Electronics

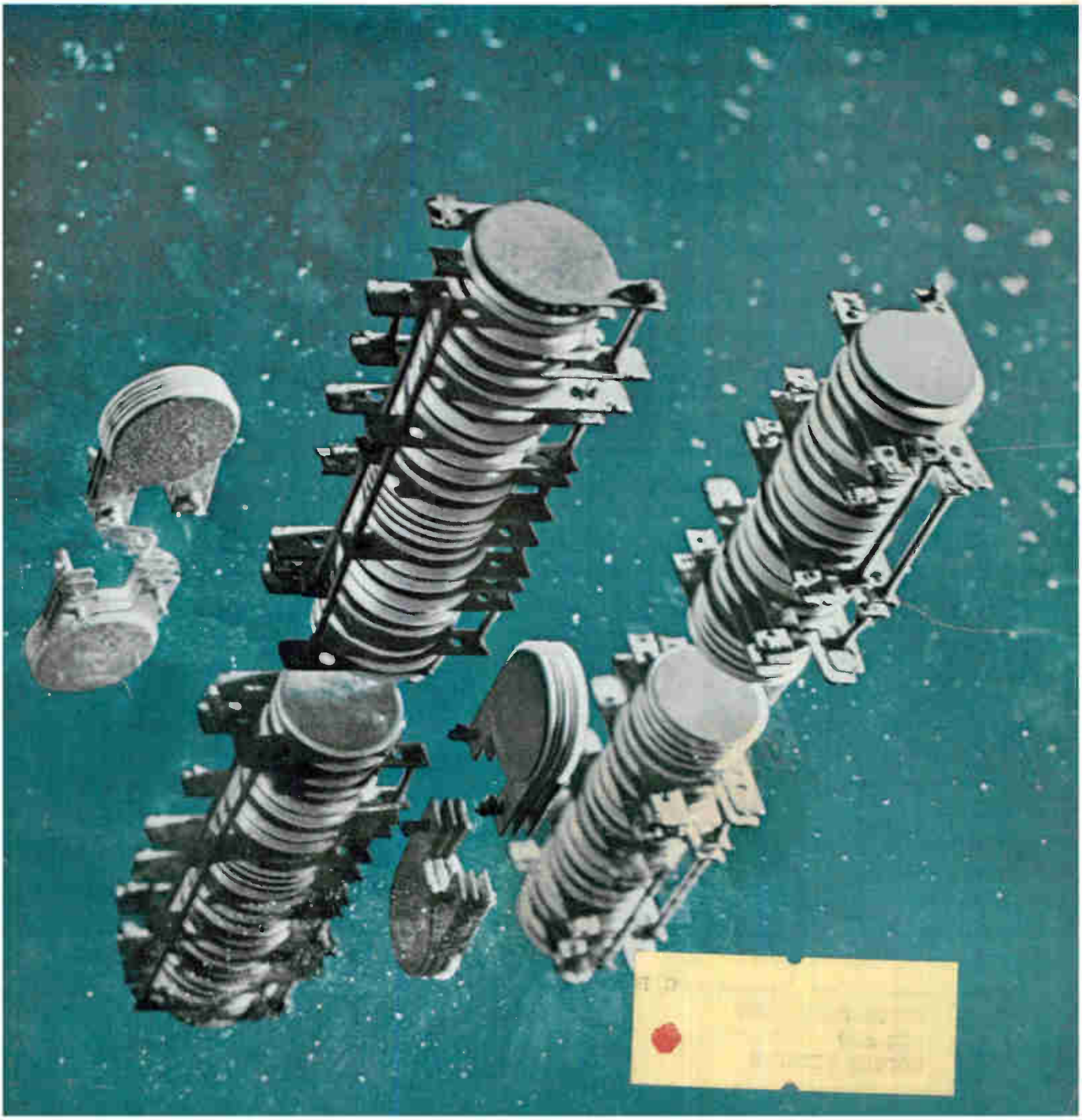
Measuring signal-to-noise with a 'scope: page 36

