $Y = t_{on}f$. The quantity X represents the modulator input signal. It is a normalized input signal between zero and one. Suppose, for a particular modulator, that an input signal of 5 volts produces a duty ratio of zero and that 9 volts produce a duty ratio of unity. Then $X = 0$ would correspond to an input of 5 volts and $X = 1$ would correspond to 9 volts.

In an errorless modulator, Y equals X. The table's bottom row shows what all three techniques have in common: Y is theoretically equal to the normalized input signal X.

In pulse-ratio modulation, only the duty ratio of the output pulse train is proportional to the input signal. In pwm, both duty ratio and pulse frequency are proportional to input. Neither pulse width nor pulse frequency are proportional to input in prm. Frequency or width proportionality is not important, however, since it is only the duty ratio which need carry the signal information.

Pulse ratio modulation does not require infinite device bandwidth for $X = 0$ or $X = 1$. In the table, pulse on-time approaches zero for pwm as X approaches zero, but for prm it approaches T_r. Also, pulse off-time for both pwm and pfm approaches zero as X approaches 1.



PULSE-MODULATOR *allowable operating region (A); pulse-modulation comparison (B)—Fig. 2*

For prm, off-time approaches T_r as X approaches 1.

COMPARISON — Although there are numerous ways to plot the relations in the table, a cross-plot of on-time against off-time is the clearest. This t_{on}-t_{off} plane is constructed by eliminating X as a variable. As shown in Fig. 1B, lines of constant X are straight lines intersecting the origin. Lines of constant pulse frequency are also shown.

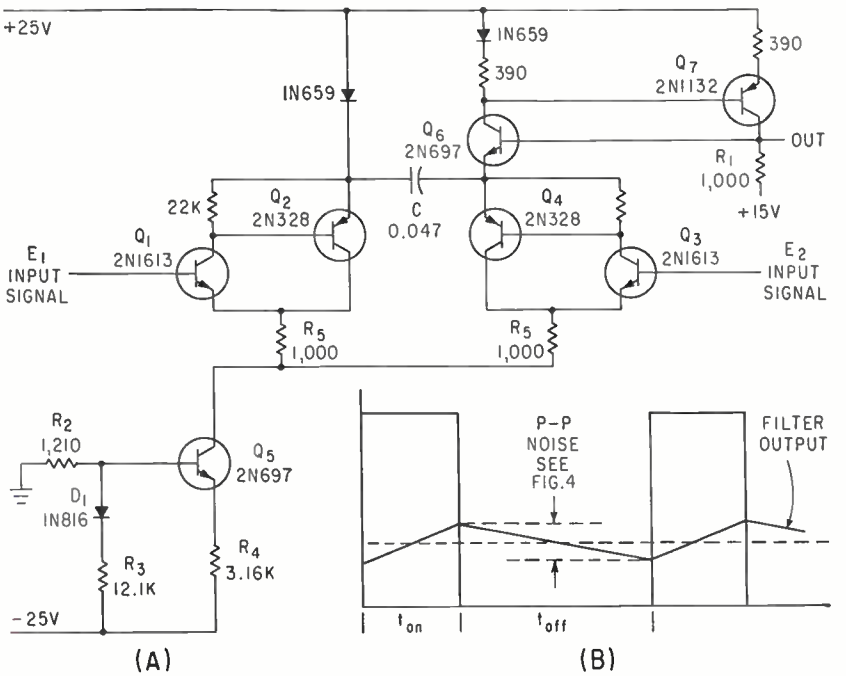
Figure 2A shows the allowable operating region when using a pulse modulator. The minimum on-time and minimum off-time are set by the bandwidth of the amplifiers or other devices the modulator must drive. These values are related to bandwidth by

$$\text{minimum } t_{on} = \text{minimum } t_{off} = \frac{1}{(2 \times \text{upper cutoff frequency})}$$

The other operating region boundary is the minimum acceptable prf. This is usually a limitation because too low a frequency requires excessive filtering to remove the pulse-train a-c components when it is desired to reconvert the signal to d-c. Low frequency also corresponds to excessive time lag in

SPACE-VEHICLE CONTROL APPLICATIONS

Pulse-ratio modulation was originally developed for space-vehicle control applications. The characteristics of prm are well suited for operation of reaction jets. These jets provide thrust either for attitude control or for linear propulsion. The jets are capable of on-off operation only, yet the system requires an average thrust proportional to the system error signal. Also, jet operation must be limited to lie between a certain minimum pulse width and a maximum repetition frequency. The minimum pulse width is determined by the response capabilities of the jet, and the full-on thrust is scaled according to the expected disturbances and required vehicle response. Using prm, up to a 10^4 range of average thrust can be obtained, from minimum to full-on conditions of operation



TEMPERATURE-TESTED *modulator (A); output of first-order demodulation filter (B)—Fig. 3*

servo and control-system applications.

The three types of modulation on the t_{on} - t_{off} plane are shown in Fig. 2B. For any given duty ratio (Fig. 1B), prm provides nearly the highest possible repetition frequency. The only possible limitation on the operating range of prm is through exceeding the minimum frequency boundry at low and high duty ratios. Often this is not important to the system; then there is no limit to the operating range of duty ratios. But, pfm is limited by minimum frequency at low duty ratios and by minimum off-time at high ratios. The limitations of pwm are minimum on-time at low ratios and minimum off-time at high ratios.

In the typical prm circuit, Fig. 3A, both E_1 and E_2 together are the input signal. The output duty ratio depends upon the difference between E_1 and E_2

$$Y = \tfrac{1}{2}\left(\frac{E_2 - E_1}{R_1 I_c} + 1\right)$$

For a single-ended rather than differential input, E_2 can be fixed at +7 to 9 v d-c. The output is 5-ma negative pulses through R_1.

The circuit is a relaxation oscillator. Transistors Q_6 and Q_7 and their circuit provide a negative resistance characteristic over a range of Q_6 emitter current. As pulse timing capacitor C times both the pulse on-time and the off-time errors in its capacitance do not affect the pulse-train duty-ratio.

Magnitudes of the capacitor charging currents during pulse timing intervals are established by the Q_1 to Q_5 circuit. The Q_1-Q_2 pair is substantially equivalent to a single, high-gain *npn* transistor, as is Q_3-Q_4. Transistor Q_5 sets a constant current I_c and Q_1-Q_2/Q_3-Q_4 regulate the division of this current for capacitor charging. The Q_1-Q_2 collector current sets the pulse off-time where the Q_3-Q_4 current sets the pulse on-time. Minimum pulse on and off times are $T_r = t_{on}$ minimum $= t_{off}$ minimum $= 0.7\ CR_1 = 700C$ *sec*, and can be set at any value over at least the range of 10 microseconds to 0.2 second.

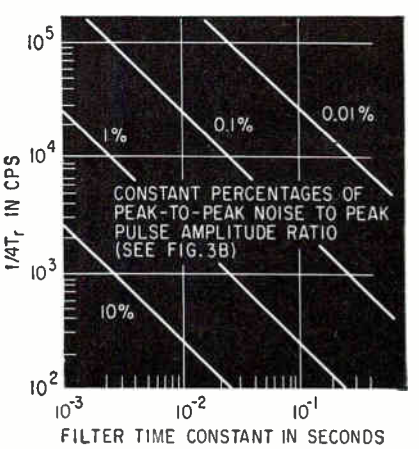
LINEARITY—Measurements at a 20 C ambient show deviation from straight-line terminal linearity less than 0.02 percent over most of the operating range and not exceeding 0.06 percent at the worst point. A test at +125C showed a gain change of −1.2 percent with little linearity degradation. This gain change, representing 100 ppm per degree, can be reduced by design of the Q_5 current source and selection of stable resistors.

Modulator gain can be varied with an electrical signal. From the equation for the duty ratio Y, modulator gain is $1/R_5I_c$. Therefore, I_c variations represent gain changes. The I_c can be varied by replacing the R_2, R_3 and D_1 components in Fig. 3A with a variable voltage supply. Modulator gain will then equal approximately R_4/R_5V where V is the applied control voltage. The remainder of the circuit must be designed to accomodate the range of gains.

Before use of the signal information, the pulse train is demodulated. Demodulation is accomplished with a lowpass filter. If the output is to operate a motor, then the motor and load lowpass characteristics will suffice. If the output is to be a signal, an R-C filter can be used. The output from such a filter is shown in Fig. 3B.

A certain amount of noise will exist in the demodulated signal, as shown in Fig. 3B. This signal will have a triangular waveform if the filtering is effective. The amplitude of the noise can be related to the filter time constant and to the minimum on and off times, T_r. Figure 4 shows loci of constant noise amplitude as a function of filter time constant and $1/4T_r$. Note that $1/4T_r$ is equal to the maximum pulse repetition frequency at the maxima seen in Fig. 1A.

FREQUENCY RESPONSE — The frequency-response capabilities of the modulator are defined in that



FILTER OUTPUT *noise for given time constant and T_r—Fig. 4*

the net response of the modulator plus filter is virtually identical to the filter alone—under the condition that the output noise is less than 25 percent of the peak pulse amplitude. Therefore, Fig. 4 gives modulator response capabilities. For example, suppose that signal information with a bandwidth of 10 cps is to be handled and that the demodulated output signal must not exceed 1 percent of the peak pulse amplitude. The filter time constant, since it represents overall response, must be less than $\frac{1}{2\pi f} = 15.9$ msec ($f = 10$). Therefore, a maximum pulse frequency or a $\frac{1}{4}T_r$ in excess of about 1.5 Kc will suffice so that T_r must be less than 0.167 msec.

In pulse modulation, and prm specifically, the advantages and disadvantages of pulse modulation, and of prm against pwm and pfm must be considered. Generally, advantages obtained by any pulse modulation technique result from a bandwidth trade-off. To handle, by analog methods, a signal whose information content lies between 0 and 1,000 cps requires a bandwidth of 1,000 cps. To handle the same signal by pulse modulation may require a bandwidth from 10 Kc to 100 Kc. Higher-speed devices are required.

The pulse ratio modulator, Fig. 3A, provides high stability and linearity over a wide range of duty ratio. Modulators for pwm and pfm are often bandwidth-limited in the range of duty ratios they can produce. Another factor in superior performance with prm modulators is that pulse timing is based on charging and discharging a single capacitor to a fixed level of voltage change across the capacitor terminals. Both pwm and pfm require that a variable voltage level be detected. Where current variations of several orders of magnitude can be easily obtained, it is only with difficulty that a 50-to-one range of voltage variation can be exceeded.

GAIN STABILITY—The gain stability and linearity obtained in prm modulators is an advantage. Coupled with a general advantage of pulse modulation, that overall results are independent to a substantial degree of amplifier or other device non-linearities, this can result in a highly accurate system using nonprecision components.

For example, linearities on the order of 0.05 percent can be obtained, using 20-percent amplifiers, without overall feedback. For a given modulator accuracy, pwm and pfm also permit this. However, when the short on-and-off times associated with pwm and pfm are encountered, the amplifier nonlinearity begins to detract from the overall linearity.

Amplifiers are also simplified by any pulse modulation technique in that saturating switches and nonlinear semiconductor switching devices can be used. The power dissipated in each stage is reduced, the overall efficiency is improved and high power gains are obtained with a minimum number of components. Here, prm offers better results since switching amplifiers will not respond at all to pulses below a certain duration.

The signal information in a pwm, pfm or prm pulse train is redundant in a sense. The Fourier series representing the pulse train can be divided into two components at any arbitrary frequency f. Both components of the series, that is, from 0 to f and from f to ∞, fully define the signal information. Thus either low-pass or high-pass devices can be used to operate on the pulse train without loss of signal information or accuracy. Either a d-c amplifier or an a-c amplifier, for example, can be used. The technique for recovery of signal information does differ though between these two.

Consider the three forms of modulation over a range of duty ratio from zero to one. Since all three carry the signal information in a signal frequency component, any linear lowpass device with signal bandwidth can handle the pulse train without loss of information. At the high frequency end of the spectrum, above f, only in prm do the amplitudes of the higher-frequency components become negligible above a certain frequency. This means that a high-pass device, such as an a-c amplifier, need have only a finite upper cutoff frequency to recover the signal information from the output. In pwm and pfm, a truly infinite frequency response capability is required (for X sufficiently near either zero or unity). A reasonable upper cutoff frequency for prm is about $1/(2T_r)$.

DEFINITIONS

Pulse modulation is the process of converting an analog signal into a pulse carrier. Pulse modulators are pulse generators that control the output pulse-train characteristics with an electrical input signal. The pulses are often rectangular and have a constant peak amplitude. In most cases, either the pulse duration (width) or the pulse repetition frequency is varied by the input signal

DIFFERENCES BETWEEN TYPES OF PULSE MODULATION

TYPE OF MODULATION	DURATION t_{on}	OFF TIME t_{off}	REPETITION FREQUENCY f	DUTY RATIO Y
PFM	T_f	$T_f \frac{1-X}{X}$	$\frac{X}{T_f}$	X
PWM	$\frac{X}{f_w}$	$\frac{1-X}{f_w}$	f_w	X
PRM	$\frac{T_r}{1-X}$	$\frac{T_r}{X}$	$\frac{X(1-X)}{T_r}$	X

T_f = CONSTANT PULSE WIDTH

X IS PROPORTIONAL TO INPUT SIGNAL

f_w = CONSTANT PULSE FREQUENCY

T_r = MINIMUM ON AND OFF TIME

REFERENCE

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Reliable Circuit Supplies High Peak Deflection Voltages

Circuit achieves high reliability using output stage redundancy. Up to ten input signals can be displayed on a large cathode-ray tube for analog computer readout. Rapid collector turnoff insures efficient flyback operation

By RALPH S HARTZ
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Holmdel, N. J.
Computer Products, Inc.,
South Belmar, N. J.

MAGNETIC DEFLECTION for large cathode-ray tubes usually requires high-speed and high-current switching. Short retrace periods introduce a high peak-voltage requirement. This circuit was designed to drive the deflection system of a solution-display device used in analog computers. While it features rapid turn-off of collector current for efficient flyback operation, the peak voltage generated during retrace exceeds 300 volts. High reliability is achieved by output stage redundancy.

DISPLAY UNIT—The circuit consists of driver, buffer and output stages of the deflection system of a high-accuracy oscilloscope. Vertical grid lines are generated on a flat-faced, high-resolution 22-inch crt. The beam is deflected vertically at a rate of 50 Kc and horizontally at up to 100 cps. The vertical lines are brightened 51 times during each horizontal sweep. To form horizontal grid lines, the crt is brightened for short intervals during each vertical sweep. These intervals are interpreted in voltage. Input signal lines are obtained similarly and displayed with the horizontal and vertical grid lines. The analog solution is displayed on a parallax-free, electronically generated grid. As many as ten inputs may be viewed at one time.

DEFLECTION SYSTEM — The system requires a precision yoke with an inductance of 165 microhenries and a series resistance of 0.31 ohm. A peak-to-peak yoke current of 5 amperes is required for full 70-degree deflection. The operating frequency of 50 Kc gives a total usable period of 20 μsec. To use the largest part of this period, the retrace time was minimized. A 16-μsec display and a 4-μsec retrace are used; this is well within the fall-time capability of a standard 2N1073 diffused-alloy power transistor. The resonant frequency of the tuned circuit is about 125 Kc. Peak voltage generated during retrace, may be approximated from

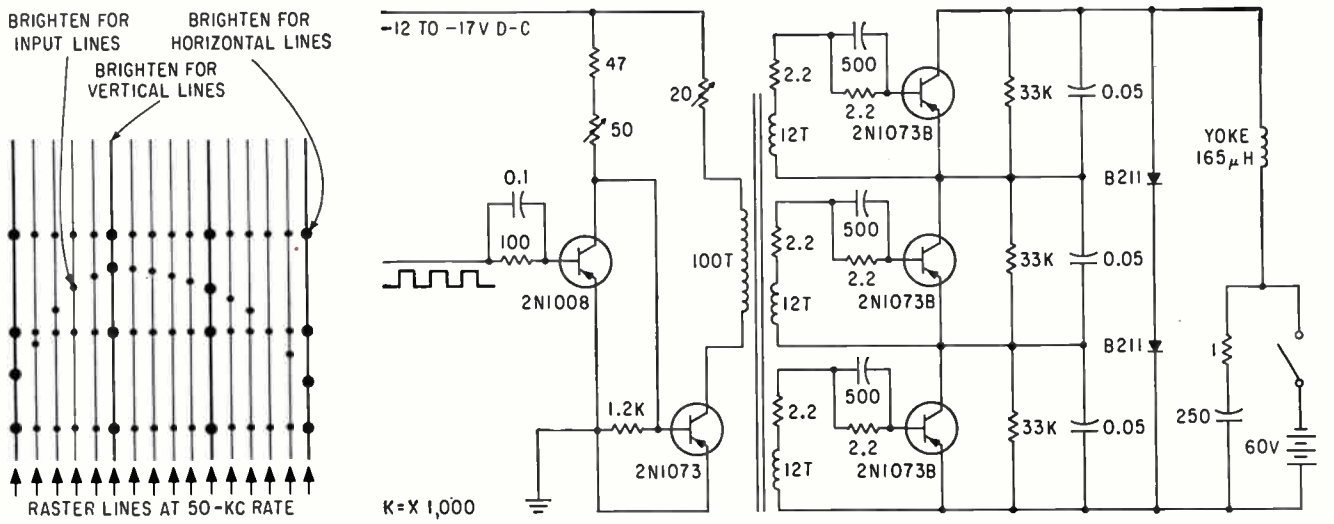
$$t_r = \pi\sqrt{LC} \qquad (1)$$

at resonance

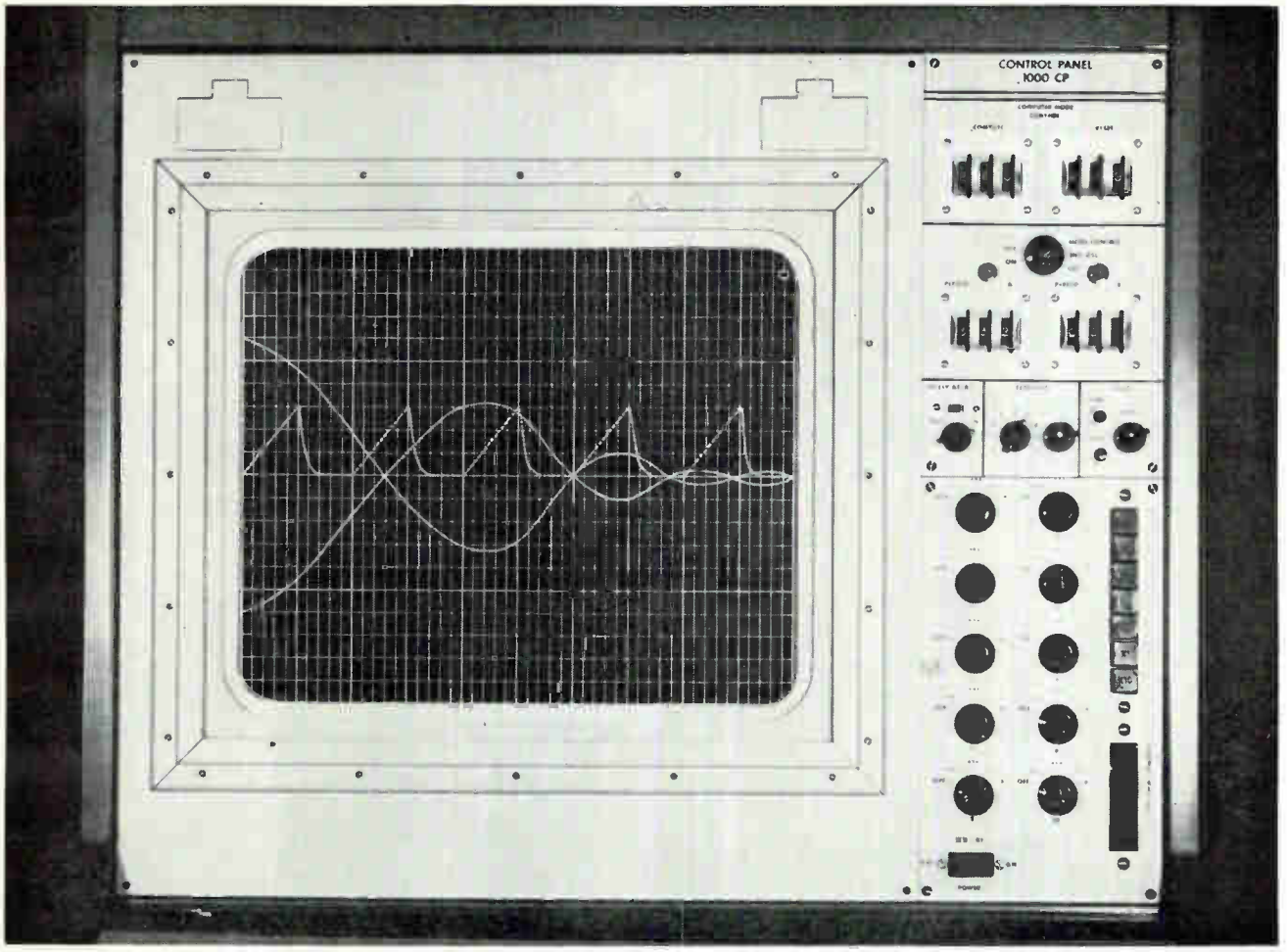
$$V_p^2 = L/C\,(I_p)^2 \qquad (2)$$

from Eq. 1 and Eq. 2

$$V_p = \pi L I_p/t_r \qquad (3)$$



DEFLECTION CIRCUIT *driven at 50 Kc from a square-wave generator and formation of vertical, horizontal and signal lines comprising crt display*



COMPUTER *control panel illustrates unit's ability to display multiple input signals*

where V_p = peak retrace voltage, I_p = peak yoke current, L = yoke inductance and t_r = retrace time. This provides about 320 volts peak during retrace.

A pair of 2N1073B transistors connected in series could do the job; they would, however, be operating near their maximum limitation. Any uneven voltage distribution would tend to overstress one unit; a voltage fault might overstress both. To eliminate this, a third 2N1073B was added in series. To insure even voltage distribution, a resistor and capacitor are placed from collector to emitter of each transistor. While the shorted-base breakdown voltages are not matched for the transistors, the greatest variation in voltage division for any two transistors is 20 percent. The average division runs about 10 percent.

Two B-211 diodes are series connected as dampers; however, voltage division is a problem and the diodes have to be matched.

DRIVE CIRCUIT — Drive to the output transistors is critical. It must be sufficient to maintain them in saturation for most of the trace period. The turn-off current waveform must be steep to effect a fast collector current decay.

A 2N1073 transistor is used as a driver and transformer-coupled to the output transistors with three identical, trifilar secondary windings. Each winding has 2.2 ohms series resistance, which prevents a shorted secondary winding, should the emitter-base junction short. A 2N1008A buffer is direct-coupled to the driver. Supply voltage for the buffer and driver stages is nominally 12 to 15 volts.

CIRCUIT OPERATION—The lab model, was driven at 50 Kc from a square-wave generator. The system in the display unit, however, is driven by a crystal-controlled oscillator.

The drive circuit draws 400 ma and the output stage about 200 ma. Turn-off time averaged 500 nsec for the output.

To test the effectiveness of the protective circuits in the output stage, one transistor was shorted collector-to-emitter and the circuit continued to operate. The same transistor was then shorted emitter-to-base. The circuit still functioned. The reliability of the output stage is greater than that of any individual transistor.

Each output transistor, as well as the driver, is mounted on a three-by- three inch aluminum heat sink, one-eighth inch thick.

50-KC DEFLECTION CIRCUIT FOR 22-INCH, 70-DEGREE CRT

Here is a description of a novel circuit that will deflect the beam of a high-resolution, flat cathode-ray tube at a vertical rate of 50 Kc.

Use of transistors results in highly efficient flyback operation and system reliability. When applied to a computer-display device, up to ten separate signal inputs may be viewed

---

Tunnel-Diode Oscillator Delivers R-F and Audio

By WEN H. KO
Case Institute of Technology,
Cleveland, Ohio

THIS OSCILLATOR can provide r-f as well as audio signals for checking such equipment as a-m receivers.

The Ga-As tunnel diode (D_1) in Fig. 1 is the active element. Diode D_2 and R_1 in series with the battery provide the regulated d-c supply to the tunnel diode. The radio frequency is determined by L_1, L_2 and C_1 and the audio frequency by L_3 and C_3. Equivalent circuits for r-f and a-f are shown in Fig. 2. In Fig. 2A, D_1 is represented by C_d shunting $-R_d'$; in Fig. 2B, D_1 is represented by $-R_d''$.

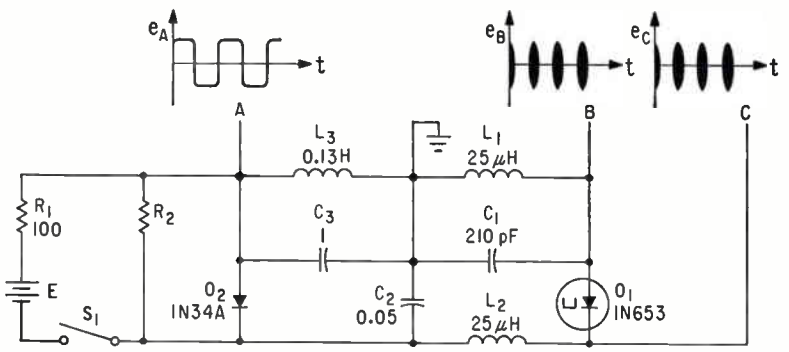
The characteristic curve of D_1 is shown in Fig. 2C. The approximate design equations[1, 2, 3] are listed in the Table.

The r-f frequency, which is approximately determined by L_1-C_1, is 0.6 Mc and the audio frequency is about 400 cps. The audio output A in Fig. 1 is a relaxation-type wave. The audio oscillation, superimposed on the d-c supply, sweeps the tunnel-diode bias across its negative-resistance region and causes the r-f oscillations to be interrupted at twice the audio frequency. Thus, the r-f is pulsed at 800 pps. The pulsed r-f fundamental appears at B and pulsed r-f harmonics appear at C.

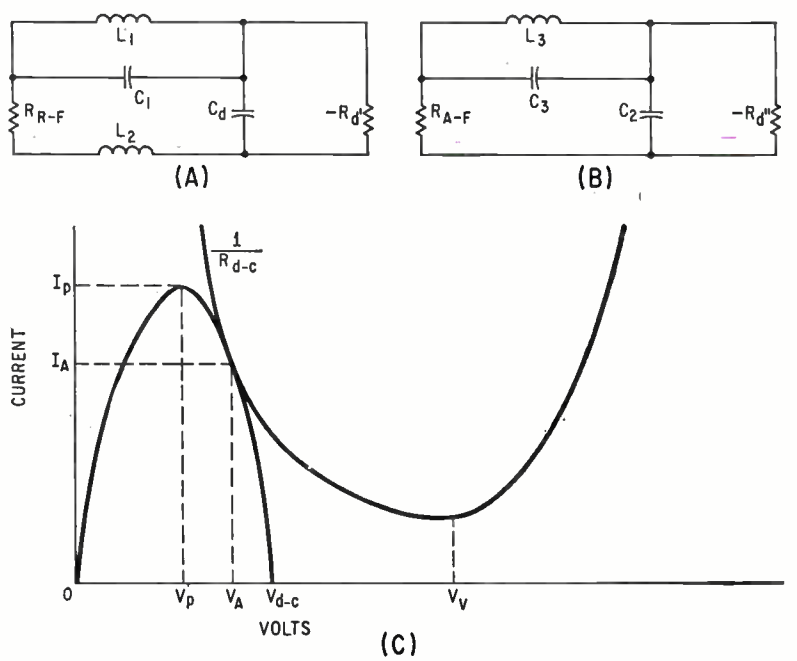
Without an antenna, the oscillator signal can be picked up by a table-model receiver at a distance of about 2 feet. With a single-wire antenna, the range is about 20 to 40 ft.

POSSIBLE CIRCUIT MODIFICATIONS

(1) Use Ge or Si tunnel diodes instead of the Ga-As type shown in Fig. 1. A backward diode should be used instead of D_2 to provide operating voltage for the Ge or Si D_1
(2) Omit L_2 and C_1 if you don't need sine-wave r-f. Both r-f and a-f will now be relaxation oscillations and the r-f relaxation frequency will vary during each pulse
(3) Since the required power is only about 0.9 mw, the d-c source can be a battery, solar cell, thermocouple, fuel cell or even a sandwich of a silver quarter and a penny with a sheet of salt-water-soaked paper in between (for a 1-ma Ge tunnel diode)



TUNNEL DIODE'S *r-f outputs B and C are pulsed at twice the frequency of audio output A—Fig. 1*



EQUIVALENT CIRCUITS *for r-f (A) and a-f (B) networks of Fig. 1. Characteristic curve is shown in (C)—Fig. 2*

DESIGN EQUATIONS[a]

$$a_{r-f}{}^{b} = L_1/R_d' R_{r-f} C_1 > 1$$
$$a_{a-f} = L_3/R_{dt}'' R_{a-f} C_3 \gg 1$$
$$R_{r-f} + R_{a-f} = R_{d-c} < R_d$$
$$V_{d-c} = V_A + R_{d-c} I_A$$

(a) The a constants represent criteria for r-f and a-f conditions; (b) $L_2 = L_1$

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(2) U. S. Davisohn et al., Designing With Tunnel Diodes, *Electron Des*, Feb. 3 and 17, 1960.
(3) W. H. Ko, Designing Tunnel Diode Oscillators, ELECTRONICS, p68, Feb. 10, 1961.

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Linearity (Independent)	±0.25%
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70°C (158°F) Ambient	1.0 watt
125°C (257°F) Ambient	0 watts
Operating Temp. Range	—65 to 125°C

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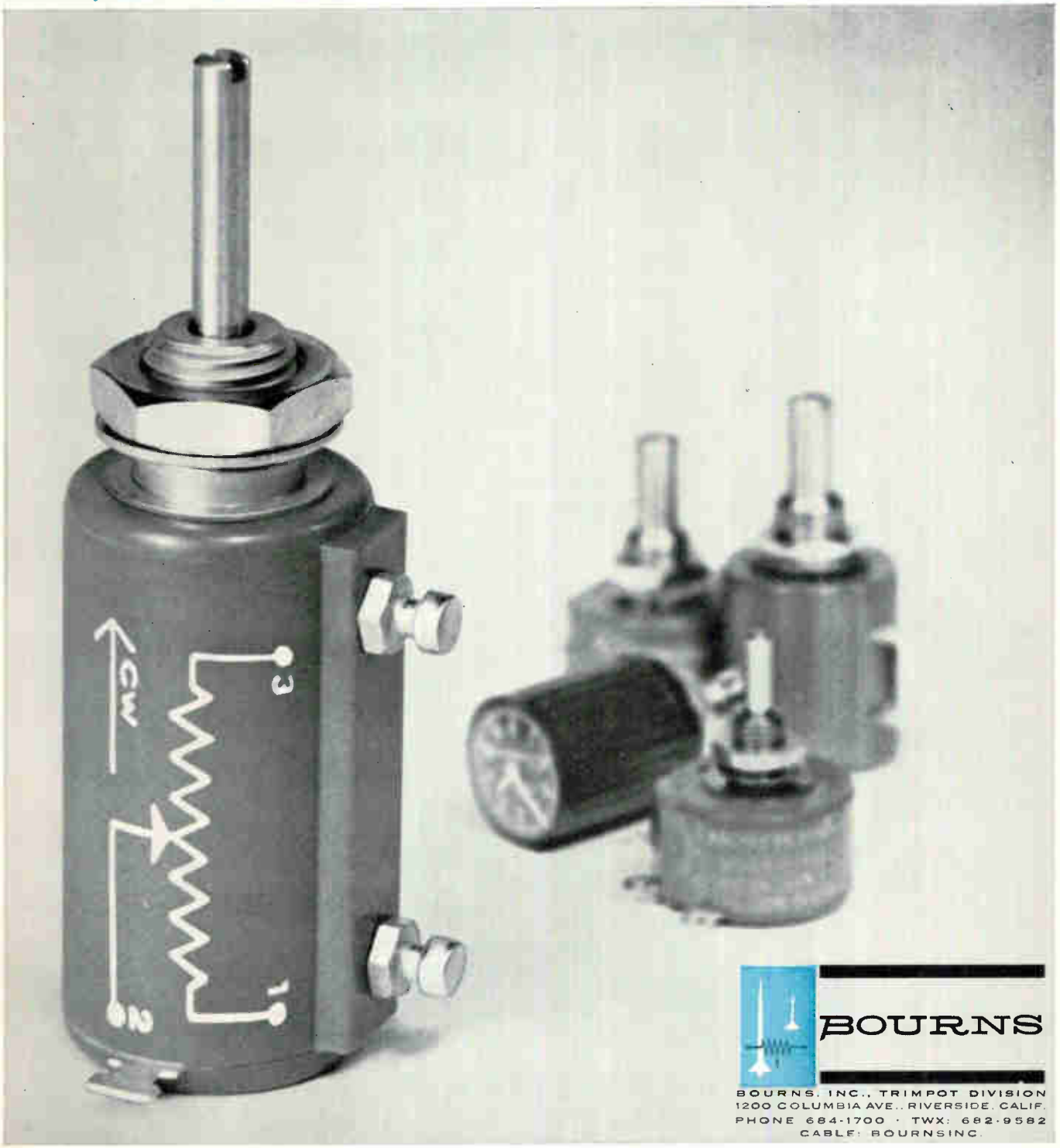

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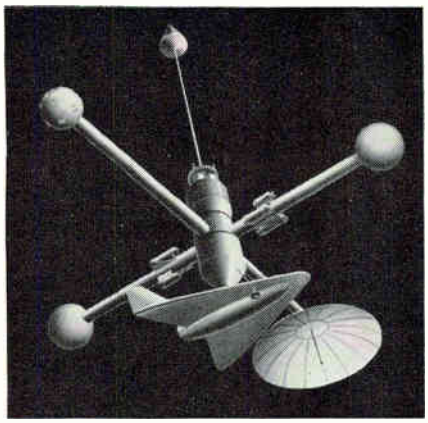

LOCKHEED Aerospace Traffic Control Center Timetable: 1970's

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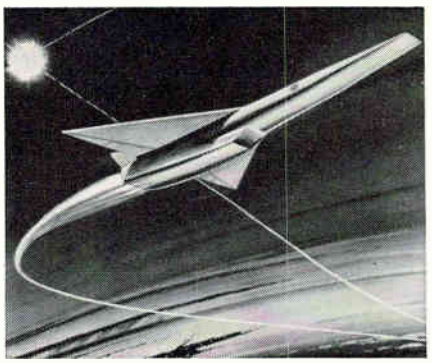

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3) The Hydrofoil—whose stability, control and noise are now under intensive study by the Company.

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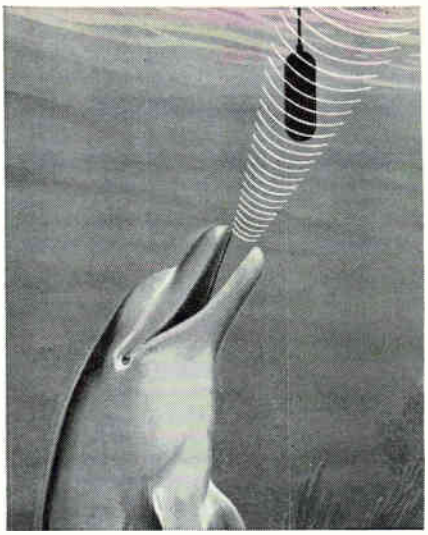

This dolphin is talking...and LOCKHEED is listening!

Yes, Lockheed oceanographers and marine scientists listen to "dolphin talk." Studying acoustical characteristics of underwater creatures is part of their daily work. Unraveling the mysteries of the sea is typical of the many research projects in which they are engaged—projects that constantly create new openings, fresh opportunities. Other fields now being probed: Internal waves; low-level marine meteorology; marine geology. Moreover, for its own use, Lockheed has adapted and commissioned the deep-sea research vessel Sea Quest—one of the few such ships owned by industry.

The Sea Quest already has revealed many significant facts about sub-surface sound emission. For instance:

It has been discovered that the "sonar" system of a porpoise can sense underwater obstacles as far as a quarter mile away. Readings so obtained are added to the library of underwater animal sounds. This already includes sea lions, seals, porpoises, shrimp and many varieties of fish.

Other Lockheed scientists and engineers are busy on other projects. For example: One group is absorbed in the improvement of airborne ASW avionics. Geophysicists are concerned with the interaction of ocean, atmosphere and geography.

Scientists and Engineers who couple intellectual curiosity with creative ability—who like to brave the unknown and untried—will do well to investigate these opportunities: Hydrodynamics; Aerodynamics for Marine Vehicles. Write today Mr. E. W. Des Lauriers, Manager, Professional Placement Staff, Dept. 1510, 2408 N. Hollywood Way, Burbank, California. An equal opportunity employer.

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Telemetry Concept Could Speed Space Program

Expected tenfold cuts in power drain could be traded for increased resolution

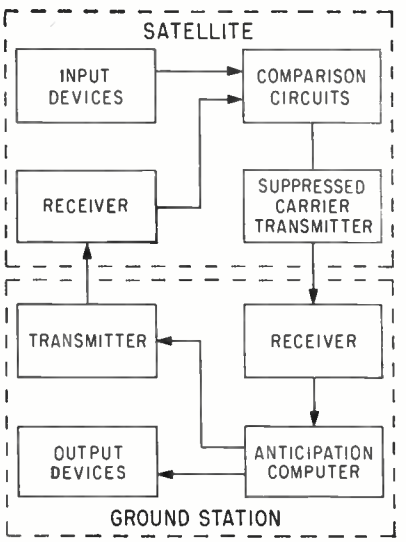
By FREDERICK W. KANTOR
Integrated Research and Technology, Inc.
Bellerose, N. Y.

TENFOLD reductions in power consumption appear to be possible in some space telemetry transmitters. These power savings could also be exchanged for increased resolution where desired. The basis for reducing power drain is to transmit data only when it differs from that predicted by a computer.

The special conditions of space telemetry require a small, remotely located, low-power station to transmit to the ground. The severe restrictions on the remote station do not apply to the ground station, which can be as heavy and powerful as desired.

PREDICTING DATA—Most systems now used for space telemetry are similar to those used on the ground, which may not be optimal from a total systems viewpoint. It would be desirable instead to transfer to the ground station as much of the total system power requirement as possible. Much of the power drain could be transferred to the ground station if it could anticipate the information likely to be transmitted by the remote station.

By transmitting anticipated data to the remote station, circuits in the space vehicle could compare the predicted and actual signals, as shown in Fig. 1. If the signals differ more than a preset amount, the correct information is transmitted by the remote station. However, if the two signals agree, no data is transmitted by the remote station and the power that would otherwise have been used is saved. The value of this approach to space telemetry depends on the information content of the signal sent by the remote station and on the ability of a computer on the ground to discern it.



SATELLITE *transmitter operates only when anticipated data sent from ground does not agree within preset limits with actual data—Fig. 1*

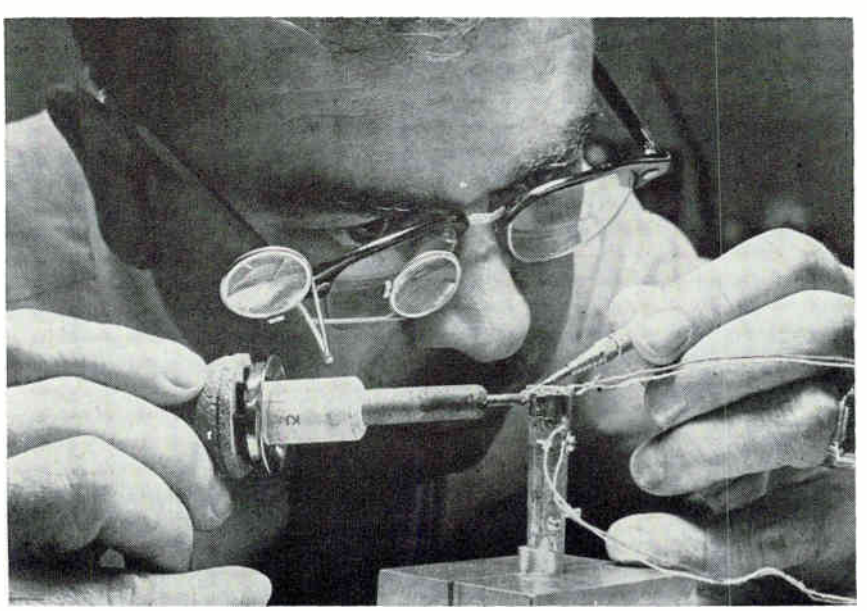
A satellite that transmits tv pictures of cloud cover could be used as an example of the application of this concept. The line most recently transmitted by the satellite can be used conveniently to anticipate the next line. Thus the received line after an appropriate time delay is retransmitted from the ground to the satellite.

As shown in Fig. 2, the only difference between the scan lines results from the changed boundaries of the cloud. Thus the satellite consumes only as much power as is needed to transmit the outlines of the clouds.

Telemetry signals could be anticipated by using delay line or cathode-ray tube storage. The preceding frame could be retransmitted on successive frames with appropriate corrections for such factors as orbital motion, earth motion and changes in propagation delay resulting from changes in distance to the satellite.

ADVANTAGES—This type system might not seem to be optimal because the transmitter is not always

Cooler Reduces IR Detector Noise



THERMOELECTRIC *cooler to increase sensitivity of infrared detectors is tested at Westinghouse Astroelectronics Laboratory. Laboratory model is larger than actual device*

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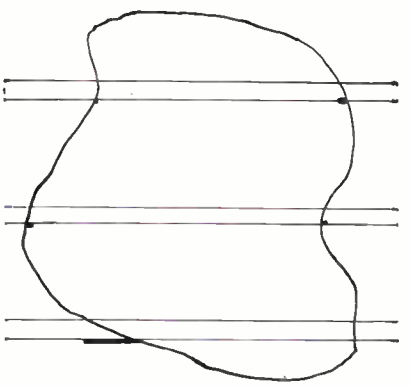
used at its full power. Such operation might be achieved by requiring the satellite to transmit digitized information indicating where and how the signal from the ground station was in error. However, the direct-comparison, suppressed-carrier system is simpler and it enables the system to report promptly any sudden changes in the signal. Thus it is more useful in surveillance and weather satellites than a more sophisticated method using completely digitized signals.

Power used by the remote transmitter in the direct-comparison system would be proportional to



RETRANSMITTING *preceding scan line from cloud-cover satellite after time delay requires satellite to send only dark portions of typical scan lines—Fig. 2*

only those parts of the picture where the ground-station signal was in error. However, a picture is always available at the ground station that is known to agree with the actual signal with the tolerance permitted by the comparison circuit in the satellite. The tolerance could be made adjustable from the ground.

In cloud cover pictures, the area of the boundaries is almost always less than 10 percent of the total picture area. Hence tenfold or greater reductions in power consumption can be expected using a suppressed-carrier transmitter operating only during the changes. On clear days, the satellite would only transmit the highly predictable outlines of large land masses, and far greater power savings could be expected.

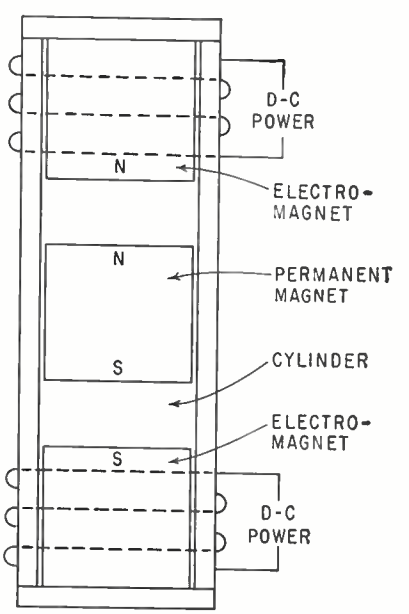
RESOLUTION—According to the modified Hartley theorem, these savings in power consumption can be exchanged for increased resolution. Thus this system approach could make missile-launch surveillance satellites available sooner than conventional approaches. The power savings could also make possible transmission of pictures of Mars and Venus with slight modifications of present equipment. However, the rapid changes in propagation delay would complicate the problem of anticipation.

Measuring Acceleration By Magnetic Suspension

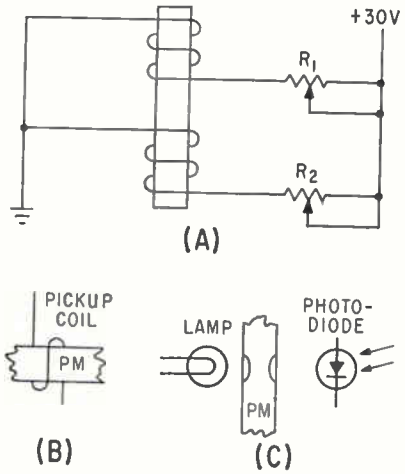
By FRED W. KEAR
Lytle Corp., Albuquerque, N. M.