More applications of the FET: page 45

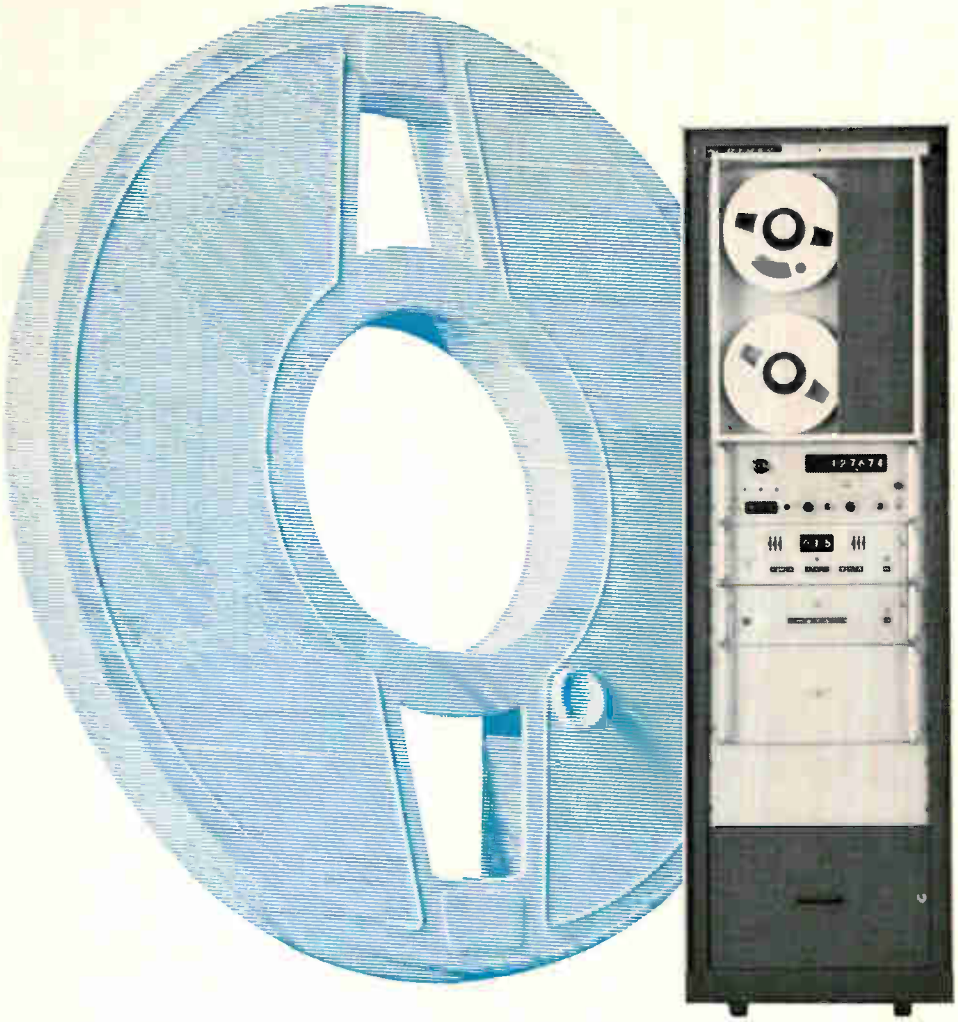
Infrared device ends free parking: page 72

December 28, 1964
75 cents
A McGraw-Hill Publication

Below: compact ceramic tubes make space circuits radiation-proof, page 61



get speed and data density of magnetic tape . . .



—with new standard digital data acquisition systems!

ADD: **The advantages of standard systems—complete system specifications, immediate delivery, proven reliability, low cost** **TO:** **The benefits of magnetic tape recording and data processing**
AND GET: **Fast automatic measurement of dc volts, low-level dc, ac volts, resistance and frequency recorded on an incremental recorder in computer compatible format—as fast as 10 channels per second—with up to 440,000 unattended measurements and recordings.**

Heart of these magnetic tape systems, as of other Dymec 2010 Data Acquisition Systems, is the DY-2401B Integrating Digital Voltmeter, a floated and guarded instrument which lets you measure extremely low-level signals even in the presence of severe common mode and superimposed noise. The 2401B measures dc voltages to 1000 volts with 300% overranging on the lower ranges. It also measures frequency 10 cps to 300 kc, and you can add an optional converter to measure ac and resistance.