ACCELERATION forces can be measused through their affect on a magnetically suspended mass. The measurement can readily be made if the affect is movement of a permanently magnetized body suspended between the unlike poles of two other magnets.

One method for using magnetic suspension to measure acceleration forces is shown in Fig. 1. The permanent magnet is suspended in a cylinder between the poles of two electromagnets. The magnetic lines of force of the permanent magnet are parallel to the cylindrical axis of the magnet. Both electromagnets are wound in the same direction so that a North pole is near the North poles of the permanent



PERMANENT *magnet is suspended in chamber between two electromagnets to sense acceleration forces—Fig. 1*



BALANCING *flux densities and controlling sensitivity are accomplished with potentiometers (A). Pickup coil (B) and light source and photodiode (C) can measure magnet movement—Fig. 2*

magnet and a South pole near the South pole of the permanent magnet.

When no power is applied to the electromagnets, the permanent magnet is free to move in response to any acceleration force, such as gravity. If only one electromagnet is energized, the permanent magnet is held against the other electromagnet with a force proportional to coil current in the electromagnet. When both electromagnets are energized, the permanent magnet assumes a position between the two electromagnets with the distance separating it from them inversely proportional to the ratio of the densities of the magnetic fields of the electromagnets. The opposing magnetic field of the permanent magnet remains effectively constant.

BALANCING FLUX—With no acceleration force acting on the permanent magnet and equal current in both electromagnet coils, the permanent magnet would theoretically assume a position in the magnetic chamber equidistant from its ends. However, tolerances in machining of the electromagnet cores and variations in core composition result in slight variations in flux density with the same current in each coil.

The method used to balance flux density, and thus position the permanent magnet to sense acceleration, is shown in Fig. 2A. Resistors R_1 and R_2 provide a means for

balancing flux density and also for controlling sensor sensitivity. With the flux densities balanced, sensitivity of the instrument is proportional to flux density in the sensing chamber. In practice, one resistance is varied to provide sensitivity compatible with the application while the other resistance is varied for balancing.

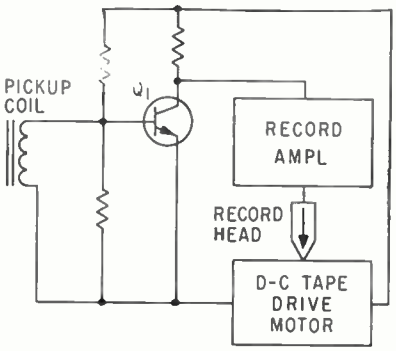
The device senses acceleration in either direction along its cylindrical axis. If it is to be used in the gravitational field, a bias current equivalent to one g must be established in the lower coil to provide a zero reference.

The effects of acceleration are measured by the movement of the permanent magnet in the magnetic chamber. To determine the magnitude and duration of shock and other acceleration forces, the amplitude and time of this movement must be measured.

MEASURING MOVEMENT—Two methods for detecting and measuring movement of the permanent magnet are shown in Fig. 2B and C. The pickup coil in Fig. 2B is position over the region of the cylinder in which the permanent magnet moves and is in the magnetic fields of both electromagnets as well as the permanent magnet. The lines of force of these magnets however do not cut the turns of the pickup coil until movement of the permanent magnet in the cylinder induces a voltage pulse in the coil. Magnitude of accelerations, although somewhat affected by mechanical damping, can be determined from the amplitude of the voltage pulse produced. Duration of acceleration must be determined by the time of occurrence of the negative voltage pulse when the permanent magnet returns to rest.

The light source in Fig. 2C is interrupted by the permanent magnet and light is sensed by a photodiode. As acceleration moves the magnet downward, more light is permitted to reach the photodiode, causing a variation in the voltage produced by it. Duration of acceleration is determined from the decay of the voltage produced by the photodiode.

A typical circuit for recording data from the acceleration sensor



ACCELERATION *data can be recorded with simple circuit using transistor preamplifier—Fig. 3*

is shown in Fig. 3. Transistor Q_1 is a preamplifier to drive the recorder amplifier, which in turn drives the recording head of a d-c powered tape recorder.

Study of Lasers, Plasma Could Improve Radar

QUANTUM and plasma electronics are under investigation in efforts to increase the effectiveness of radar. The research is being conducted at Cornell University, School of Electrical Engineering, under Air Force contract.

Previously unobtainable power levels are being sought at higher frequencies than are currently used. Achieving these goals would enable increases in the range and resolution of radar.

The research team hopes to bring theoretical science and practical applications closer together in a two-pronged program. One of the two concurrent projects is a study of the generation, maintenance and application of a hydrogen plasma in a confined volume. The second part of the program is a study of the effects of laser light on matter and of matter on laser output.

The atoms of pure hydrogen gas will be ionized in the plasma study to achieve microwave effects not possible with conventional metallic electrodes. The investigators hope to determine how the hydrogen plasma interacts with an electron beam and to harness the resulting beam for microwave power.

The interaction of the laser beam will be studied to determine how it may be applied to microwave electronics.

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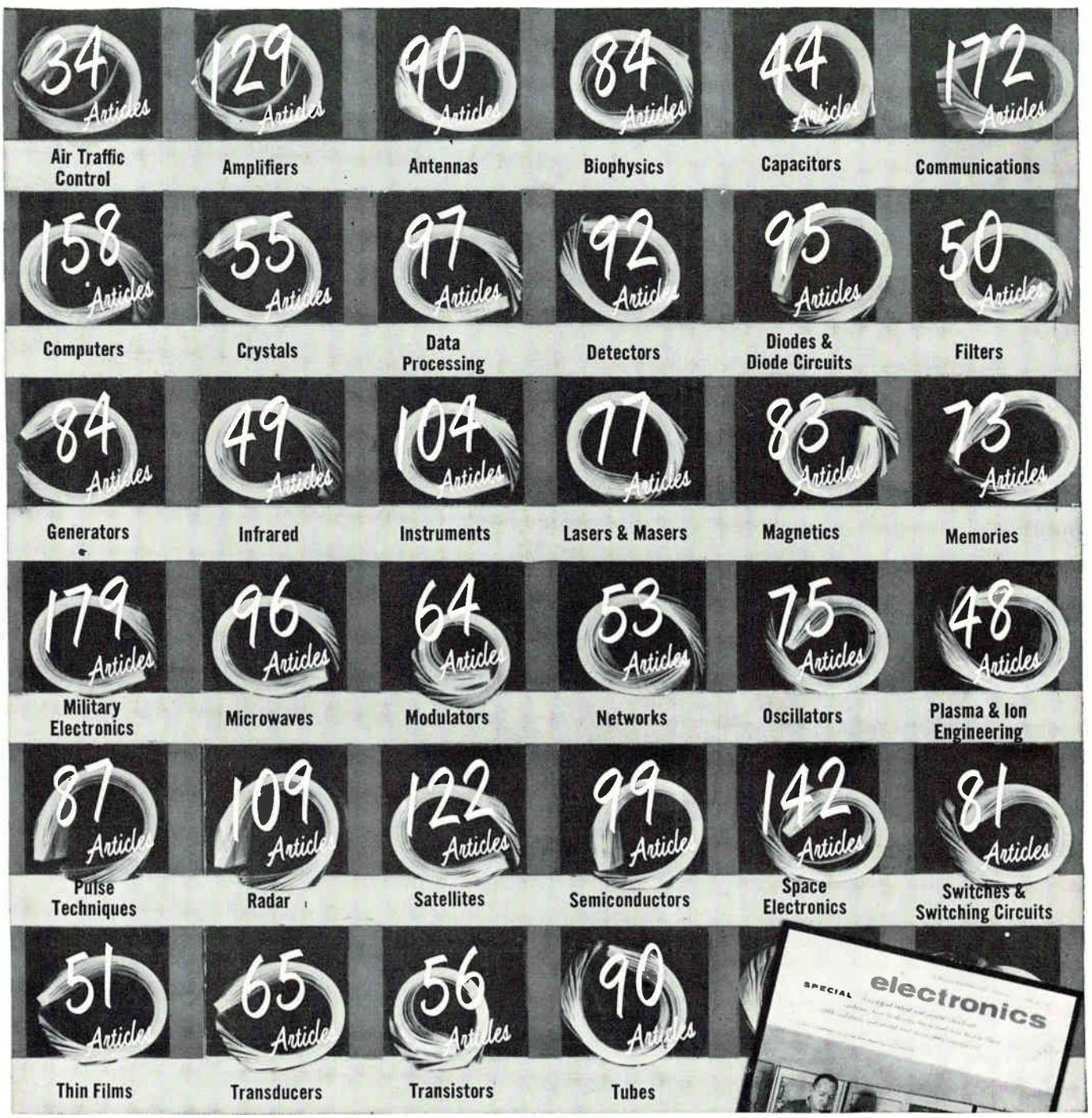

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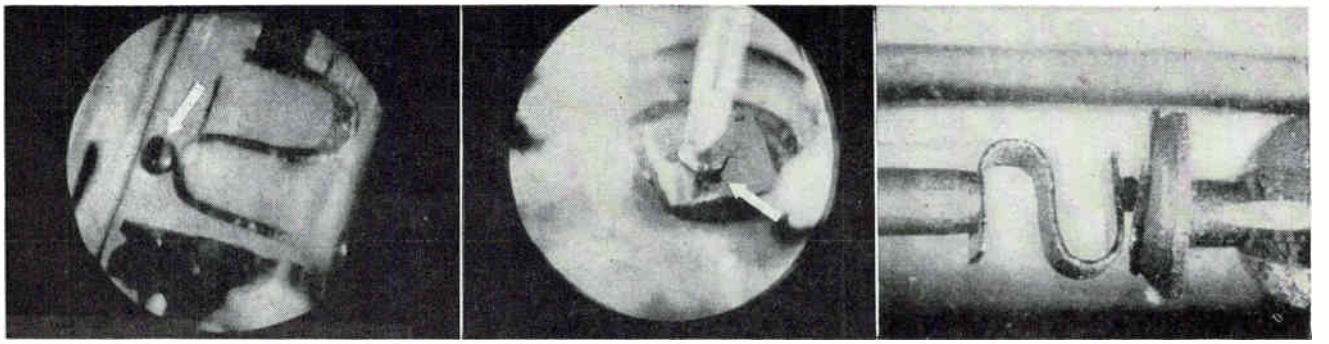

EXAMINATION *of diode faults revealed: open caused by disloged button (left), short due to excessive solder buildup (right), and open due to thermal stress during potting (center)—Fig. 1*

Failure Analysts Curb Device Faults

Determining basic cause of failure, recommending corrective action

By NELSON A. VELEZ
CHARLES L. VOGT, JR.,
Light Military Electronics Department,
General Electric Company,
Utica, New York

CASE HISTORIES of some unusual failures of devices have been selected from a typical electronic equipment presently in production. Confronted by a particular failure, the failure analyst chooses a particular method of analysis based on deduction, determines the cause, and recommends specific action to be followed in eliminating future failures of the same type.

DIODES—Several types of diode failures are recorded: open, shorted, open after potting, and diode with excessive leakage.

In the case of the diode reported as open, Fig. 1 (left) the failure was verified and microscopic examination revealed that the aluminum button between spring and crystal had been dislodged and was loose within the envelope. Similar diodes were examined and it was found that the buttons could be dislodged under similar operating conditions. Consultation with the vendor resulted in a subsequent manufacturing change to a different length spring and a soldered joint at the button and spring interface.

Microscopic examination of the shorted diode Fig. 1 (right) revealed excessive solder built up under the crystal and cracked crystal. Crack probably occurred when the diode was installed in the equipment. Normal solder temperature allowed the spring to exert excessive stress on the gold ball and crystal assembly, producing the crack. As a result of this analysis, vendor controls and inspection were improved, x-ray examination was recommended for each coming inspection. Heat sinks were used and soldering times were reduced for equipment assembly.

One diode was reported to be open after potting. Electrical tests confirmed this failure, and examination revealed a permanent twist in the metal envelope. The envelope was removed, and microscopic analysis showed a crack between the whisker and crystal, see Fig. 1 (center).

Electrical tests prior to potting did not reveal any discontinuity. However thermal stresses developed during potting operation, combined with the existing mechanical stresses were sufficient to produce the electrical failures. Assembly instructions and their im-

PHYSICS OF FAILURE MECHANISMS

Failure analysis is a logical testing and mental process that determines precisely the underlying causes of component failures and takes the corrective actions required to preclude their occurance.

Failure-analysis programs are straightforward enough. They require an accurate and complete reporting system, to record the failure mode, component life, conditions of failure, environments, and any other significant information.

The failure analyst must be not only well versed in components, but must possess a particular aptitude as a diagnostician. The failure analyst may have to work closely with equipment designer, vendor, incoming inspector, manufacturing engineer, production worker, and test personnel.

A broad-based failure-analysis program, well supported by management, can do much to improve product reliability, as well as to reduce cost and help meet delivery schedules. Originally demanded in military electronic programs, failmay be encountered in components detail for airborne electronic equipment, missile programs, and electronic systems installed in fleet and shore activities.

Selection of case histories of component failures, presented in this article, may exercise an important mental muscle and increase an awareness of failure areas that may be encountered in components

STANDARD NYLON CONNECTORS

Molded of tough, low-loss, shock-proof nylon—will not chip or crack, even when subjected to extreme temperature changes or severe mechanical stress. Voltage breakdowns to 12,500 volts DC. Wide line: Tip Plugs and Jacks; Metal Clad and Rapid Mount Jacks; Banana Plugs and Jacks; Binding Post. Designed for fast, easy mounting—available in 13 colors for coded applications.

Other Connectors—

Johnson also manufactures a complete line of standard connectors in addition to the nylon types. For complete information write for our newest components catalog.

OPERATING VOLTAGES TO 1500 VOLTS RMS... 5 AMPERES MAXIMUM CURRENT CARRYING CAPACITY!

These tiny Johnson Nylon Tip Plugs and Jacks are ideally suited for limited space applications! Extremely compact—highly resistant to extremes of shock, vibration, temperature and moisture. Body, tough low-loss polyamide per MIL-P-17091 (Du Pont Zytel 101 nylon.) Available in 13 colors, including basis colors for MS16108C coding applications. Contact Resistance: less than 2 milliohms. Capacitance between two adjacent jacks: less than one mmf. at 1MC.

Series 105-751 Horizontal Jack—Unique design accepts .080" diameter tip plug in either end, or from top or bottom. Formed silver-plated beryllium copper contact. Two terminals.

Series 105-851 Vertical Jack—Mounts through single .052" hole, requires minimum mounting area. Formed silver-plated beryllium copper contact.

Series 105-771 Sub-Miniature Tip Plug—For use with miniature jack, only .080" diameter. One-piece nickel-plated, machined brass tip. Solder type lead connection.

Series 105-881 Long Sub-Miniature Tip Plug—Identical to tip plug above, but with 4" nylon body to permit access to "hard to reach" test points.

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MINIATURE
Nylon Plugs and Jacks

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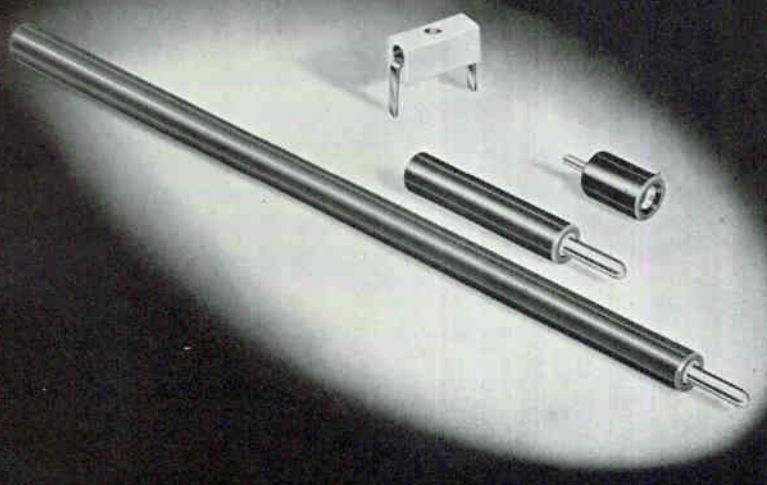
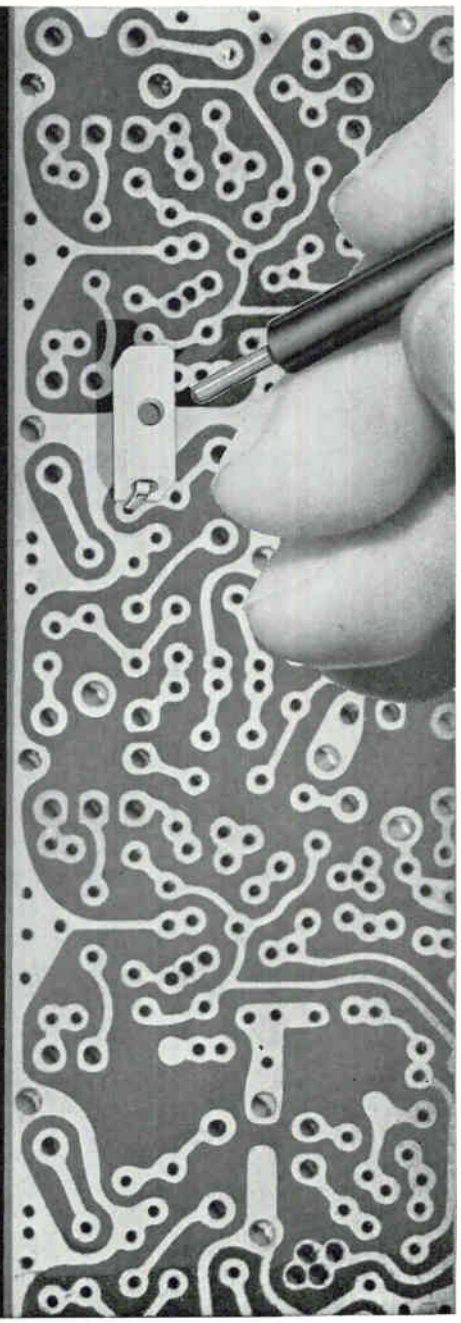
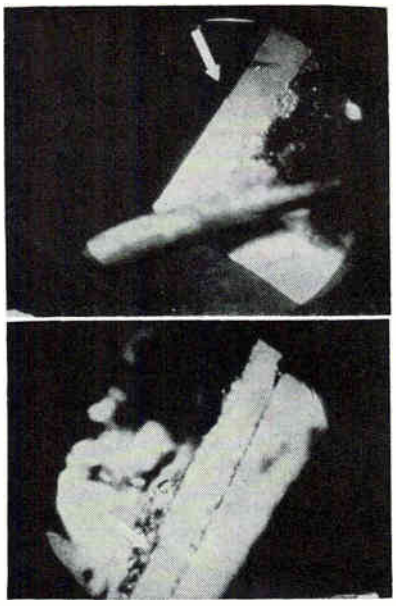


ACTUAL SIZE



DETAILED COMPONENTS CATALOG AVAILABLE—Write today on company letterhead

• CAPACITORS • TUBE SOCKETS • CONNECTORS • PILOT LIGHTS • INSULATORS • KNOBS AND DIALS • INDUCTORS • HARDWARE



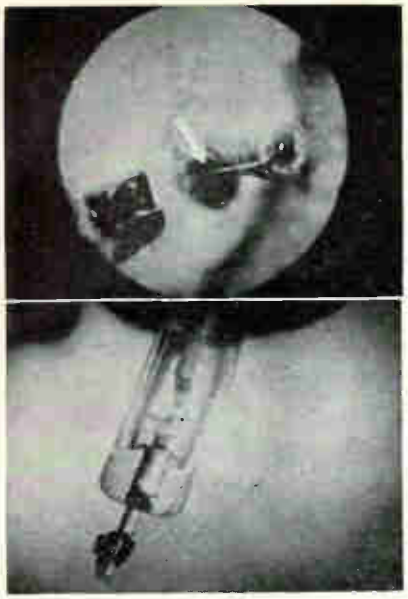
CERAMIC *dielectric capacitor failures revealed crack between plates (top), and short caused by excessive solder (bottom)—Fig. 2*

plementation were reviewed to preclude recurrence.

CAPACITORS—Two types of failures were recorded for ceramic dielectric capacitors. In one case, excessive high potential failures were noted at incoming test. The encapsulant was removed from forty capacitors selected at random, and nearly all showed cracks between the plates, see Fig. 2 (top). Of course, this offered an air dielectric rather than the ceramic. Although the actual cause of failure is not known, faults in the encapsulation process, rough handling, faulty examination were suspected. More flexible leads were then provided to reduce stress concentrations, and a structural encapsulant was provided rather than the conformal coating previously applied.

Short in a fixed ceramic capacitor was confirmed. After the encapsulation was removed, microscopic examination revealed that the short was caused by extraneous solder, see Fig. 2 (bottom). Failure was attributed to faulty manufacturing controls on the quantity of solder used to affix the leads to the capacitor body. Manufacturer's process-control procedures were amended to preclude this type of defect, and inspection levels were tightened.

TRANSISTORS—Three transistor failures were selected from the fail-



MODULE *failures were caused by shorter base lead of transistor (top), and poorly-constructed diode (bottom)—Fig. 3*

ure analysis program. A transistor in a flip-flop was suspected as open; another transistor in double NOR module had excessive storage time; and the third transistor shorted base-to-case under vibration.

In the failure involving transistor of flip-flop module suspected as open, encapsulation was removed from the module to permit electrical measurement and microscopic inspection. The base lead of the transistor was melted open, see Fig. 3 (top), arrow. A diode in the base circuit of the transistor was also found to have been shorted by excessive current. Both failures were induced by an error during equipment test. Test procedures were reviewed to prevent similar occurrences and to ascertain whether other components of the same assembly might have been overstressed.

Following removal of the encapsulant in the transistor in double NOR module that had excessive storage time, transistor was found to be within specification. On checking other components a diode was discovered with misaligned whiskers, Fig. 3 (bottom). Although module failure was never substantiated, the poorly constructed diode was considered to be a reliability risk. The module manufacturer instituted improved techniques to screen out similar oper-

BENT *tip in klystron caused poor frequency profile—Fig. 4*

able, but unreliable components.

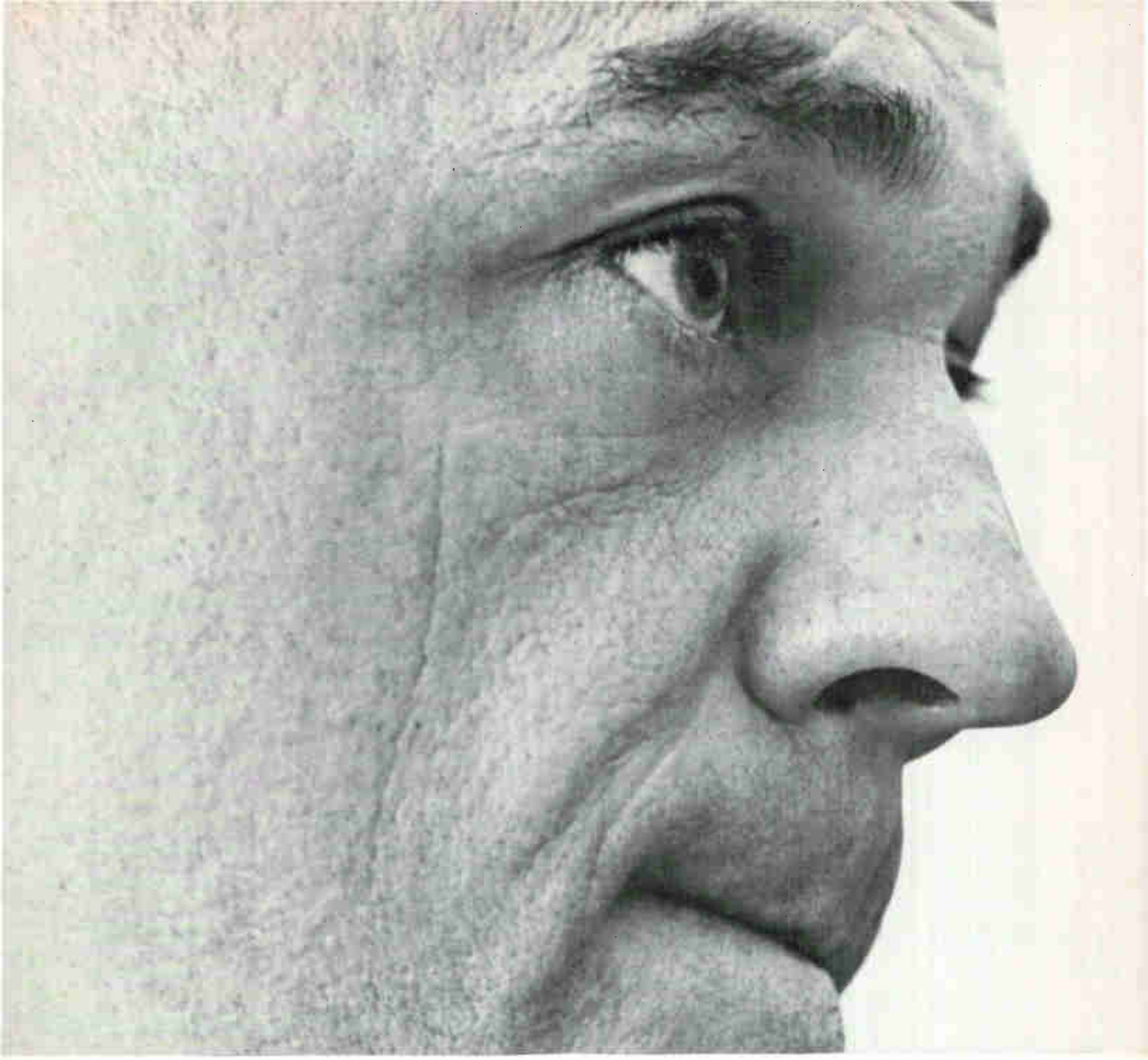
Failure analysis of the transistor shorted base-to-case under vibration revealed that gold plating had flaked from the crystal structure and was shorting to the case. Examination of additional transistors, selected at random from the same lot, revealed this to be a common fault. Vendor instituted additional manufacturing controls to prevent reoccurrence.

OTHER COMPONENTS — Klystron tube was examined because of poor frequency profile. Measurement indicated degradation of parameters. Photomicrographic examination of evacuation tip, Fig. 4, revealed that the tip had been bent and cracked before the tube was painted. Failure of klystron was attributed to minute air leaks that allowed degradation before the life end point was reached. Device was returned to vendor for replacement.

Case history of a shorted transformer revealed the short in winding to core. Upon disassembly it was observed that the polytetrafluorethylene tape had broken down dielectrically, thus permitting the arcing winding-to-core.

It was learned that, on occasion, the transformer was used in a moderately high altitude environment and with sufficient voltage to produce corona. Corona caused decomposition of the insulating tape. The design was changed to hermetically isolate the transformer from altitude environments.

In a pulse transformer failure, open windings were suspected. Disassembly showed lead from terminal to the winding was separated within the potting. These separations were located at the crevices in the potting compound where the



The best men are often failures.

Their thinking doesn't stop with the tried-and-true. They like going out on technological limbs, exploring the unexplored, working in areas where a breakthrough may be preceded by many blind alleys.

Are you this breed of man? If so, you'll like Northrop. You'll especially like the unconstrained atmosphere where you're free to try the untried. We are currently at work in more than 70 active projects, and we're constantly evaluating new lines of inquiry. Projects range from space guidance and navigation to automatic checkout equipment, from computer design and world-wide communications to laminar flow control.

On the following pages you'll find some specific positions available now at Norair Division. Look them over. One may be just the spot for you.

But even if you don't find your specialty listed — don't go away. We simply don't have room to mention all the opportunities to be found throughout Northrop's several divisions. If you're the kind of man who likes to investigate new areas of technology, there's bound to be a place for you at Northrop. Write to Dr. Alexander Weir at Northrop Corporation, Box 1525, Beverly Hills, California, and tell us about yourself. You will receive a prompt reply. **NORTHROP** An equal opportunity employer

winding leads crossed the crevices at nearly right angles. Analysis revealed that the potting compound, upon hardening, produced large fissures which caused tensile failures of the leads. After extensive investigations, vendor eliminated the problem by changing to another potting compound.

Relay failure showed an open after vibration. Since one relay lead was missing, the leads were examined microscopically. Missing lead was determined to have failed in fatigue. Examination showed other leads of the relay were potential failures at the butt weld on the relay header. Excessive stress concentration at the butt weld on the relay header caused the failure. Consultation with the relay manufacturer resulted in the use of feedthrough tapered leads to eliminate the points of stress concentration and still allow lead flexibility for assembly.

Intent in promoting corrective action in these case histories is not to point the finger at a vendor or designer, for example, as being responsible for a problem, but rather to make those aware of the problem and to assist them in every way possible in obtaining a solution.

Perhaps the most intriguing portion of the program is the analysis itself. This requires a laboratory with extensive electronic component-test equipment. Laboratory personnel probe, dissect, hypothesize, evaluate, and then conclude. They suspect everything, and are surprised at nothing.

Significant product improvements have been obtained as a result of the corrective actions.

Direction Stabilizer Uses Piezoelectric Effect

HOLLOW cylinder, suspended midway between its open ends, acts as a reference in space, detecting any motion that tends to swing it from its position.

Solid-state gyro, made of barium titanate, substitutes back-and-forth radial motion of a cylinder for the rotary motion of a wheel. Radial motion is obtained by exciting the cylinder with a small high-

frequency voltage. Applied voltage is converted into mechanical vibrations, and back into electricity. In vibrating, the open ends of the cylinder expand and contact in opposite directions 100,000 times a second.

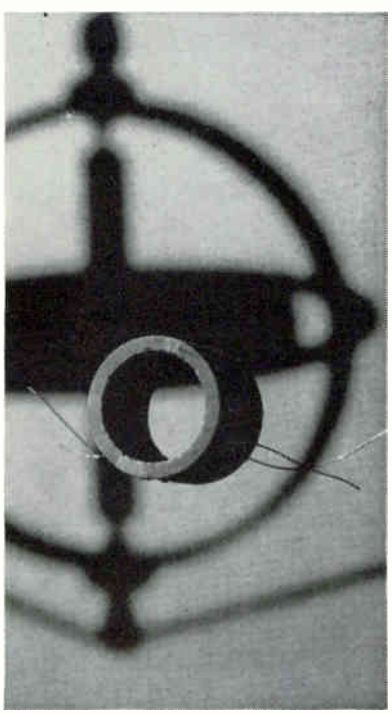
Actual movement is so small it cannot be detected by an ordinary microscope.

When vibrating, cylinder detects any move to rotate it about its axis and responds by adding a right-angle lengthwise twist to its motion. Action produces useful electrical signal that is picked off and amplified.

Cylinder aligned with axis of a space vehicle detects any drift from axis, electrical signals correct drift. Gyro stabilizes vehicle for left and right motion (yaw), up and down motion (pitch) or corkscrew motion (roll).

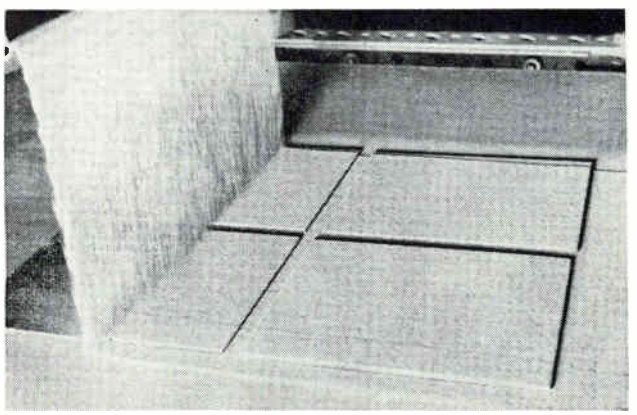
Extremely slow rates of drift-required for yaw control of space satellite could be controlled. Power requirements are met by solar cells or weak electrical sources now available in spacecraft.

Further development on vibrating gyro is now being carried out at Westinghouse defense center arm division, Baltimore, Md., under contract with Air Force.

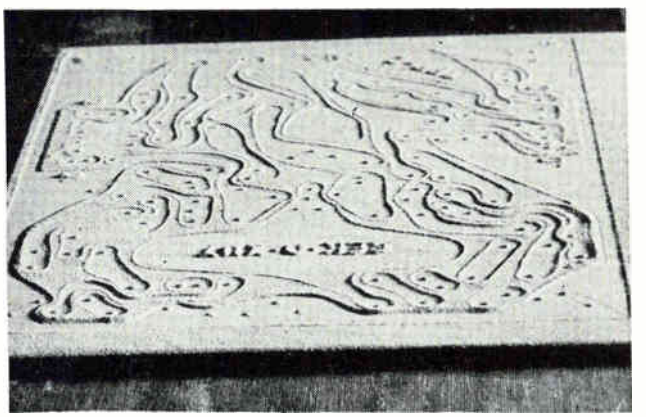


VIBRATIONS *in cylinder perform same basic function as gyroscope*

Stamping Process Used for Circuit Boards



BOARDS COATED *with adhesive are dusted with special metal powder as they move along on a conveyor*



CIRCUIT BOARD *after stamping shows circuit pressed into adhesive, untouched powder*

Simple process is easily adapted to automation methods

CIRCUIT PATHS are stamped into adhesive on base boards in a patented circuit board manufacturing technique developed in England and being applied in this country by Yolatron Inc., Dallas, Texas.

Base boards can be made of many types of insulating material and can be of almost any thickness. To demonstrate the versatility of the process, circuits have been put on tissue paper.

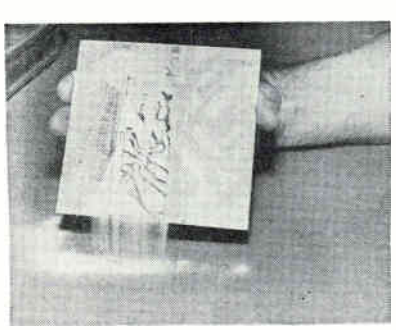
The photographs illustrate the major steps in the process. First the base board is coated with a urea formaldehyde resin varnish, which is then partially cured at 70 C or lower. Next, a special powdered metal is applied uniformly over the whole board. Powdered copper, powdered silver, or silver-coated copper powder have been found satisfactory for the application. The powder particles are not smooth spheres but have irregular, interlocking facets or fingers.

The coated board is then placed in a press and the circuit die is applied with from 1,000 pounds to 12 tons pressure per square inch for about ten seconds. Powder under the desired circuit paths is pressed into the adhesive and forms a continuous conducting path, typically about 0.0015 inch thick; but conductor thickness can be varied to some degrees.

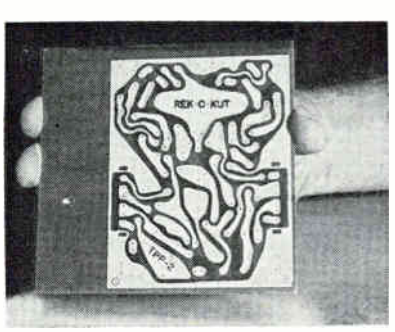
When the board is removed from the press, the loose powder is shaken off—it is reuseable—and the board is then cured at 130 C for ½ hour.

One of the photographs shows the strength of the bond between the printed circuit and the base board. The phenolic board itself was torn loose in a pull test of a wire soldered to a conducting path.

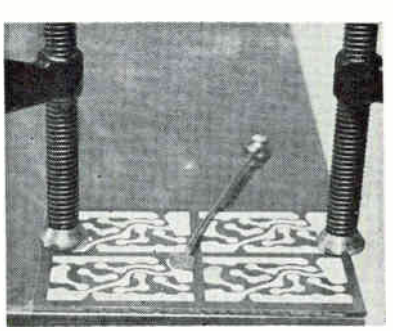
Line widths possible with the process are normally $\frac{1}{32}$ inch or larger, but under special conditions widths of 0.02 inch can be obtained. Since the surface of the circuit is usually fine silver, plating with



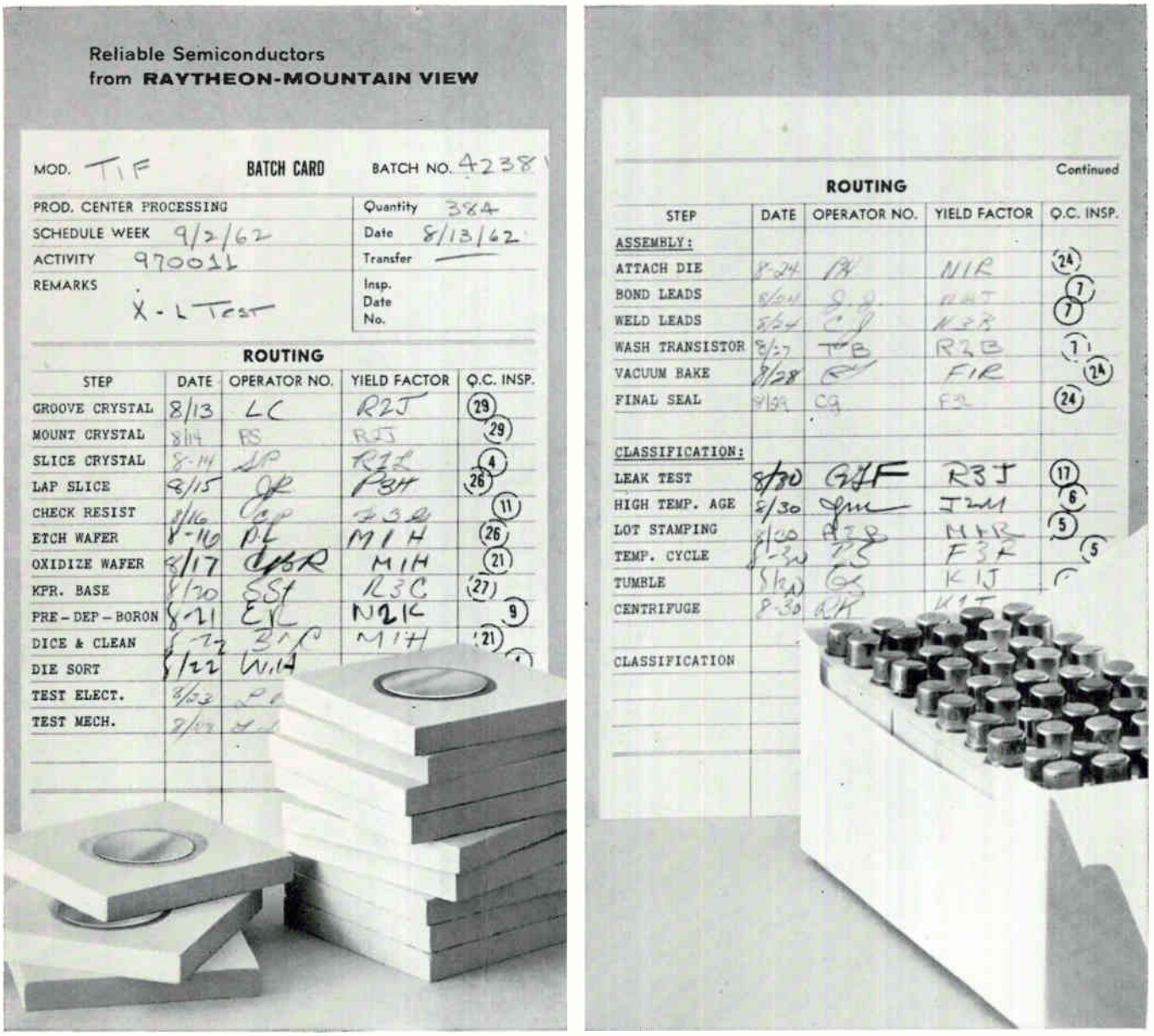
POWDER *not pressed into adhesive is shaken off and will be reused*



BOARD *after curing. Absence of draft covers during photography caused feathered path edges.*



CIRCUITS *cannot normally be peeled from base boards. Pull test removed part of phenolic base*



Small Batch Control makes Raytheon/Mountain View Silicon Planar Transistors consistently more reliable

Only Raytheon/Mountain View silicon planar transistors start life with a pedigree — a batch card which records every step of production from ingot to final shipment. Conventional manufacturing practice does not call for unit identification until after the final assembly operation.

At Raytheon/Mountain View, each batch of approximately 2,000 transistors is restricted to one operator or one machine at each process step. The resulting homogeneity permits more valid sampling, more effective quality control.

This unique emphasis by Raytheon/Mountain View on small batch identity gives you silicon planar transistors with consistently higher quality and reliability — at no extra cost.

Popular types include 2N1613, 2N1890, and 2N1893 in TO-5, TO-18, and microbloc packages. To satisfy your most critical design requirements, call on Raytheon/Mountain View. Your nearest Raytheon distributor or Field Office is ready to serve you. *Semiconductor Division, Lowell, Massachusetts.*

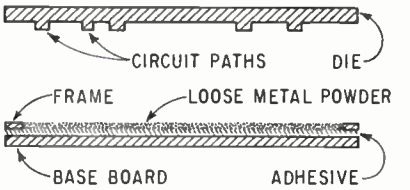
RAYTHEON

solder or silver is normally not required.

Circuits produced with the process have good electrical characteristics. For a conductor $\frac{1}{32}$ inch wide, for example, d-c resistance is typically 0.1 ohm per inch of conductor; at 40 Mc, resistance of 0.14 ohms per linear inch was measured.

Current carrying capacity for a $\frac{1}{32}$ inch wide conductor—for 40 C rise—is approximately 5 amps. For conductors spaced 0.05 inch apart, initial strikeover voltage has been tested at 2.6 Kv.

Circuits can be printed on both sides of the boards, and one of the main advantages claimed for the process is that through-plated holes can be made easily and reliably.



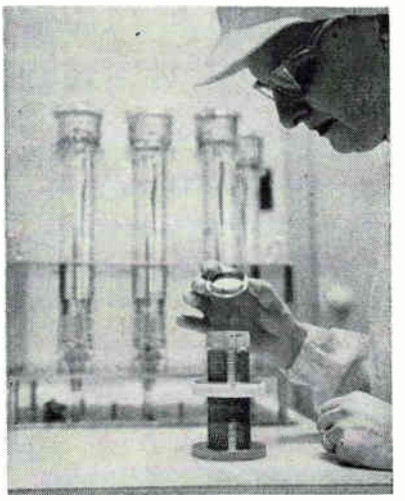
FOR SOME *applications a matching female die is used on the circuit board to contain the loose powder or to build up circuit thickness*

Electrical connections can be made with standard techniques, including welding and soldering. Soldering iron temperature can be as high as 250 C.

Image Orthicons Get Special Handling

EXTREMELY DELICATE targets of image orthicons are now being installed in tubes with an elevator device at General Electric's Cathode Ray Tube Dept., Syracuse, N. Y. Another technique to improve reliability and uniformity uses a number of separate white rooms for various assembly operations.

The cellular assembly approach permits each operation of image orthicon fabrication and assembly to be performed in a separate white room. In planning the layout of the new facilities, each step was analyzed to keep to a minimum the movement of parts, subassemblies, and operators, since reduction of movement reduces the amount of dust and lint in the air.



DELICATE TARGET *for image orthicon tube—in mounting ring—is placed on platform of permanently mounted hydraulic elevator*

The target insertion technique eases the most critical operation of image orthicon assembly. It is performed in one of the small white rooms of the new facilities.

In inserting the delicate, extremely thin target subassemblies —some of glass and some of a proprietary, magnesium oxide film— into the 13-inch-long tube body, a newly designed hydraulic elevator replaces the difficult hand insertion operation formerly used.

The lift mechanism is a permanently mounted hydraulic piston with the same diameter as the target assembly but slightly smaller than the diameter of the long neck of the orthicon tube.

The delicate target, held by a metal ring, is placed on top of the elevator and the glass tube is then set over the elevator. When the elevator is actuated by operating a lever, it rises slowly and carries to target into position. At the top of the tube (near the face plate), the target mounting ring is snapped into a clip.

The magnesium oxide target used in ultrasensitive image orthicons is about two inches in diameter and

TUBE BODY *is placed on elevator over target*

OPERATING *the lever causes fluid to drive elevator up until target mounting ring snaps in place*

so thin that 1,500 of them in a stack would equal the thickness of a human hair. If a target escapes from its mounting ring it will float endlessly on the minute currents of air caused by breathing and normal body motions.