The newest of Dymec's standard systems comes in two models, the 2010J and the 2010H, which differ only in scanning capability. With the 2010J you can measure up to 200 3-wire channels, or measure up to 100 channels with the 2010H System.

Now from nine standard systems you can select a wide variety of input capabilities and recorded output, including printed paper tape, punched tape, punched cards . . . and magnetic tape. Prices of the newest systems: DY-2010H, $15,365; DY-2010J, $17,415.

Data subject to change without notice. Prices f.o.b. factory.

Write on your company letterhead for your copy of Dymec's digital data acquisition system handbook, a syllabus of digital system fundamentals, applications and operation.

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Electronics

December 28, 1964
Volume 37, Number 32

Electronics Review

Electronics Abroad

Probing the News

Technical Articles

I. Design

II. Application

Electronics

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Readers Comment

Kudos

My hat is off to your story about "The little train that wasn't" [Nov. 30, p. 86]. It is the most interesting story that I have read all year.

Bernard Fudim
Calvert Electronics, Inc.
New York

Nimbus photo

The reception of the Nimbus I weather-satellite photo [next page] was spawned by an Electronics article, "Bird's-eye view of the weather" [July 27, p. 81].

R. L. Tucker, director of research for the Birdwell Logging division of the Seismograph Service Corp., read the article and realized that equipment used by Birdwell in oil-well logging could be adapted to receive pictures from the APT system in the satellite.

Dave Miller
Ferguson-Miller, Inc.
Tulsa, Okla.

■ The picture, sent from an altitude of 500 miles, was obtained on a device usually used to record subsurface geological data thousands of feet underground. Another essential part of the system was a surplus two-way taxicab radio. The photo shows nearly a million square miles of the earth's surface; an overlay shows the principal features.

The Nimbus satellite was designed to provide pictures of cloud cover and weather. The APT (Automatic Picture Transmission) system takes a picture every 208 seconds and retains the image on a one-inch storage vidicon tube. The image is scanned by an electron beam that converts the picture to electrical signals which are transmitted to earth.

The scanning requires 200 seconds at four lines per second, so that the picture actually is made up of 800 individual lines, compared to the 525 lines of a tv picture.

The Birdwell group recorded these signals on magnetic tape, then ran them through a Birdwell 3-D logging camera, which con-

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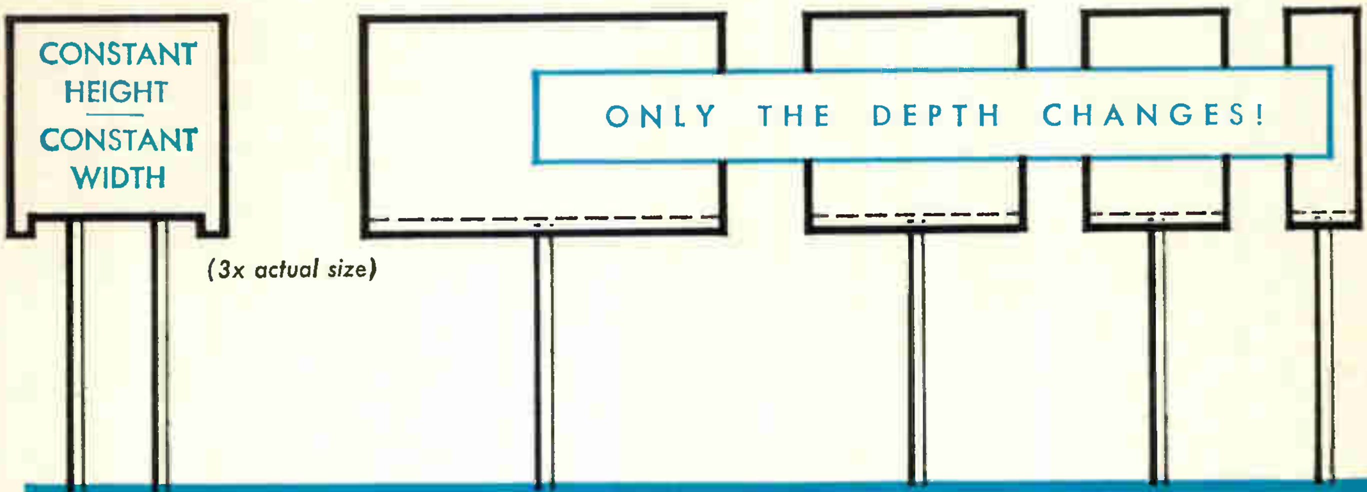
A MOLDED SOLID TANTALUM CAPACITOR THAT MAKES SENSE



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Especially qualified for applications such as printed circuits, where board space is at a premium and must be fully utilized.