Metal-Ceramic Sealing At Lower Temperature

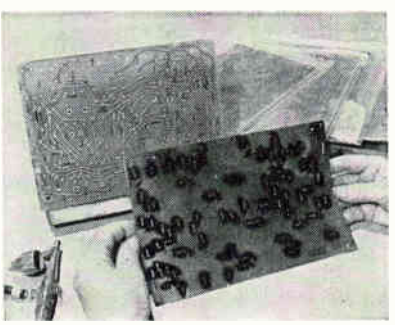
A NEW low-temperature metallizing process that produces metal to ceramic seals with 12 percent greater tensile strength than those made by other processes has been developed by Sperry Electronic Tube Division, Gainesville, Fla. Metal-ceramic components made with the new process also have greater relia-

bility. The raw technique is said to eliminate several production steps, allowing higher production rates, more stringent quality control, and lower unit cost.

Sintering temperatures in the new method range from 1,050 C to 1,150 C in a wet or dry hydrogen atmosphere. The conventional molybdenum-manganese process uses sintering temperatures of 1,350 to 1,500 C and requires a wet hydrogen atmosphere. To promote wetting, nickel or copper platings are also applied in the conventional method. Plating is unnecessary in the new process.

Using high alumina ceramics and copper solder, seals with an average tensile strength of 13,000 psi are obtained. These seals have been able to withstand a series of reliability tests without failure.

Several types of the low-temperature seals are now being used in the klystrons, traveling wave amplifiers and backward wave oscillators manufactured by the division.



Brass Stencils for Miniature Markings

TECHNIQUE for labeling terminal points on miniaturized electronic equipment to give more precise, legible and durable markings than present methods uses stencils made from thin sheets of brass. With miniaturized equipment, identification figures as small as 0.03 inch are sometimes required.

Silk screen and paper stencils lose their shape after ink has been applied a few times. Also, silk screen types do not always fit flush in small housings, boxes, covers and brackets, or on contoured surfaces, and temperature changes sometimes causes them to shrink.

Paper decals are difficult to position and do not adhere permanently.

Using the metal stencils, labels can be positioned accurately to within thousandths of an inch and can still be read easily.

In the photographic etching process, engineering drawings are made, then photographed and reduced in a 48-inch template camera. Before the master is placed in the camera, bars are drawn through the circles in "0"s, "9"s, and "6"s to prevent them from dropping out during etching.

A film positive is then made and placed on a 0.004 inch thick sheet of photo sensitized brass and exposed to arc light rays. The background area is thereby made acid resistant while letter and symbol images remain soluble in water.

Next, the sensitized sheet is placed in a dye which makes the image area visible.

The brass sheet is then held under running water to wash off the unexposed sensitizing solution on the letter and symbol images, and a liquid etch resist is then brushed on the back of the brass sheet.

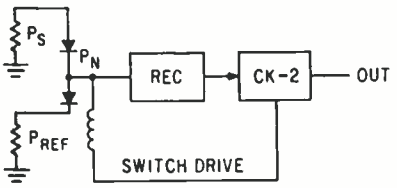
The brass sheet is placed in ferric chloride and etched for about six minutes. After cleaning, the stencil is ready for use.

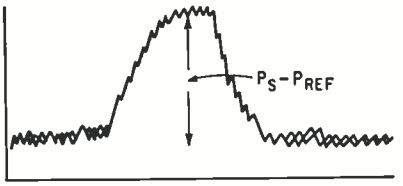
In devising the method, General Dynamics experimented with several materials but brass proved the most suitable for sharp etching. Cost of the metal stencil is about the same as for a silk screen stencil.

Committee Studies Infrared As Quality Control Tool

BOSTON—More than 15 companies were represented recently at the first meeting of a newly organized ad hoc Committee on Infrared Techniques for electronics. The meeting, sponsored by Raytheon, followed a seminar last May to explore utilization of infrared for electronic equipment reliability improvement. Goal is to develop techniques to take advantage of infrared radiation emitted by energized electronic components for engineering design evaluation, reliability analysis and manufacturing quality control (p 72, July 6).

DESIGN AND APPLICATION

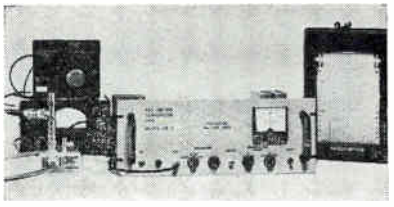




Radiometer Unit Digs Signals Out of Noise

Device used with ordinary receiver detects signals 30 db below receiver noise

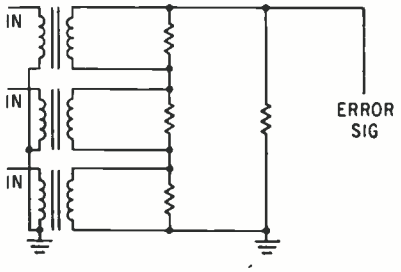
ANNOUNCED by Triconix Inc., Bear Hill, Waltham, Mass., the model CK-2 radiometric conversion unit is a synchronous detection system permitting conventional receivers between 4 and 400 Mc to detect and measure signals buried between 20 and 30 db below receiver noise. As shown in the sketch, a low-loss diode switch is inserted at the receiver input and is driven at a 1 Kc rate to alternately connect the receiver between a reference load and the unknown signal being measured. Difference in power level between unknown and thermal noise power level of reference load appears as amplitude modulation on the receiver signal level. This component is amplified and converted to a d-c voltage whose magnitude and polarity is a direct measure of the difference between the unknown signal and the reference load thermal noise power level. In a typical example of small signal detection using a receiver having a 3 db noise figure, 300 Kc bandwidth and a 10 second integration time, the small-signal capability was improved from −120 dbm to −140 dbm.

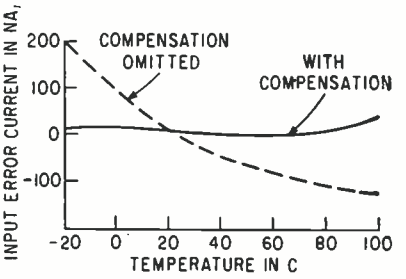


CIRCLE 301, READER SERVICE CARD

A-C Summing Network Has 0.002-Percent Accuracy

NEW from Siltronics, Inc., 2231 Saw Mill Run Blvd., Pittsburgh 10, Pa., the Akra-Sum is an ultra high precision a-c summing network using specially-designed transformers. Summing accuracies of 0.002 percent with a maximum phase shift of one second is typical. It can also cancel inherent system phase shifts and eliminate quadrature rejection in many cases. The unit can sum an unlimited number of voltages with frequencies between 60 cps and 5 Kc. Input impedances are available up to 1 megohm and output impedances under 500 ohms. It has been designed for servo systems, analog computers, and process controls requiring high degree of accuracy. The unit basically consists of a number of transformers whose secondary windings are connected in series resulting in a vector summation of those voltages imparted on each primary winding. (302)





Operational Amplifier Has Very Low Error Current

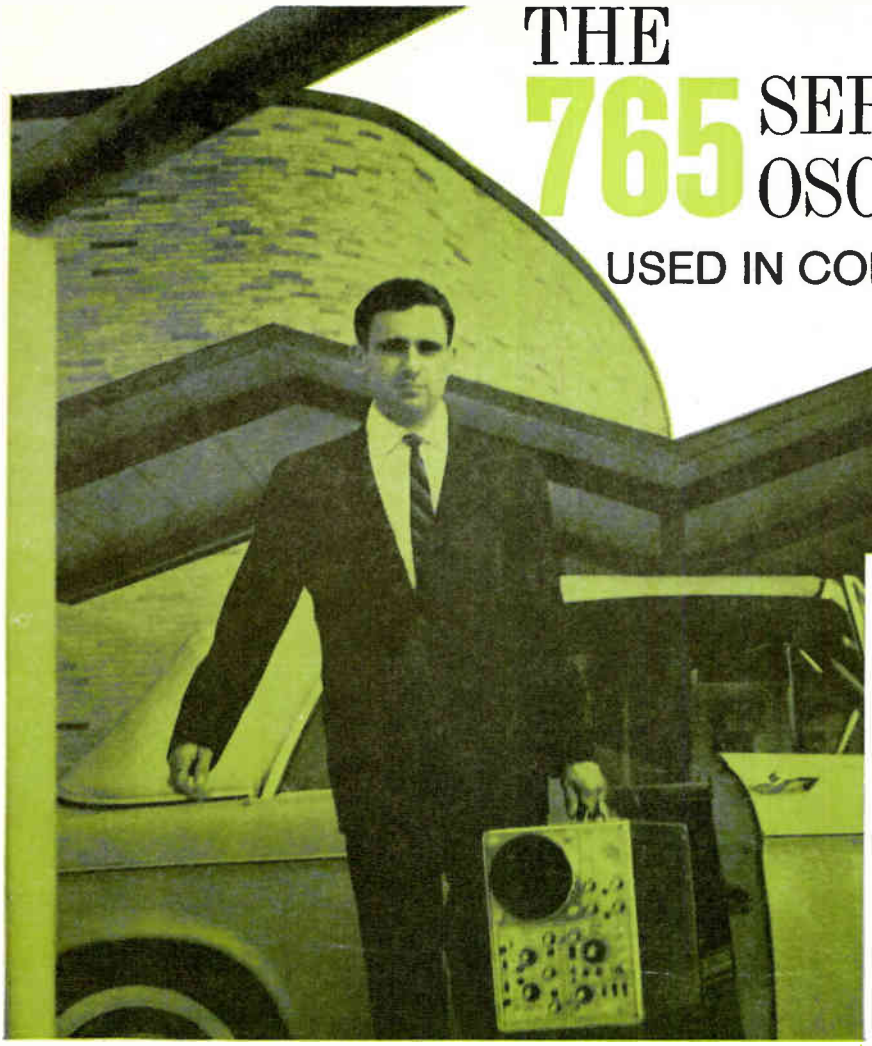
PRODUCED by Nexus Research Labs., Inc., 19 Needham St., Dedham, Mass., the type CA-2 miniature silicon solid state amplifier has a unique temperature compensation circuit that provides an order of magnitude reduction in input error current deviation with temperature changes. The unit was designed for use in adders, integrators, etc. The sketch shows input error current in nanoamperes plotted against temperature change. (303)

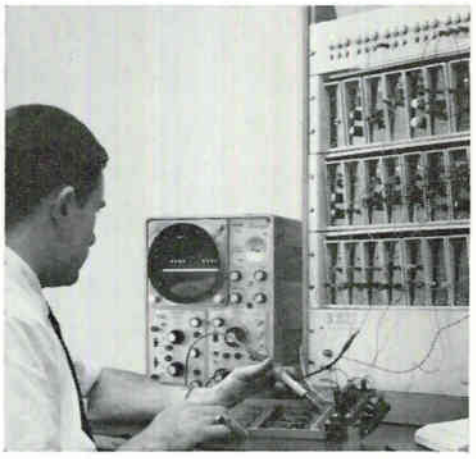
High Vacuum A-C Unidirectional Motor

MANUFACTURED by Photonetics Corp., Walker Valley, N. Y., is a small size, no load speed of 2,800 to 3,200 rpm, 1/20 h-p clockwise rotation motor designed to operate within ultra-high vacuum chambers. All electrical wiring is outside of the vacuum chamber. Starting torque is 1 lb per in. with a running torque of 0.6 lb per in. The $\frac{1}{4}$-in. diameter nonmagnetic stainless steel shaft can drive several gear

THE 765 SERIES OSCILLOSCOPES

USED IN COMPUTER CHECKOUT





The need for professional, laboratory-type high-frequency oscilloscopes—easily transported in the lab or in the field—was one of the design parameters that prompted the development of Du Mont's new, solid-state, light-weight 765 series of oscilloscopes. A 5 mv/cm sensitivity at 25 Mc, a 14.8 nsec risetime, together with dual-beam capabilities are part of the specifications which are incorporated.

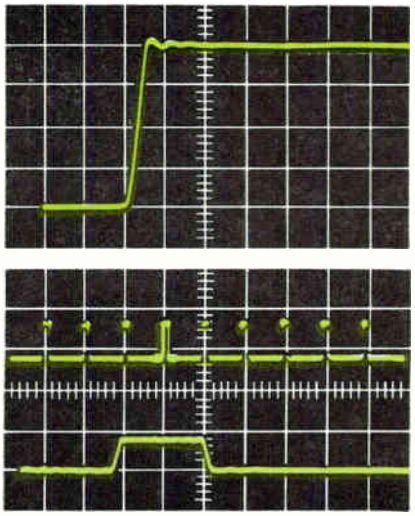
An example of the use of this new, highly-portable scope is illustrated by Mr. David Denniston, sales engineer of Digital Equipment Corporation, Maynard, Massachusetts, who utilizes it in the field and in his laboratory to periodically check and maintain computer modules manufactured by the firm. The compactness and light weight features enable Mr. Denniston to readily transport his Du Mont 766 bench type high frequency scope in his car. As a result, there is no need to depend upon a customer's oscilloscope. He knows that the instrument he uses is correctly calibrated and that field test measurements are valid.

THREE VERSIONS—The 765 Series comes in three different mechanical configurations to meet user requirements. The 765 PortaScope* for real portability. The 766 Bench Version. The 767 Rack Mounted version only 7-inches high.

* T.M.

TYPE 767 OSCILLOSCOPE
—shortest (only 7" high) rack-mount, high-frequency oscilloscope available.

- **Ten times more sensitive (5 mv/cm) at 25 Mc.**
- **Silicon solid-state circuitry**
- **Flexibility of dual plug-in circuits driving CRT directly**
- **Smallest high-frequency oscilloscope available**
- **Three versions—for bench, portable or rack use.**

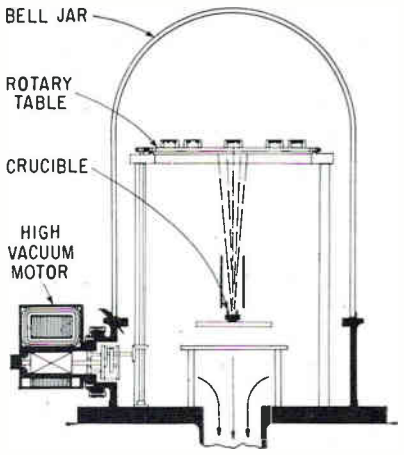


Upper oscillogram displays how a 3 nsec risetime looks on a 765 Series Oscilloscope when using a Type 76-01 Single-Channel Plug-in. Rapid switching transients are easily "captured" to establish necessary corrective measures on system under test. Sweep rate is 10 nsec/cm as provided by a Type 74-03 Time Base Plug-in. Below: Type 74-13 Dual Time Base Delaying Sweep Plug-in provides a strobe to select a particular pulse or trace sector (as depicted by brightened pulse), and enables its expansion for detailed investigation. Used with Type 76-02 Dual Channel Plug-in, expanded trace can be studied simultaneously as shown in lower trace.

GET ON BOARD THE NEW, GROWING DU MONT. Top opportunities for oscilloscope and other instrument engineers. Engineering openings also in storage tubes, multiplier phototubes. Tube sales engineers, district sales and engineers for mobile, and closed-circuit television engineers and sales engineers. Write or call George Vetan. Industrial Relations, PRescott 3-2000.

DU MONT

ALLEN B. DU MONT LABORATORIES
DIVISIONS OF
FAIRCHILD CAMERA AND INSTRUMENT CORPORATION 750 BLOOMFIELD AVENUE, CLIFTON, N.J.

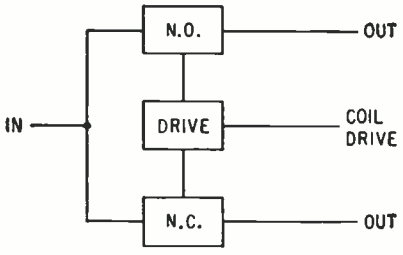


heads from 1 rpm to 400 rpm. Motors are mounted on a highly-polished stainless steel flange mating the customer's high vacuum system. Indium wire is provided as vacuum gasket but Viton or gold may be provided upon request. The motor can be made reversible and studies are going on to provide the motor with shading coils so that a servo motor may be fabricated for operation inside the vacuum chamber.

CIRCLE 304, READER SERVICE CARD

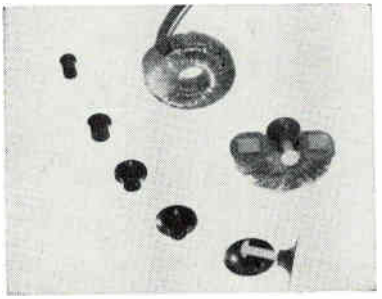
Direct-Writing System

BRUSH INSTRUMENTS, Division of Clevite Corp., 37th and Perkins, Cleveland 14, O. An eight-channel, direct-writing system accepts a variety of plug-in preamplifiers which adapt it to a broad range of recording applications. (305)



Electronic Switch Can Flip 50 v in Less Than 1 μsec

RECENTLY announced by GPS Instrument Co., Inc., 180 Needham St., Newton 64, Mass., the model ES 1060F electronic switch units use solid state components and printed circuits to produce switching times from normally-closed to normally-open (pick up time) in less than 1 μsec and from normally-open to normally-closed (drop out time) in less than 2 μsec. As shown in the sketch, input is triggered by any positive signal between 5 and 20 v (12 v normal) and will switch any input from 10 mv to 50 v. Contact resistance is 50 ohms closed position and 50 megohms open position nominal. (306)



Toroid Retainers Made in Five Sizes

MODULAR ELECTRONICS, 6211 South LaBrea Ave., Los Angeles 56, Calif. Toroid retainers are made of molded phenolic and diallyl phthalate. When attached with Nylon screws, they provide a vibration proof unit without the need of supplementary locking devices. No metal inserts are used that might interfere with the inductance of the toroid. In addition, the requirements for encapsulating are reduced. Units are manufactured in five sizes with prices of $0.27 to $0.08 each varying with size and quantity. (307)

Precision Voltmeter

WILK INSTRUMENTS, 3700 South Broadway, Los Angeles 7, Calif., announces an a-c/d-c voltmeter with 0.05 percent accuracy, a 20 Kc bandwidth and 0.5 to 1111.111 v range in 7 decades. (308)

Ferrite Isolators Span 33 to 36 Gc

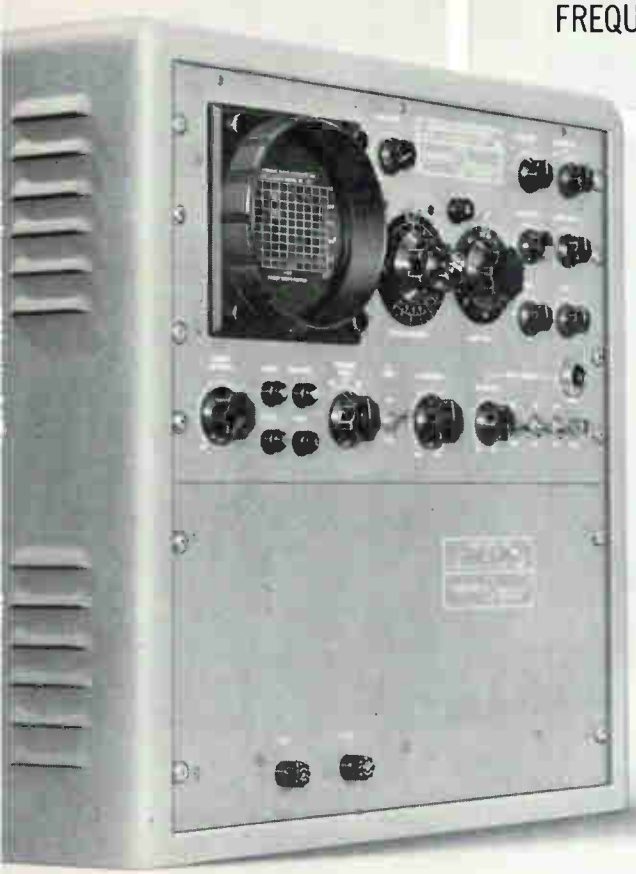
FERROTEC, INC., 217 California St., Newton 58, Mass. Two ferrite iso-

CIRCLE 85 ON READER SERVICE CARD→

1kc to 25mc
FREQUENCY RANGE

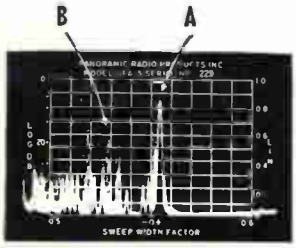
up to 3mc
SWEEP WIDTH

2μv
USABLE SENSITIVITY

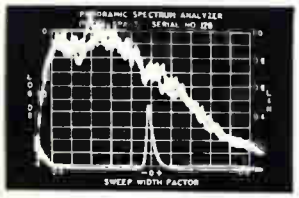


MORE CAPABILITIES for MORE APPLICATIONS

PANORAMIC MODEL SPA-3/25 SPECTRUM ANALYZER



Analysis of multiplexed voice communications circuit pinpoints high channel level (A) due to "singing" or oscillations. Adjacent channels at 4 kc intervals, some voice modulated, are also seen. Voice peaks (B) show up clearly. 40 db log scale.



Noise spectrum analysis using internal video smoothing filter displays average noise level versus frequency in easily appreciated form. Internal marker pips are 500 kc apart.

Wide frequency coverage to 25 mc, scanning width to 3 mc and sensitivity to 2μv plus many other exceptional performance characteristics enable the SPA-3/25 to provide accurate graphic measurement of virtually all types of signals; CW, AM, FM, pulsed, and noise. Its versatility and convenience for a multitude of applications have resulted in widespread acceptance.

The calibrated sweep width and center frequency controls are readily adjusted to select broadband scans or high resolution "zoomed in" analyses. Resolution capability is 200 cps. Crystal controlled markers check the frequency calibrations. The high persistence 5" CRT readout includes 3 selectable calibrated level scales; linear, 40 db log, and power. An adjustable smoothing filter facilitates single line noise density plotting. *(See screen photo at lower left)* Scanning rate is adjustable from 1 to 60 cps.

For applications requiring measurement only up to 15 mc, specify Model SPA-3. It includes all the outstanding features of the Model SPA-3/25. A companion Sweep Frequency Generator, Model G-6 is used with the SPA-3/25 or SPA-3 for single line response plotting to 15 mc. With the G-6, testing and alignment of filters, I-F's, and other networks are performed in a fraction of the time required for manual tuning methods.

dependable CERTIFIED SPECIFICATIONS for accurate data

HIGHLIGHT SPECIFICATIONS

Frequency Range 1 kc—25 mc (usable to 200 cps) (SPA-3 to 15 mc)

Sweep Width Adjustable, calibrated from 0 to 3 mc

Center Frequency Adjustable, calibrated from 0 to 23.5 mc.

Markers Crystal controlled, 500 kc and harmonics to 25 mc.

Resolution I-F bandwidth adjustable, 200 cps thru 20 kc

Sweep Rate 1 to 60 sweep/sec. continuously adjustable. Sweep operated synchronized to power line, or non-synchronized.

Amplitude Scales Linear, 40 db Log and Power

Sensitivity 20 μv to 2 v full scale. Min. discernible level = 2 μv

Attenuator 100 db calibrated

Response Flatness ±15% or ±1.5 db up to 23.5 mc

Input Impedence 72 ohms: (50 ohms optional. High impedence probe PRB-1, optional)

Comprehensive technical bulletins are available on SPA-3/25, SPA-3, G-6, and other Panoramic instruments used from 0.5 cps to 44 kmc.

Panoramic products
MANUFACTURED BY

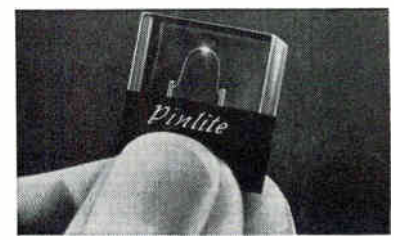
FOREST 6-3201
SINGER METRICS DIVISION
THE SINGER MANUFACTURING COMPANY
915 PEMBROKE STREET • BRIDGEPORT 8, CONNECTICUT

lators cover the 33 to 36 Gc range. Model R-343L features a 20 to 1 db ratio in a 1 in. by 1 in. cylindrical package. Model R-295L provides a 20 to 0.5 db ratio in a 2 in. by 1 in. cylindrical package.

CIRCLE 309, READER SERVICE CARD

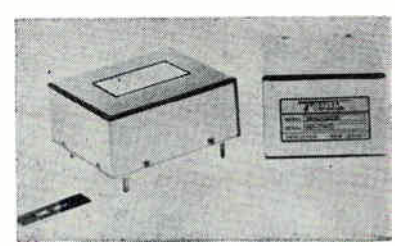
Memory Stack

RADIO CORP. OF AMERICA, Somerville, N. J., announces a new word-address memory stack capable of a complete read-write cycle in 300 nsec with less than 350 ma drive current. **(310)**



Test Component for Microminiature Lamps

KAY ELECTRIC CO., Pine Brook, N. J., announces a clear plastic device containing a microminiature Pinlite incandescent lamp, a small battery and a switching arrangement for use as a practical test component. Called the Thumb-Thing, the device provides engineers with the opportunity to test Pinlites in any of their thousands of applications without fear of losing or mishandling the tiny lamps. Removal of the easily replaceable battery for the Thumb-Thing exposes two sturdy leads to which an external power source or test signal may be applied. **(311)**



Sampling Switches Have High Accuracy

TELEPLEX CORP., US 206 & Cherry Valley Road, Princeton, N. J. Type 300 multichannel sampling switches, with an overall transfer accuracy of 0.1 percent, incorpo-

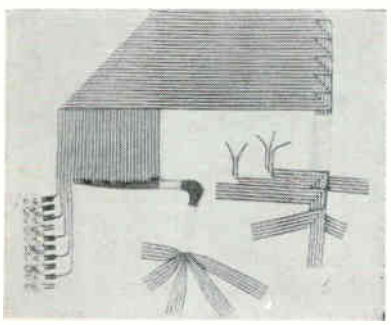
rate all-silicon solid state devices. Low back current of ±1 μa permits sampling of sources as high as 50,000 ohms. Standard output formats, per IRIG telemetry standard are pam, pdm and simultaneous pam and pdm. An optional record output is available for any unit with a pdm output format for direct entry into a tape recording head. Input is about 60 ma from a 28 ±3 v d-c source. (312)

Variable Wound Coil

CAMBRIDGE THERMIONIC CORP., 445 Concord Ave., Cambridge 38, Mass. Part No. 3341 variable wound coil is provided in overlapping frequencies ranging from 2.17 μh to 1,200 μh for i-f and r-f use. (313)

UHF Receiver Monitors F-M Signals

BABCOCK ELECTRONICS CORP., 1640 Monrovia Ave., Costa Mesa, Calif. The BCR-55 is a uhf receiver designed to monitor f-m signals in the 406-550 Mc range. It monitors carrier deviation of up to ± 300 Kc at an r-f level of 5μv or more at the receiver input. Crystal controlled operation insures stability of ± 0.005 percent. (314)

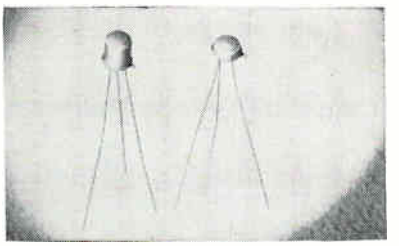


Flat Bonded Cable Offers Flexibility

SPECTRA-STRIP WIRE & CABLE CORP., Box 415, Garden Grove, Calif. Flat bonded cable combines flexibility

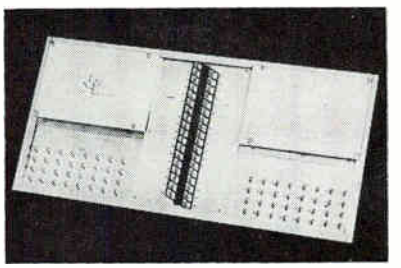
and precision of a high order. It is available in gages from No. 10 to No. 30 Awg. Color coding can be standard or customer's special. Any number of conductors. Illustration (p 87) shows physical flexibility and design flexibility. Available in vinyl insulation or any insulation with a PVC jacket.

CIRCLE 315, READER SERVICE CARD



Silicon Transistors Suited for Low-Level Use

SPERRY SEMICONDUCTOR, division of Sperry Rand Corp., Norwalk, Conn., has available small signal *npn* silicon planar transistors suited for low-level, low-noise amplifier applications. Series features high beta at extremely low-collector current, low-capacitance, low-leakage current and noise. (316)



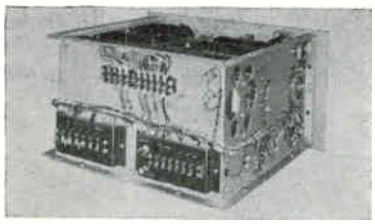
Magnetic Memories Feature High Speed

TEXAS INSTRUMENTS INC., P. O. Box 5012, Dallas 22, Texas. High-speed, word-organized memory systems use continuous sheets of thin magnetic film deposited on aluminum substrates as the storage medium. Low noise level, low drive power and excellent mechanical rigidity result from the use of aluminum substrates. Typical system has a memory of 8,000 words, 50 bits per word, cycle time 1.0 μsec. (317)

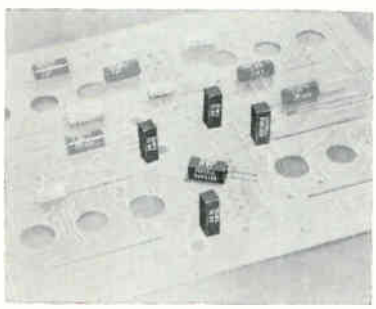
Programmable Source Housed in Modular Panel

MID-EASTERN ELECTRONICS, Springfield, N. J., offers a remotely programmable power source at 1,000

ohms per volt for life testing and systems applications. The MT32-35 has a d-c output of 0 to 32 v at 0-35



amp, regulation of 0.05 percent and less than 2 mv ripple. Input is single phase 105-125 v 57-63 cps, with overcurrent protection circuit, variable 10 μsec overvoltage circuitry and true constant current as well as constant voltage operation. Price is $1,475. (319)



Square Electrolytic Is Flush-Mounted

CORNELL-DUBILIER ELECTRONICS DIVISION, 50 Paris St., Newark 1, N. J., has developed a miniature flush-mounted square electrolytic capacitor for low-voltage printed circuits. It is leak-proof, moisture-tight and shock-resistant. It operates at 3 vdcw to 75 vdcw. Operating temperature range is from −20 C to +65 C. (320)

D-C Amplifier Offers Low Noise and Drift

DYNAMICS INSTRUMENTATION CO., 583 Monterey Pass Road, Monterey Park, Calif. Model 6109 is designed to drive h-f galvanometers. Output

is ± 10 v, 100 ma (simultaneously) from d-c to 30 Kc; voltage gain range is 0.1 to 100 continuously variable between steps. A rack cabinet houses six amplifiers. Price is $565.

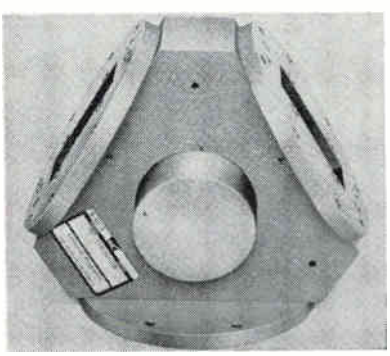
CIRCLE 321, READER SERVICE CARD

Interposing Relay

MILITARY AND COMPUTER ELECTRONICS CORP., 900 N. E. 13th St., Ft. Lauderdale, Fla. Solid state magnetic interposing relay has control sensitivities from 1 to 100 ma for output power levels up to 150 w. (322)

Varactor Diodes Feature Solder Seals

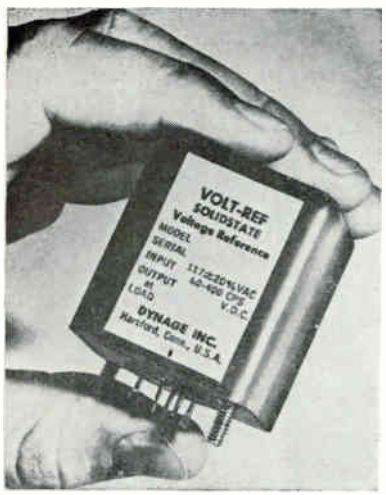
MSI ELECTRONICS INC., 116-06 Myrtle Ave., Richmond Hill 18, N. Y. Series 300 exhibit high frequency cutoff from 30 Gc to 150 Gc. The diffused silicon mesa diode is mounted in the low loss ceramic cartridge especially designed for minimum inductance. Diodes find immediate application as harmonic generators with the higher frequency cut-off types giving good multiplication efficiency. Series 300 has reverse working voltage of up to 30 v with junction capacitance of the order of 2.0 pf. (323)



Junction Circulator Spans 2,200-2,700 Mc

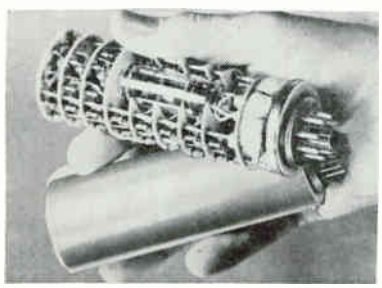
CASCADE RESEARCH, 5245 San Fernando Road West, Los Angeles 39, Calif. Model SL-43-3 junction circulator has better than 20 db isolation, less than 0.5 db insertion loss, and a vswr less than 1.2 over a 15

to 20 percent frequency band. It maintains these characteristics from 2,200 to 2,700 Mc and comes in RG104/U waveguide. **(324)**



Voltage References Offered in Two Series

DYNAGE, INC., 390 Capitol Ave., Hartford, Conn. Series 220 miniature solid-state voltage references provide approximately 1 ma at output voltages of 6.2, 11.7 or 17.9 v d-c. Series 240 supply 10 ma at output voltages of 6.2 and 11.7 v d-c. Temperature coefficients of ±0.001 percent/deg C and ±0.0005 percent/deg C are available. Voltage regulation is ±0.001 percent for 117 v a-c ±10 percent input, 50 to 400 cps. **(325)**



Frequency Control Has Octal Socket

INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Philadelphia 8, Pa. Series SF-1019 crystal-controlled, solid-state oscillators supply 8 v p-p output at any specified frequency from 30 cps to 100 Kc. Stability is conservatively rated at 10 ppm between 10 and 50 C, or 2 ppm at 25 C, in a 10-oz package measuring 1⅞ in. in diameter by 4⅞ in. in height. Unit takes the place of a tuning fork and amplifier. **(326)**

PRODUCT BRIEFS

TRANSFORMERS have high degree of shielding. Standard models available with up to 160 db of common mode rejection. James Electronics Inc., 4050 N. Rockwell St., Chicago 18, Ill.
CIRCLE 327, READER SERVICE CARD

K-BAND KLYSTRON uses sapphire rod tuning. It delivers 20 mw with a resonator voltage of only 375 v. Raytheon Co., Foundry Ave., Waltham 54, Mass. (328)

CAPACITANCE TESTER for semiconductors. Price is $2,295. Micro Instrument Co., 3851 Sepulveda Blvd., Culver City, Calif. (329)

DATA TRANSMISSION CONTROLLER is a 15-channel unit. It sells in the $30,000 to $38,000 range, with leasing terms available. General Electric Co., Phoenix, Ariz. (330)

MINIATURE TUBULAR CAPACITORS with weldable leads. They are rated at 50 v d-c over a temperature range from −55 C to +150 C. Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J. (331)

PISTON TRIMMER CAPACITORS make it possible to solder directly to the electrode band. They cover the 0.5 to 100 pf range. Roanwell Corp., 180 Varick St., N.Y.C. (332)

TEMPERATURE CONTROLLER is transistorized. Full span is 100 F in various ranges from −50 F to 280 F. The Powers Regulator Co., 3400 Oakton St., Skokie, Ill. (333)

ENCAPSULATED TOROID for p-c board mounting. It is available in a variety of windings. Sangamo Electric Co., Springfield, Ill. (334)

COLORIMETER/SPECTROPHOTOMETERS for lab or production use. Design features external filter adjustment. Instrument Development Laboratories, Inc., 67 Mechanic St., Attleboro, Mass. (335)

INDUCTANCE MATCHING COMPARATOR is completely automatic. It is designed for use with most toroidal coil winders. Electro Devices Inc., 75 Adams St., Newton, Mass. (336)

R-F MICROPOTENTIOMETER covers d-c to 900 Mc. It is suitable for use as a relative or an absolute voltage standard. Filmohm Corp., 48 W. 25th St., N.Y.C. (337)

LOGIC DEMONSTRATION EQUIPMENT is transistorized. Plug-in logic cards utilize p-c construction on epoxy-glass base. Munday Lab, 3520 S.W. 106th St., Seattle, Wash. (338)

REVERSIBLE CURRENT MULTIPLIER has powerhandling capabilities for accuracy of 0.1 percent for each 5-w section. Ratio accuracy to 1 ppm. Consolidated Ohmic Devices, New Hyde Park, N. Y. (339)

SNAP-ACTION SWITCH rated at 15 amp, 125-250 v a-c. Models with nine basic actuator types are available as

standard stock items. McGill Mfg. Co., Inc., Valparaiso, Ind. (340)

RUGGED LOGIC TRANSISTORS are low in cost They feature max switching times of 150 nsec. Texas Instruments Inc., P.O. Box 5012, Dallas 22, Texas. (341)

ULTRASENSITIVE RELAY features welded-seal construction. It is designed for dry circuit to 3 amp operation, and meets MIL-R-5757D. Babcock Relays, 3501 Harbor Blvd., Costa Mesa, Calif. (342)

SERVO ANALYZER provides amplitude and phase angle response measurement. Accuracy is 0.5 percent of setting. Astrodata Inc., 240 E. Palais Road, Anaheim, Calif. (343)

FINE-GRAIN GRAPHITE for semiconductor jigs. It features high density, low gas evolution, and high thermal conductivity. National Carbon Co., 270 Park Ave., N.Y.C. (344)

SIGNAL SAMPLING NETWORK features versatility. It measures spurious and harmonic signals with ± 3 db accuracy. Electromagnetic Technology Corp., 1375 California Ave., Palo Alto, Calif. (345)

MINIATURE BELLOWS COUPLINGS for precision instrument drives. Ten different solid hub models are available. Nilsen Mfg. Co., P. O. Box 127, Haines City, Fla. (346)

VOLTAGE MONITOR for missile checkout equipment. Sensitivity is 10 mv. P. R. Mallory & Co. Inc., Indianapolis 6, Ind. (347)

MICROMODULE RESISTOR is temperature-compensated. Resistance tolerance is ±0.1 percent. Vishay Instruments Inc., 63 Lincoln Highway, Malvern, Pa. (348)

DIRECT READING ATTENUATOR is continuously variable up to 10 db. It covers the frequency range from d-c 1 Gc. Weinschel Engineering, 10503 Metropolitan Ave., Kensington, Md. (349)

SEALED RELAY with 1 milliwatt sensitivity. Contact carrying capacity ranges from dry circuit loads to 5 amp. General Automatic Corp., 123 33rd St., Union City, N. J. (350)

POWER SUPPLY TRANSFORMERS for low-voltage applications. They are hermetically sealed to meet MIL-T-27A. Microtran Co., Inc., Valley Stream, N. Y. (351)

X-BAND TUNABLE MAGNETRON offers low torque. It features a jam-free tuner. Sylvania Electric Products Inc., Williamsport, Pa. (352)

LAPPING MACHINE is a compact unit in an economy package. It features self-truing action by precision retainer rings. Spitfire Tool and Machine Co., 2931 N. Pulaski Road, Chicago 41, Ill. (353)

VARIABLE TRANSFORMER with max output current of 3.75 amp. Max load rating is 0.53 Kva. Staco, Inc., 2240 E. Third St., Dayton 3, O. (354)

CIRCLE 209 ON READER SERVICE CARD

Literature of the Week

CHARGE AMPLIFIER Kistler Instrument Corp., 15 Webster St., North Tonawanda, N.Y. Model 552 transistorized charge amplifier is described in an illustrated bulletin.
CIRCLE 355, READER SERVICE CARD

SOLID STATE RELAY Sparton Corp., Jackson, Mich. Product data sheet No. 3 contains features and specifications of a long life and light weight solid state relay. (356)

POLYCRYSTALLINE SILICON Dow Corning Corp., Midland, Mich. A data sheet describes hyper-pure polycrystalline silicon for infrared transmission applications. (357)

MAGNETOSTRICTIVE FILTERS Spectran Electronics Corp., 146 Main St., Maynard, Mass. A four-page technical pamphlet describes magnetostrictive filter arrays. (358)

CERAMIC CAPACITORS Erie Resistor Corp., 644 W. 12th St., Erie, Pa. Bulletin NP-131 presents the latest additions to the Weecon line of rectangular, ceramic capacitors designed for p-c applications. (359)

PRECISION CALIBRATOR Ballantine Laboratories, Boonton, N. J. A catalog sheet describes model 420 d-c and a-c precision calibrator. (360)

POWER SUPPLIES Power Devices, Inc., 8710 Darby Ave., Northridge, Calif., offers a data sheet on transistorized power supplies with line regulation, load regulation and stability (in 24 hr) all at 1 percent. (361)

PRECISION WELDING EQUIPMENT Raytheon Co., 225 Crescent St., Waltham 54, Mass., offers a catalog on a line of resistance welding equipment designed for high-speed production, low cost, uniform precision welding. (362)

INSTRUMENTATION PRD Electronics, Inc., 202 Tillary St., Brooklyn 1, N. Y. Bulletin 900 describes a line of electronic instrumentation for microwave systems. (363)

TANTALUM CAPACITORS Aerovox Corp., New Bedford, Mass. A 28-page technical manual on solid electrolyte tantalum capacitors is available by writing on company letterhead.

VARIABLE RESISTORS CTS of Asheville, Inc., Skyland, N. C. Catalog 2100 fully describes and illustrates the series AW, a 5-w variable resistor. (364)

COMPONENTS CATALOG Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N.J., has published a component catalog highlighting tunnel diode amplifier and other solid state components. (365)

POWER OSCILLATORS Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif. Two power oscillators, which

CIRCLE 94 ON READER SERVICE CARD

together offer a frequency range of 200 to 1,050 Mc are described in a catalog sheet. (366)

ACCELEROMETER Columbia Research Laboratories, MacDade Blvd. & Bullens Lane, Woodlyn, Pa. Data sheet T-119 describes a water-cooled accelerometer for ultra-high temperature applications. (367)

POWER RESISTORS California Resistor Corp., 1631 Colorado Ave., Santa Monica, Calif., has available a 16-page catalog on a standard line of precision power resistors. (368)

SEMICONDUCTOR PRODUCTS Tung-Sol Electric Inc., One Summer Ave., Newark 4, N. J., has published a quick reference guide listing its complete line of silicon rectifiers and both power and switching transistors. (380)

WIRE MARKERS Western Lithograph Co., 600 E. 2nd St., Los Angeles 54, Calif. An 8-page stock list covers an entire line of self adhering E-Z Code wire markers. (369)

THIN FILM MAGNETIC ANISOTROPY Burroughs Corp., Detroit 32, Mich. Technical bulletin discusses controlled anisotropy variations in evaporated nickel-iron thin films. (370)

ACCELEROMETER Clevite Electronics Components, 232 Forbes Ave., Bradford, O., offers literature illustrating and describing model 25D21 self-generating accelerometer. (371)

SHAFT POSITION ENCODER AR&T Electronics, Inc., 1101 McAlmont St., Little Rock, Ark. Bulletin 011 illustrates and describes an 18-digit shaft position encoder. (372)

POWER SUPPLIES Astronetic Research Inc., Milford Road, Nashua, N.H. Brochure covers a line of transistor supplies, power for instrumentation, r-f tube power supplies, airborne inverters, h-v converters, and programmable supplies. (373)

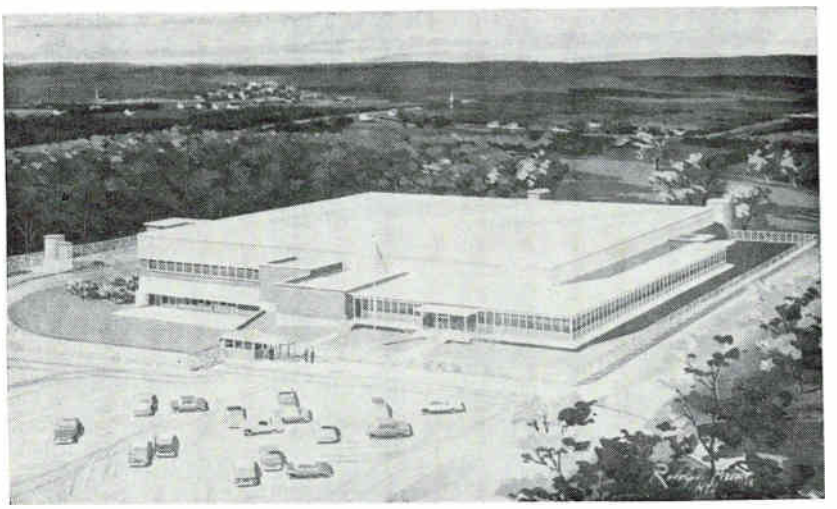
ELECTROSTATIC GENERATOR S.A.M.E.S., 269 Commercial Ave., Palisades Park, N.J. Two-page data sheet describes model AC751 electrostatic generator. (374)

P-M ALTERNATOR Kearfott Division, General Precision, Inc., Little Falls, N.J. A catalog sheet illustrates and and describes a size 5 permanent magnet alternator, a 2-phase device with harmonic content 8 percent of fundamental. (375)

CERAMIC LADDER FILTERS Clevite Electronic Components, 232 Forbes Road, Bedford, O., offers a bulletin graphically showing results of vibration tests run on its ceramic ladder filters. (376)

STRIP TRANSMISSION LINE MODULES Sanders Associates, Inc., 95 Canal St., Nashua, N. H., has published a 32-page catalog on Tri-Plate strip transmission line modules. (377)

CORONA TESTING James G. Biddle Co., Plymouth Meeting, Pa. Bulletin 66 includes drawings and data on corona test equipment. (378)



Sylvania Erecting Tube Plant

SYLVANIA ELECTRIC Products Inc. has under construction a 100,000-square-foot electron tube plant in Brookville, Pa. Sylvania is a subsidiary of General Telephone & Electronics Corp.