- Only the depth changes from case to case—face area remains constant, making Type 190D Capacitors extremely well-suited for automatic insertion.
- Carefully selected height (0.350") corresponds with most acceptable maximum height in normal printed board spacing.
- Uniform width (0.375") permits neat, space-saving alignment on wiring board.
- Present lead spacing based on popular 0.100" printed board grid. In anticipation of the 0.125" grid, Type 190D Capacitors will also be available with new lead spacing when required by future circuit designs.
- Encapsulated in tough molded case with excellent dielectric properties, Type 190D Capacitors fully meet environmental test requirements of Specification MIL-C-26655A.
- Capacitance values from .01μF to 330μF—voltage range, 6 to 50 vdc.
- Stand-off feet at base of capacitors permit complete circulation of air, preventing moisture and solvent traps.
- Unlike many solid tantalums, these new capacitors exhibit the low impedance at high frequencies desired for high-speed computer applications.
- Low dissipation factor (high Q) permits higher ripple currents.

For complete technical data write for Engineering Bulletin 3531 to Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Massachusetts.

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verted the signals back into a picture. The orbital pattern and speed of the satellite permitted about three orbital passes a day to be recorded.

Tucker and his group are still perfecting their equipment, and hope to receive even better pictures when the next APT system is launched in a satellite. Nimbus II is tentatively scheduled to be launched during the last quarter of 1965.

Modified Sarah

The unsolicited testimonial by R. G. Whiteing for Sarah recovery equipment [Comment, Nov. 30, p. 4] was very much appreciated. While the British equipment can be purchased abroad, domestic sales are made through Simmonds Precision Products, Inc., the sole licensee to produce this equipment in the United States.

To bring some of our older customers up to date, the Mark II and III Sarah receivers can now be modified with a simple conversion kit to permit improved operation compatible with either our standard pulsed Sarah beacons, or with any manufacturer's continuous-wave (modulated) beacons. At the same time, Simmonds has also developed cw-type beacons in the standard distress band, for use here and abroad. These are microminiature units, suitable for personnel or package recovery.

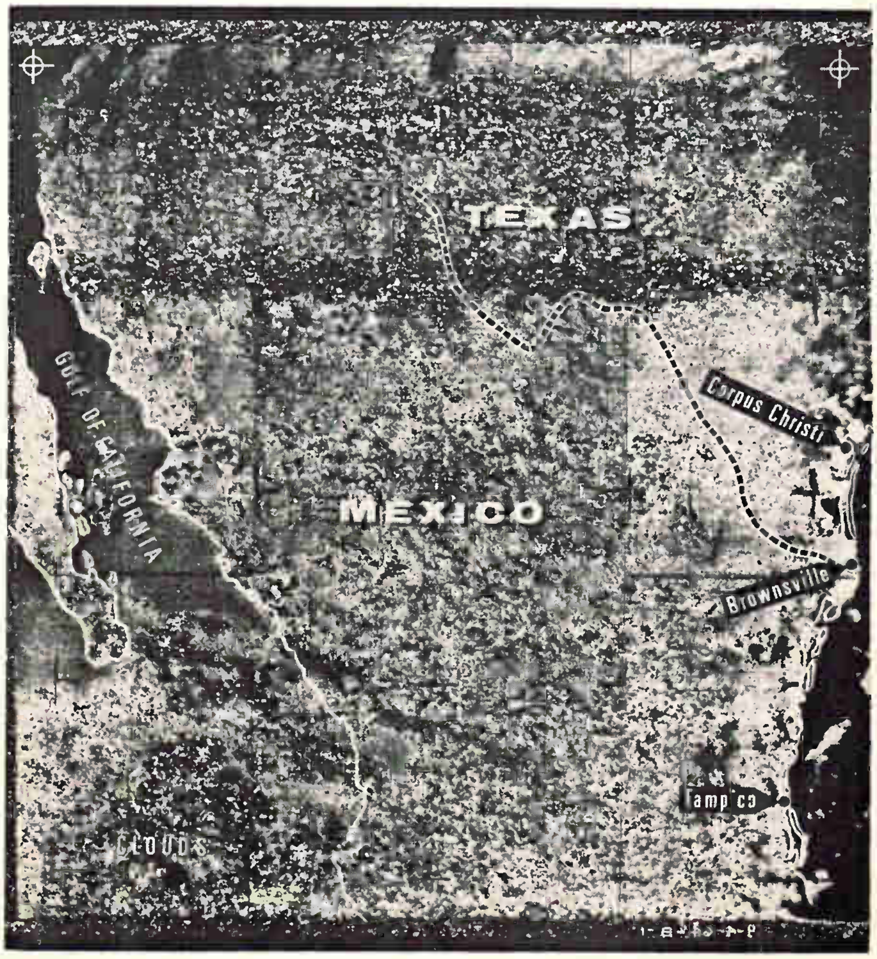
Lastly, in reply to the editor's comment on Whiteing's letter, accuracy and range of Sarah equipment have indeed been improved.

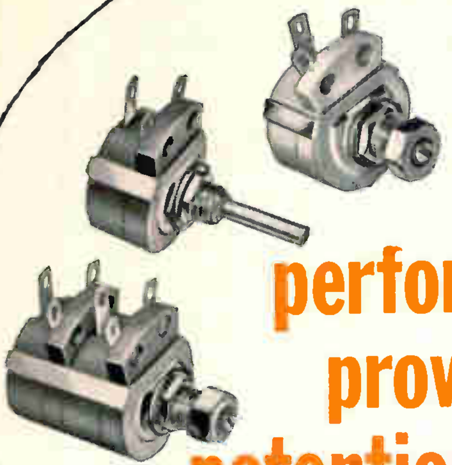
George N. Krassner
Simmonds Precision Products, Inc.
Tarrytown, N. Y.

Operational trigger

I enjoyed Peter Lefferts' article on an "Operational trigger for precise control" [Nov. 2, p. 50]. My fellow readers might be interested to know that we manufacture a two-level, three-mode, general-purpose controller (Model 77) using very similar techniques.

Ludwig Luft
Luft Instruments, Inc.
Lincoln, Mass.





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Series 49M pots are available as single or dual units, with a choice of standard or split-bushing mountings. They're perfect for trimmer requirements calling for high resolution. Units are manufactured to MIL-R-19 specifications, Style RA 10.

SPECIFICATIONS: Power Rating 1.5 watts @ 40°C, or .005 watt per degree of effective rotation maximum. Derated linearly to zero power @ 125°C. Working Voltage 175 volts maximum. Resistance Range 1 ohm to 20,000 ohms linear functions. Resistance Tolerance ±10%, closer tolerances on order. Effective rotation 300° ±5°. Mechanical & Electrical Rotation - 300° ±5°. Torque: .3 to 6 oz. in. Locking type bushing: 20 oz. in. minimum with jam nut tightened. Typical Weight .02 lb.

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Circle 7 on reader service card

People

John B. Montgomery, new president and chief executive of the Marquardt Corp. in Van Nuys, Calif., brings to the company background in electronics and aviation that closely matches Marquardt's interest in jet engines and air instruments.

His experience in diversification could be an asset for Marquardt, which has remained at a $50 million sales plateau for three years.