The multi-million dollar plant will be "the most advanced electronics manufacturing facility in the world and will help us to meet increasing foreign and domestic competition," Merle W. Kremer, a senior vice president with responsibility for Sylvania's Electronic Tube division, reported. It will replace three plants in Brookville which total 60,000 square feet. The company has four other receiving tube facilities totaling nearly 1 million square feet.

Kremer said "The demand for receiving and other types of electronic tubes is leveling off at an extremely high plateau. We expect that over the next five years, receiving tube sales will be at the very high rate of 350 to 375 million units annually. In that period, we expect that Sylvania's sales will increase to the point at which we shall record a substantial gain in industry position. Traditionally, we have been one of the two largest manufacturers of receiving tubes."

The new plant, to be located on a 20-acre tract, is expected to commence operations late next year. John L. Minno will continue as manager of the Brookville operation, a post he has held for the past 18 years.

Sylvania's Electronic Tube division employs approximately 7,000 persons at receiving tube plants in Altoona, Brookville, Emporium, and Williamsport, Pa., and Burlington, Iowa, and at picture tube plants in Seneca Falls, N. Y., Ottawa, Ohio, and Fullerton, Calif. Currently there are about 800 employees at the Brookville facilities.

Machlett Laboratories Advances Skehan

JOSEPH W. SKEHAN moves up from executive vice president to president of The Machlett Laboratories, Inc., Springdale, Conn., a subsidiary of Raytheon Co. Also announced was his being named general manager of the Machlett Laboratories division of Raytheon.

Skehan, first man hired after Machlett was incorporated in 1931, succeeds Wilbert E. Stevenson who becomes chairman of the board of The Machlett Laboratories, Inc.

Melabs Names Wolfe to Fill New V-P Post

ROBERT E. WOLFE has been named to fill the new post of vice president of manufacturing for Melabs, Palo Alto electronics firm which designs and builds microwave systems, equipment and components.

Wolfe joined Melabs in 1960 as production manager. Before coming to Melabs, he was production manager of the Electronic Processes Corp.

Sonnenschein Takes New Position

APPOINTMENT of A. H. Sonnenschein as vice president of the Federal Scientific Corp., New York City, has been announced. Sonnenschein, who is also a director of the firm, was formerly assistant to the president at Polarad Electronics Corp.

Federal Scientific Corp., a subsidiary of Polarad Electronics Corp., is engaged in the research and development of advanced electronic systems.

Gentry Assumes Additional Post

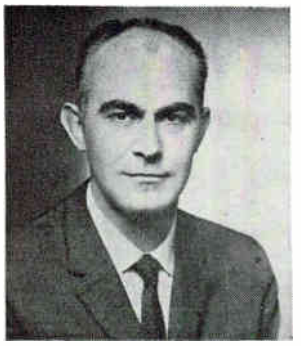
KENNETH GENTRY has been named assistant to the general manager, Chicago Center, Morotola Military Electronics division. He will also retain his former position of associate director of research and development for the Military Electronics division.

The Motorola military products

facility in Chicago designs, develops and manufactures advanced electronic systems and equipment for surface and air communications, radar displays and data transfer, and undersea applications.

Robert Bakish Joins Electronics and Alloys

ROBERT BAKISH, formerly with Alloyd Electronics Corp., has joined Electronics and Alloys Inc., Ridgefield, N.J., as executive vice president and director of research and development. He continues with his duties as acting director of research for Republic Foil Inc.



REL Elects Hull V-P of Engineering

ROBERT E. HULL, chief engineer, has been elected to the post of vice president of engineering at Radio Engineering Laboratories, Inc., Long Island City, N.Y. REL is the communications subsidiary of Dynamics Corp. of America in New York City.

Hull joined REL in 1954 as assistant to the vice president in charge of research and development to assume responsibility for detailed engineering of REL tropospheric scatter and other communications equipment. In 1957 he was named chief engineer.

Sanders Moves Up At Teleregister

MILTON SANDERS has been elected vice president, engineering, of The Teleregister Corp., Stamford, Conn. He succeeds Alexander Greenfield who was named executive vice president in June.

Sanders steps up from the post

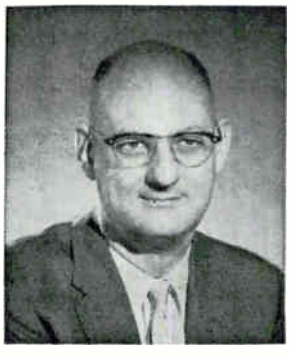
of assistant vice president, engineering.

Sylvania Promotes J. E. Storer

APPOINTMENT of James E. Storer as director of the Applied Research Laboratory of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., Waltham, Mass., is announced.

For the past year, Storer has served as acting director of the Laboratory in the absence of Leonard S. Sheingold, who recently completed a one-year appointment as chief scientist of the U.S. Air Force. Sheingold was appointed vice president-advanced technology on his return to the division.

Storer joined Sylvania in 1957. Prior to that he served as a consultant to the Applied Research Laboratory on studies relating to military systems analysis.



Sperry Gyroscope Advances Harris

APPOINTMENT of Herbert Harris, Jr., as director of engineering for Sperry Gyroscope Co., Great Neck, N.Y., is announced. In the newly established position he becomes advisor for engineering operations for the company at all of its plants and divisions.

Harris was formerly manager of

Sperry Gyroscope Company's Air Armament division.

Andersen Laboratories Hires Mark White

MARK P. WHITE has been appointed chief engineer of the Electronics division at Andersen Laboratories, West Hartford, Conn. The new post will include direction of the electromagnetic and magnetostrictive departments and development of associated delay line circuitry.

White was previously staff engineer at Reflectone.

Kaiser Electronics Names Diepeveen

NEAL DIEPEVEEN has been appointed engineering manager for Kaiser Electronics, Inc., Union, N.J., manufacturer of precision power conversion equipment. He was former engineering manager for the Walter Kidde Co. Electronics Laboratory.

Adler Electronics Appoints, Promotes

ADLER ELECTRONICS, INC., New Rochelle, N. Y., has announced the appointment of John C. Fletcher and Sam Steinberg as project engineers in the systems engineering department, Government Products division. Prior to joining Adler,

LEGAL NOTICE

STATEMENT REQUIRED BY THE ACT OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, JULY 2, 1946 AND JUNE 11, 1960 (74 Stat. 208) SHOWING THE OWNERSHIP, MANAGEMENT AND CIRCULATION

Of ELECTRONICS, published weekly at Albany, New York for October 1, 1962.

1. The names and addresses of the publisher, editor, managing editor, and business manager are: Published by McGraw-Hill Publishing Company, Inc., 330 West 42nd St., New York 36, N. Y.; Editor, William W. MacDonald, 330 West 42nd St., New York 36, N. Y.; Managing editor, John M. Carroll, 330 West 42nd St., New York 36, N. Y.; Business manager, R. S. Quint, 330 West 42nd St., New York 36, N. Y.

2. The owner is McGraw-Hill Publishing Company, Inc., 330 West 42nd St., New York 36, N. Y. Stockholders holding 1% or more of stock are: Donald C. McGraw, Elizabeth McGraw Webster, Donald C. McGraw, Jr. & Harold W. McGraw, Jr., Trustees under Indenture of Trust m/b James H. McGraw, dated 1/14/21 as modified; Donald C. McGraw & Harold W. McGraw, Trustees under an Indenture of Trust m/b James H. McGraw, dated 7/1/37 as amended; Donald C. McGraw, individually; Estate of Mildred W. McGraw, Donald C. McGraw and Catharine McGraw Rock, Executors; (all of 330 West 42nd Street, New York 36, N. Y.); Grace W. Mehren, 536 Arenas St., LaJolla, California; Douglass & Co. (Affiliated Fund), 140 Broadway, New York, N. Y., Touchstone & Co., c/o Wellington Fund, Inc., Claymont, Delaware.

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5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: 56,411.

McGRAW-HILL PUBLISHING COMPANY, INC.
By JOHN J. COOKE, Vice President & Secretary.

Sworn to and subscribed before me this 14th day of September, 1962.
[SEAL] JANET A. HARTWICK.
(My commission expires March 30, 1963)

Fletcher was with Canadian Westinghouse and Steinberg was with Dalto Electronics.

Joel Julie has been promoted from project to executive engineer in the division's radio development department.

PEOPLE IN BRIEF

Charles K. Hartwigsen, ex-ITT Federal, named general marketing mgr., aircraft electronic products, the Bendix Radio div. **John L. Maynard** leaves RCA to join National Transistor as application engineer. **Kenneth E. Cochran** moves up at Battelle Memorial Institute to asst. mgr. for operations in the dept. of engineering physics. **R. Everett Curtis,** formerly with Hughes Aircraft, appointed v-p, g-m of Tracerlab-Waltham. **Andrew J. Koll, Jr.,** previously with Aero Geo Astro Corp. named president of the newly formed Control Science Corp. **E. Eastwood,** director of research at the Marconi Laboratories, is now group director of research for the English Electric group of companies, of which Marconi's is a member. **D. H. Wilke** advances to g-m of the Micronics div., Industrial Group, Elgin National Watch Co. **Robert E. Baker** promoted to plant mgr. of the Speer Resistor div. **Jerre K. Ferguson,** ex-Martin Marietta Corp., named senior engineer in the telemetry and communications section of the Engineering div. of Ortronix, Inc. **Robert W. Hughes** and **W. H. Highleyman,** previously with ITT and Bell Telephone Laboratories, respectively, are co-founders of Data Trends, Inc. They are president and technical director, respectively. **Arthur V. Sommer** elevated to executive asst. to the div. mgr. at Arma div., American Bosch Arma Corp. **Maurice J. Regan** moves up to succeed him with the new title of director of engineering & research. **Ernest Stern,** previously with Sperry Gyroscope and GE, named v-p and director of microwave research of Microwave Chemicals Laboratory, Inc. **Carl H. Berg,** from Collins Radio Co., to the marketing staff of Granger Associates as senior applications engineer.

electronics

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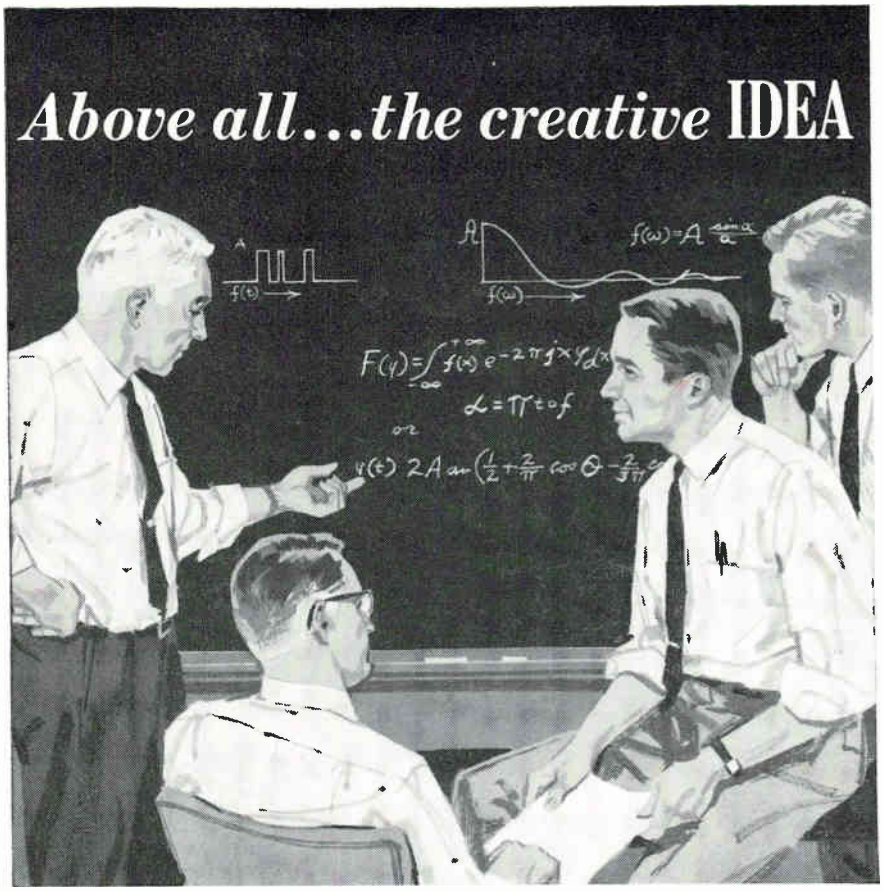

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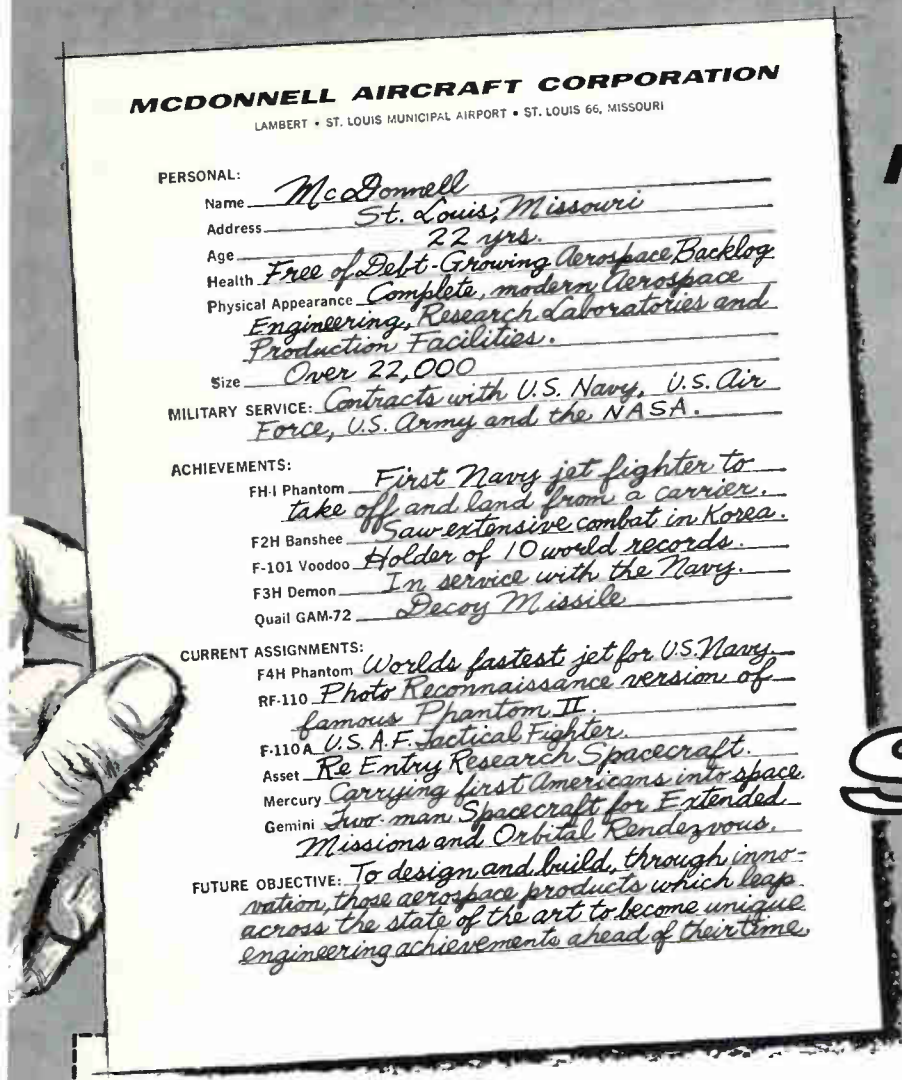

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The AIR FORCE LOGISTICS COMMAND has been assigned the mission of insuring that Air Force combat units throughout the world are equipped for instant action to meet any emergency. AFLC's SERVICE ENGINEERING organizations in nine locations throughout the nation have been called upon to pick up the challenging responsibility for maintaining the design and performance integrity of Air Force systems and equipment once they become operational. Included are missile systems, space systems, aircraft systems and command and control systems.

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- **Monitoring of prototype development and testing**
- **Monitoring of engineering modification contracts**
- **Evaluation of contractor's engineering change proposals**
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- **Telemetry**
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- **Flight Controls**
- **Engineering Information Research**

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electronics

WEEKLY QUALIFICATIONS FORM FOR POSITIONS AVAILABLE

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* These advertisements appeared in the October 5, 1962 issue.

SPECIAL PURPOSE TUBES

OA2	.80	4-65A	12.00	25Z6WGT	1.50	725A	10.00	5751WA	2.00
OA2WA	2.00	4-125A	20.00	26Z5W	1.50	726A	5.00	5763	1.75
OA3	.85	4-250A	35.00	FG-27A	20.00	726B	5.00	5777	150.00
OB2	.60	4-400A	30.00	28D7W	3.50	726C	7.50	5778	150.00
OB2WA	2.00	4-1000A	80.00	FG-32	10.00	750TL	112.50	5783	2.25
OB3	.70	4AP10	10.00	35T	10.00	NL-760	20.00	5784	2.50
OC3	.50	4B31	12.50	35TG	2.50	802	7.50	5787	2.50
OD3	.30	4C35	15.00	FP-54	100.00	803	3.50	5796	10.00
C1A	8.50	4CX250B	30.00	FG-57	10.00	804	15.00	5800/VX-41	7.50
1AD4	1.75	4CX1000A	125.00	RK-60/1641	1.50	805	7.50	5803/VX-55	5.00
1B24	7.50	4D32	15.00	HY-69	3.00	807	1.50	5814A	1.35
1B24A	12.50	4J32	100.00	BL-75	3.00	807W	2.25	5829	1.00
1B35A	3.00	4J34	100.00	75TL	17.50	808	2.50	5836	50.00
1B63A	10.00	4J50	100.00	TG-77	7.50	809	5.00	5837	50.00
1D21/SN4	5.00	4J52	35.00	HF-100	8.85	810	17.50	5840	2.50
1C/3B22	5.00	4PR60A	50.00	100TH	12.00	811	2.50	5845	6.00
C1K	7.50	4X150A	13.50	100TL	12.00	811A	4.00	5852	5.00
1P21	32.50	4X150D	15.00	FG-105	25.00	812A	4.75	5876	7.50
1P22	8.00	4X150G	25.00	F-123A	5.00	813	12.50	5879	1.15
1P25	10.00	4X250B	20.00	FG-172	25.00	814	3.50	5881/6L6WGB	2.00
1P28	15.00	4X250F	30.00	211	2.50	815	5.00	5886	3.50
1Z2	1.50	5BP1A	9.50	212E	50.00	816	2.25	5893	10.00
2-01C	12.50	5C22	17.50	FG-235	50.00	826	3.50	5894	19.85
2AP1A	8.50	5CP1A	9.50	242C	10.00	828	12.50	5915	1.00
2B23	20.00	5CP7A	9.50	244A	3.50	829B	10.00	5931/5U4WG	3.50
2BP1	10.00	5D21	7.50	245A	3.50	832A	7.50	5933/807W	3.00
2C36	22.50	5J26	50.00	249B	8.50	833A	37.50	5948/1754	100.00
2C39	5.00	5JP1	7.50	249C	6.50	836	2.50	5949/1907	50.00
2C39A	9.75	5LP1	7.50	250R	10.00	837	1.00	5963	1.00
2C39B	15.00	5R4GY	1.25	250TH	25.00	842	7.50	5964	.85
2C40	7.50	5R4WGA	4.00	251A	50.00	845	7.50	5965	.85
2C42	3.00	5R4WGB	6.00	254A	3.50	849	75.00	5976	50.00
2C43	7.50	5R4WGY	2.00	FG-258A	100.00	851	50.00	5993	5.00
2C46	5.00	5RP1A	9.50	259A	3.50	866A	1.90	6005/6AQ5W	1.50
2C50	4.00	5Y3WGT	1.25	262B	3.50	869B	75.00	6012	4.00
2C51	1.50	5Y3WGTB	2.50	267B	5.00	872A	5.00	6021A	2.00
2C52	1.50	6AC7W	.75	271A	10.00	884	1.25	6032	10.00
2C53	7.50	6AC7WA	2.00	274A	3.50	885	.85	6045	1.15
2D21	.65	6AG5WA	1.50	283A	3.50	889RA	150.00	6072	1.50
2D21W	1.25	6AG7Y	1.00	287A	3.50	891R	200.00	6073	1.50
2E22	3.00	6AK5W	1.25	QK-288	250.00	913	9.50	6074	1.75
2E24	2.25	6AK5 (WE)	.75	HF-300	35.00	920	2.50	6080	3.35
2E26	2.50	6AL5W	.60	300B	5.00	927	1.50	6080WA	5.00
2J42	75.00	6AN5	1.75	304TH	35.00	931A	5.00	6080WB	10.00
2J51	50.00	6AN5WA	3.50	304TL	35.00	1000T	80.00	6081	25.00
2J55	75.00	6AQ5W	1.00	307A	.50	R1130B	10.00	6082	3.35
2K22	25.00	6AR6	.75	310A	3.50	1500T	150.00	6087/5Y3WGTB	2.50
2K25	8.50	6AS6W	1.00	311A	3.50	1614	2.75	6101/6J6WA	1.50
2K26	35.00	6AS7G	2.50	313C	1.50	1620	4.00	6106	1.50
2K28	25.00	6AU6WA	1.25	323A	6.00	1624	1.00	6115/QK351	50.00
2K29	25.00	6B4G	3.35	328A	3.50	1625	.50	6130/3C45	6.50
2K30	50.00	6BA6W	.75	329A	4.50	1629	.50	6136/6AU6WA	1.25
2K33A	200.00	6BE6W	1.50	336A	2.50	1846	50.00	6146	3.00
2K34	75.00	6BF7W	2.00	337A	3.50	1855	250.00	6159	3.50
2K35	200.00	6BH6W	2.75	347A	1.00	2050	1.25	6161	35.00
2K39	150.00	6BL6	20.00	348A	4.50	ZB-3200	100.00	6186/6AG5WA	1.50
2K41	50.00	6BM6	20.00	349A	3.50	5516	7.50	6189/12AU7WA	1.50
2K42	150.00	6BM6A	30.00	350A	3.50	5528/C6L	3.50	6197	1.75
2K43	200.00	6C4W	2.50	350B	2.50	5545	20.00	6199	35.00
2K44	125.00	6C4WA	1.00	352A	8.50	5550	30.00	6201/12AT7WA	1.85
2K45	20.00	6C21	25.00	354A	12.50	5552/FG235	50.00	6202/6X4WA	1.50
2K47	150.00	6D4	1.50	355A	12.50	5553/FG258	100.00	6211	.75
2K48	50.00	6F4	3.50	371B	2.50	5557/FG17	5.00	6213	2.50
2K50	125.00	C6J	10.00	388A	2.00	5558/FG32	10.00	6216	3.00
2K54	10.00	C6J/A	15.00	393A	5.00	5559/FG57	10.00	6236	125.00
2K55	15.00	C6J/K	20.00	394A	3.00	5560/FG95	25.00	6263	9.00
2K56	50.00	6J4	1.75	395A	2.25	5561/FG104	50.00	6265/6BH6W	2.75
2P21	40.00	6J4WA	2.50	396A/2C51	1.50	5586	125.00	6291	35.00
2X2A	1.25	6J6W	.60	398A/5603	3.00	5608A	6.00	6293	4.50
3A5	.75	6J6WA	1.00	401A/5590	1.00	5636	2.25	6299	37.50
3AP1A	12.50	6K4	2.00	403B/5591	3.00	5642	2.25	63 6/BL800A	100.00
3B4	2.50	6L6GAY	1.25	404A/5847	7.50	5643	3.00	6322/BL25	12.50
3B24W	3.00	6L6WGA	1.50	407A	3.75	5647	3.50	6336	8.75
3B24WA	5.00	6L6WGB	2.00	408A/6028	2.75	5651	1.00	6336A	12.75
3B25	2.50	6Q5G	2.50	409A/6AS6	1.00	5654/6AK5W	1.50	6350	1.25
3B26	2.25	6SJ7WGT	1.25	410R	75.00	5656	5.00	6352	7.50
3B28	3.00	6SK7W	.75	GL-414	80.00	5663	1.00	6385	10.00
3B29	5.00	6SK7WA	2.00	416B/6280	20.00	5665/C16J	35.00	6390	125.00
3BP1A	7.50	6SL7WGT	1.25	417A/5842	8.50	5667	125.00	6394	12.75
3C22	15.00	6SN7W	.75	418A	9.50	5670	1.00	6438	5.00
3C23	4.00	6SN7WGT	1.00	420A/5755	5.00	5672	1.35	6442	25.00
3C24/24G	7.50	6SN7WGTA	2.50	421A/5998	7.50	5675	10.00	6463	1.00
3C45	3.50	6SU7GTY	.85	429A	6.50	5676	1.25	6485	1.50
3CX100A5	12.50	6V6GTY	1.00	GL-434A	10.00	5678	1.25	6533	7.50
3D21A	5.00	6X4W	.75	450TH	40.00	5686	2.25	6542	5.75
3D22	8.00	6X4WA	1.80	450TL	40.00	5687	1.50	6550	3.50
3DP1A	5.00	6X5WGT	1.00	578	5.00	5691	5.00	6807	20.00
3E29	7.50	SRL7G	125.00	KU-610	5.00	5692	3.50	6883	3.50
3GP1	2.50	7AK7	2.50	NL-623	10.00	5693	3.50	7044	1.50
C3J	7.50	7MP7	22.50	631-P1	5.00	5696	1.00	7391	47.50
3J21	35.00	10KP7	15.00	673	15.00	5718	1.50	7521	100.00
3J31	100.00	12AT7WA	1.50	676	30.00	5720/FG33	17.50	7580	35.00
3JP1	5.00	12AU7WA	1.50	677	40.00	5721	100.00	8002R	25.00
3K21	125.00	12AX7W	1.35	701A	5.00	5725/6AS6W	1.50	8008	6.00
3K22	125.00	12AY7	1.00	703A	1.50	5726/6AL5W	.75	8013A	5.00
3K27	150.00	12GP7	25.00	707B	2.50	5727/2D21W	1.25	8014A	30.00
3K30	100.00	C16J	25.00	715C	15.00	5728/FG67	10.00	8020	4.50
3KP1	9.75	FG-17	5.00	719A	12.50	5749/6BA6W	1.00	8025A	7.50
3RP1	7.50	HK-24	5.00	721B	5.00	5750/6BE6W	1.75	9003	2.00
3WP1	12.50	25T	10.00	723A/B	3.50	5751/12AX7W	1.35	9005	3.50

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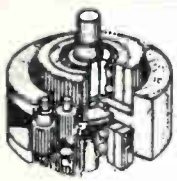
SIMPLE DIFFERENTIAL WITH BALL-BEARING SUN GEARS



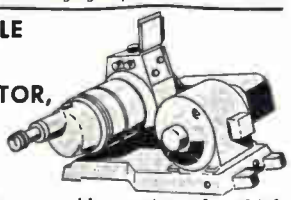
The 1:1 reverse ratio spur gears are 48-tooth, 32 pitch brass with 3/16" available face. On one side, the shaft is 23.64" dia. for 11/16" and has a pin hole, then increases in dia. to .377" for the remaining 3/16" of length. On the other side, the shaft is .377 dia. 1/4" lg. 2-13/16" dia. is required to clear the body.
Stock no. A6-115 ..... each $15.00

RCA 6032 IMAGE-CONVERTER TUBE

Combined with suitable optical systems, this 3-electrode tube permits viewing of scene with infrared radiation. Scene to be viewed is imaged by optical objective upon semi-transparent photocathode. Spectral resp., S-1; good response up to about 1200A. Max. ratings, absolute, grid #2, 20,000VDC or peak AC, grid #1,2700.
$9.95 ppd.

MINOR SWITCH 10-position, 3-pole, with stopper & reset coil 6-12 V. D.C. off-normal non-bridging wiper. wt.: 1 lb. $9.95

400-CYCLE MOTOR GENERATOR, PU-20



The generator assembly consists of a 1400-watt, 120-volt, 400-cycle inductor-alternator and a 400-watt, 27-volt D.C. generator. The alternator rotor and the D.C. generator armature are mounted on a common shaft, which is dual-belt-driven by a 3-H.P., 1750-R.P.M., 115/230-volt, single-phase 60-cycle electric motor. Weatherproof output box is mounted on top of the stator shell. It contains a rheostat, adjustable resistor, two pin jacks for plugging in an A.C. voltmeter. Size: 28" W., 33" L., 18" H. Weight, approx. 250 lbs.
Price $175.00

8-DAY ELAPSED-TIME SURPLUS AIRCRAFT CLOCK

Here's an accurate time-control center that'll help you win your next rallye. It not only tells you the date and time of day right to the second, it's a stop watch that gives you elapsed time in seconds, minutes, and hours! The 24-hour clock simplifies adding and subtracting elapsed time for your navigator. Manufactured by Elgin Watch Co. to exacting military specifications, it will remain accurate in spite of road bumps and vibrations. Uses no electrical connections. Does the job of high-cost equipment. Jeweled/Sweep Second Hand/Luminous Hands and Numerals/25-Hour Dial/Black Face and Plastic Case/3⅛" Mounting.
Cost the Government $185.00
Only $39.95 Postpaid

SPERRY VERTICAL GYRO

Part #673073, Motor 115 volts, 3 phase, 400 cycle, 8 watts, 20,000 RPM. 3-minute runup, synchro pickoffs, roll 360°, pitch 85°. Synchro excitation 26 volts, 400 cycle, 150 m.a. Vertical accuracy ±⅓°. Weight 3½ lbs. Approx. dim. 5¾" L., 4⅛" W., 4⅛" H.
Price $35.00

VARIABLE SPEED BALL DISC INTEGRATORS

(All Shafts Ball Bearing Supported)

No. 145 Forward & Reverse 2¼"-0-2¼". Input shaft spline gear 12 teeth 9/32" dia. ⅜" lang. Output shaft 15/64" dia. x 15/32" long. Control shaft 11/32" x ⅜" long. Cast aluminum construction. Approx. size 3" x 3" x 2¾" $17.50

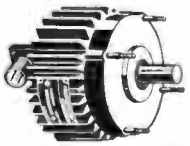
No. 146 Forward & Reverse 4-0-4. Input shaft 5/16" dia. x ¾" long: Output shaft 15/64" dia x 9/16" long. Control shaft 11/64" dia. x 11/16" long. Cast aluminum construction. Approx. size 4½" x 4½" x 4". **$18.50 ea.**

SMALL DC MOTORS

(approx. size over 3¾" x 1¼" dia.:

5067043 Delco 12 VDC PM 1" x 1" x 2", 10,000 rpm. $7.50
5067126 Delco PM, 27 VDC, 125 RPM, Governor Controlled 15.00 ea.
5069600 Delco PM 27.5 VDC 250 rpm 12.50
#5069625 120 rpm, mfr. Delco, 27 VDC governor controlled $15.00
5069230 Delco PM 27.5 VDC 145 rpm 15.00
5068750 Delco 27.5 VDC 160 rpm w. brake 6.50
5068571 Delco PM 27.5 VDC 10,000 rpm (1x1x2") 5.00
5069790 Delco PM, 27 VDC, 100 RPM, Governor Controlled 15.00 ea
#5069800 575 rpm, mfr. Delco, 27 VDC, PM reversible governor controlled, equipped with 27 VDC clutch $17.50
5072735 Delco 27 VDC 200 rpm governor controlled. 15.00
5BA10A118 GE 24 VDC 110 rpm 10.00
5BA10AJ37 GE 27 VDC 250 rpm reversible 10.00
5BA10AJ52 27 VDC 145 rpm reversible 12.50
5BA10AJ50, G.E., 12 VDC, 140 rpm 15.00
5BA10FJ401B, G.E. 28 VDC, 215 rpm, 10 oz. in., 7 amp. contains brake 15.00
5BA10FJ421, G.E. 26 VDC, 4 rpm, reversible, 6 oz. in., .65 amp 15.00

400 CYCLE PM GENERATOR



115/200 volts A.C. 1- or 3-phase, 200 watts. 4,000 r.p.m. Approx. dimensions: 4¾" dia.; 3" long; ½" shaft, AN connector. $75.00

9KVA 400-CYCLE GENERATOR

120/208 volts, 3-phase power factor 1.0 CCW rotation. Approx. 13½ lg. x 8" dia. 4000 rpm, mfg. Bendix Aviation P/N 1633-1A.
$150.00

MINNEAPOLIS-HONEYWELL RATE GYRO (Control Flight)

Part no. JG7005A, 115 volts A.C., 400 cycle, single phase potentiometer take off resistance 530 ohms. Speed 21,000 r.p.m. Angular momentum 2½ million, CM²/sec. Weight 2 lbs. Dimensions 4-7/32 x 3-29/32 x 3-31/64.
Price $22.50

SELSYNS-SYNCHROS

1CT cont. Trans 90/55V 60 cy.	$27.50
1DG Diff. Gen. 90/90V 60 cy.	34.50
1F Syn. Mtr. 115/90V 60 cy.	34.50
1G Gen. 115V 60 cy.	34.50
1HDG	37.50
1HCT	37.50
1SF Syn. Mtr. 115/90V 400 cy.	12.50
23TR4 torque receiver	34.50
23TR6 torque receiver	37.50
23CT6 control transformer	37.50
23CX6 control transmitter	37.50
23TX6 torque transmitter	37.50
7DG differential generator	37.50
2J1F1 Gen. 115/57.5V 400 cy.	7.50
2J1F3 Gen. 115/57.5V 400 cy.	10.00
2J1FA1 Gen. 115/57.5V 400 cy.	7.50
2J1G1 57.5/57.5V 400 cy.	5.00
2J1H1 Diff. Gen. 57.5V 400 cy.	7.50
2J5D1 Cont. Trans. 105/55V 60 cy.	17.50
2J5F1 Cont. Trans. 105/55V 60 cy.	17.50
2J5H1 Gen. 115/105V 60 cy.	17.50
2J15M1 Gen. 115/57.5V 400 cy.	17.50
5CT Cont. Trans. 90/55V 60 cy.	34.50
5D Diff. Mtr. 90/90V 60 cy.	34.50
5DG Diff. Gen. 90/90V 60 cy.	34.50
5F Syn. Mtr. 115/90 VAC 60 cy.	34.50
5G Syn. Gen. 115/90VAC 60 cy.	34.50
5HCT Cont. Trans. 90/55V 60 cy.	37.50
5SDG Diff. Gen. 90/90V 400 cy.	12.50
6DG Diff. Gen. 90/90V 60 cy.	25.00
6G Syn. Gen. 115/90VAC 60 cy.	34.50
7G Syn. Gen. 115/90VAC 60 cy.	42.50
C56701 Type 11-4 Rep. 115V 60 cy.	20.00
C69405-2 Type 1-1 Transm. 115V 60 cy.	20.00
C69406 Syn. Transm. 115V 60 cy.	20.00
C69406-1 Type 11-2 Rep. 115V 60 cy.	20.00
C78248 Syn. Transm. 115V 60 cy.	12.50
C78410 Repeater 115V 60 cy.	20.00
FPE 49-7 Diehl servo motor, 115 volts, 60 cycle, 10 watts	30.00

400 CYCLE, 3 PHASE GENERATOR

BY MASTER ELECTRIC

Type AG, frome 364Y, 7.5 kw, 3428 rpm, pf .95 Star connected 120/208 3 phase, 22 amps. Delta connected 120 volt single phase 6 amps. Self excited. Complete with control box, voltage regulator, AC voltmeter and frequency meter. Shaft 1" dia., 2" long; overall dim. of unit: 21"6x18"x 20".
Price $395.00 each

SENSITIVE INTEGRATING GYROS

This is the famous HIG Gyro which is being used in missile guidance systems, radar stabilization and fine control systems. Government cost approximately $1500.
PRICE $50.00

OIL CAPACITORS

1 MFD. 25,000 V. DC Westinghouse interteen type FP style 1313854.
$39.95 each
10 or more, $35.00 each.

HONEYWELL VERTICAL GYRO MODEL AG7044A17

115 volts, 400 cycles, single phase, 35 watts. Pitch and roll potentiometer pickoffs 890 ohms, 40 volts max. AC or DC. Speed 20,000 rpm, ang. momentum 12,500,000 gm-cm 2/sec. Erection system 27 VAC, 400 cycles, time 5 min. to ½°; caging mechanism operates on 24 VDC.
$49.50

400-CYCLE FREQUENCY METER IN PORTABLE METAL CASE

Range, 380-400 cps. 100-130 VAC. Nine vibrating reeds. Frequency increments of 5 cps. Frequency accuracy is ± 0.3% at 77° F. with sine wave input. With test leads. 3¼" x 3¼" x 6". Winslow Model 360. $12.50

CIRCLE 959 ON READER SERVICE CARD

SEARCHLIGHT SECTION

(Classified Advertising)

BUSINESS OPPORTUNITIES

EQUIPMENT - USED or RESALE

DISPLAYED RATE

The advertising rate is $27.25 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request. AN ADVERTISING INCH is measured ⅞ inch vertically on one column, 3 columns—30 inches—to a page. EQUIPMENT WANTED or FOR SALE ADVERTISEMENTS acceptable only in Displayed Style.

UNDISPLAYED RATE

$2.70 a line, minimum 3 lines. To figure advance payment count 5 average words as a line.

PROPOSALS, $2.70 a line an insertion. BOX NUMBERS count as one line additional in undisplayed ads.

DISCOUNT OF 10% if full payment is made in advance for four consecutive insertions of undisplayed ads (not including proposals).

INDEX TO ADVERTISERS

Audited Paid Circulation

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CLASSIFIED ADVERTISING

F. J. Eberle, Business Mgr.

INDEX TO CLASSIFIED ADVERTISERS

■

• See advertisement in the July 25, 1962 issue of Electronics Buyers' Guide for complete line of products or services.

electronics

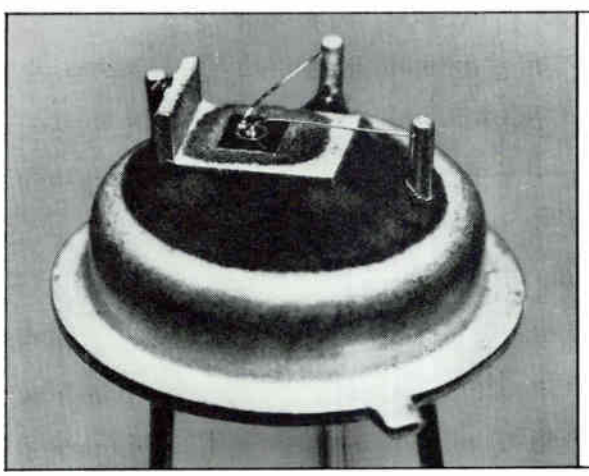
Audit Bureau of Circulations

Associated Business Publications

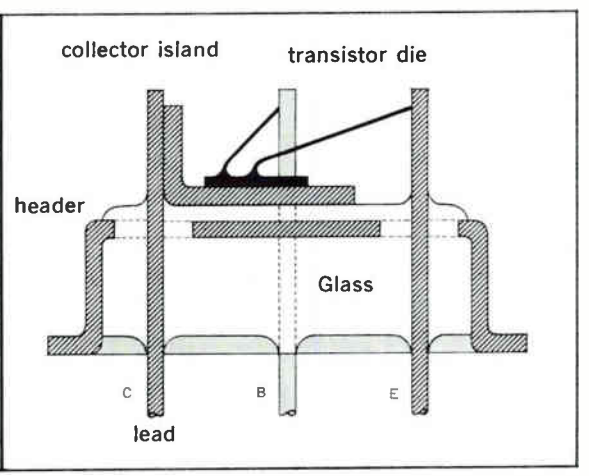
Audited Paid Circulation

From Fairchild

PLANAR* TRANSISTORS ELECTRICALLY ISOLATED FROM PACKAGE



Enlarged photo of header with can off. 7 times actual size.



Cross-section of header and isolated transistor.

Gold-plated Kovar island is electrically welded to collector lead and fused onto glass insulator completely isolating transistor from can.

Fairchild now offers Planar transistors with collectors electrically isolated from their TO-5 packages. The entire transistor die is isolated; it is bonded to a gold-plated Kovar "collector island" which is fused onto a layer of glass, providing positive insulation from the rest of the package. All three leads are glass-insulated as they pass through the header platform. This isolation means you may now design using Planar transistors which are independent of their conductive packages in the circuit. Electrically isolated transistors eliminate the cost of special design and/or assembly necessary for transistor insulation. This type of construction also offers excellent resistance to thermal shock, mechanical shock and vibration. Mounting of the silicon transistor die and attachment of leadwires inside are accomplished by standard Fairchild bonding operations.

2N1893
2N911
2N910

These types offered in TO-5 Isolated Collector packages

2N1893 Type – SP8400 2N910 Type – SP8401
2N911 Type – SP8402

Data sheets available on all items.

FAIRCHILD
SEMICONDUCTOR
545 WHISMAN ROAD, MOUNTAIN VIEW, CALIF. · YORKSHIRE 8-8161 · TWX: MN VW CAL 853
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

*Planar: A patented Fairchild process

CIRCLE 901 READERS SERVICE CARD

RCA-7586
medium-mu general-purpose industrial triode

RCA-7895
high-mu general-purpose industrial triode (mu = 64)

RCA-7587
sharp-cutoff general-purpose industrial tetrode

RCA-6CW4; 2CW4
TV and FM tuner triodes

RCA-6DS4; 2DS4
TV and FM tuner triodes with semiremote cutoff characteristic

RCA-8056
medium-mu triode for low-voltage power supply and small-signal amplifier applications in industrial service at frequencies up to 350 Mc

RCA-8058
double-ended high-mu triode for cathode-drive amplifier service up to 1200 Mc in a variety of industrial applications

Nuvistors Shown Actual Size

"Versatile" is the word for the tiny RCA nuvistor!

Nuvistor, with only 7 commercial types, runs the gamut of electronic applications...from satellites to sonobuoys...from electronic test instruments to TV tuners...from guidance and control systems to scientific measuring devices...nearly every major area of electronics.

Why? Because nuvistors provide excellent performance in a small, light package. Consider these important design advantages: Low heater drain • Very high transconductance at low plate current and voltage • Exceptional mechanical ruggedness from their all-ceramic-and-metal construction • Exceptional uniformity of characteristics from tube to tube • Operation at full ratings at any altitude • Extremely low interelectrode leakage • Low reverse grid current • High stability of characteristics • Low noise.

In addition, nuvistors are in the class of active electronic circuit components least susceptible to damage from nuclear radiation...a vital factor in the design of communications and navigational equipment that must function properly in a nuclear radiation environment.

Actual Size

One more example of the extreme versatility of the nuvistor design principle is this developmental half-size, half-watt rf tuner triode. One of the smallest electron tubes ever produced by RCA, it was developed under research and development contract for the Bureau of Ships, U. S. Navy.

Ask your RCA Field Representative how nuvistorization can benefit your critical circuits. Or, for more information on specific types, write Commercial Engineering, Section J-19-DE-2, RCA Electron Tube Division, Harrison, N. J.

FIELD OFFICES:

EAST: 744 Broad Street, Newark 2, New Jersey
HUmboldt 5-3900

MIDWEST: Suite 1154, Merchandise Mart Plaza
Chicago 54, Illinois, WHitehall 4-2900

WEST: 6801 East Washington Boulevard
Los Angeles 22, California, RAymond 3-8361
1838 El Camino Real, Burlingame, California
OXford 7-1620

RCA® **THE MOST TRUSTED NAME IN ELECTRONICS**