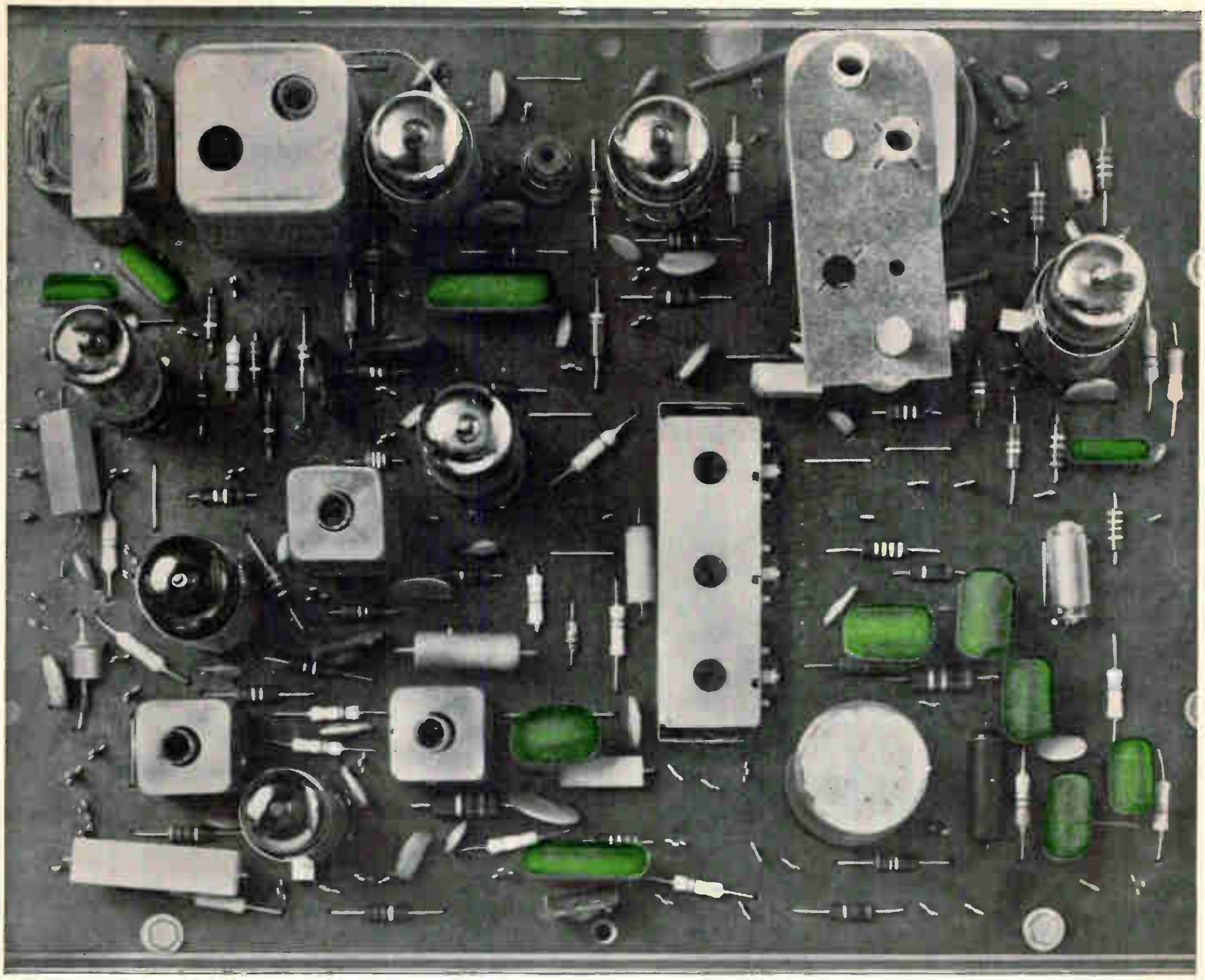
As recently as mid-October, Montgomery was named vice president of Schlumberger, Ltd., of Houston, in addition to serving as president of its subsidiary, Weston Instruments, Inc.—formerly Daystrom, Inc. Besides changing the name to Weston, he changed the business from a holding company to one active in precision measurement and analysis. Under Montgomery, Weston also acquired Boonshaft and Fuchs, Inc., and the Rotek Instruments Corp.

Montgomery is a former commanding general of the Eighth Air Force, Strategic Air Command. He resigned his commission as major general in 1955 to become vice president of American Airlines' maintenance and engineering department. Later he became vice president of the General Electric Co.'s turbine engine division.

Roy E. Marquardt, former president, will continue as chairman.

Paul W. Knaplund, who helped to plan and coordinate the later development of the System 360 computer and other major IBM products, has been named a group executive of three of the 12 divisions of the International Business Machines Corp.—Data Systems, General Products and Components. The divisions manufacture all of IBM's computers and accounting equipment.

Knaplund joined IBM in 1950 and has held several managerial positions. Previously he was assistant group executive of the same three divisions.



In Westinghouse TV, capacitors of "Mylar"® replaced those of molded paper–

Bob Tesno, TV Engineering Supervisor, tells why:

1. Reliability

"We ran extensive tests comparing capacitors with a dielectric of 'Mylar'* with ones of paper, molded paper and dual dielectric. We found that the capacitors of 'Mylar' came out on top—with virtually no temperature, humidity or leakage problems. In the four years since their adoption, the reliability of capacitors of 'Mylar' in the field has been nearly perfect."

2. Size

"Actually, we first adopted capacitors of 'Mylar' for all Westinghouse TV receivers when printed circuit boards became important factors in production. Capacitors of 'Mylar' are considerably smaller than molded-paper ones of equivalent value. This avoids crowding of components on the board."

*Du Pont's registered trademark for its polyester film.

3. Price

"As a clincher," adds Tesno, "in most cases* capacitors with a dielectric of 'Mylar' cost no more, and, in fact, often cost less than molded-paper or dual dielectric capacitors." *(Note: This applies to capacitors that are up to .1mfd 400v in size.)

Can your designs benefit from the many advantages of capacitors of "Mylar"? For complete data, write Du Pont Film Dept., N10452 B-22, Wilmington, Delaware 19898.

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Meetings

Reliability and Quality Control National Symposium, ASQC, IEEE, IES, SNT; Hotel Fontainebleau, Miami Beach, **Jan. 12-14.**

Fundamental Phenomena in the Material Sciences Annual Symposium, Ilikon Corp.; Sheraton Plaza Hotel, Boston, **Jan. 25-26.**

Integrated Circuits Seminar, IEEE; Stevens Institute of Technology, Hoboken, N.J., **Jan. 28.**

Northwestern University Science Symposium, NU; Pick-Congress Hotel and Thorne Hall of Northwestern University, Chicago, **Jan. 28-29.**

Winter Power Meeting, PEEC/IEEE; Statler-Hilton Hotel, New York, **Jan. 31-Feb. 5.**

Institute on Information Storage and Retrieval, The American University; the Willard Hotel, Washington, **Feb. 1-4.**

On-Line Computing Systems Symposium, UCLA Extension Service, Informatics, Inc.; University of California Los Angeles, **Feb. 2-4.**

Winter Convention on Military Electronics, PTGMIL & L.A. Section of IEEE; Ambassador Hotel, Los Angeles, **Feb. 3-5.**

Electrical/Electronic Trade Show, Electrical Representatives Club, Electronic Representatives Assn.; Denver Auditorium Arena, Denver, **Feb. 15-17.**

Solid-State Circuits International Conference, University of Pennsylvania, IEEE; University of Pennsylvania and Sheraton Hotel, Philadelphia, **Feb. 17-19.**

Annual West Coast Reliability Symposium, ASQC, UCLA; Moore Hall, University of California Los Angeles, **Feb. 20.**

Particle Accelerator Conference, AIP NSG/IEEE, NBS, USAEC; Shoreham Hotel, Washington, **Mar. 10-12.**

ISA National Conference on Instrumentation for the Iron and Steel Industry, ISA; Pick-Roosevelt Hotel, Pittsburgh, **Mar. 17-19.**

IEEE International Convention, IEEE; N.Y. Coliseum and New York Hilton Hotel, New York, **Mar. 22-25.**

Society of Motion Picture and Television Engineers Semiannual Conference and Exhibit, SMPTE; Ambassador Hotel, Los Angeles, **Mar. 28-Apr. 2.**

Electron Beam Annual Symposium, Pennsylvania State University, Alloyd Corp.; Pennsylvania State University, University Park, Pa., **Mar. 31-Apr. 2.**

Electronic Parts Distributors Show, Electronic Industry Show Corp., New York Hilton and Americana Hotels, New York, **Mar. 31-Apr. 4.**

Cleveland Electronics Conference, Cleveland Electronics Conference, Inc., IEEE, ISA, CPS, Western Reserve University, Case Institute of Technology; Cleveland Public Auditorium, Cleveland, **Apr. 6-8.**

Conference on Impact of Batch-Fabrication on Future Computers, PGEC/IEEE; Thunderbird Hotel, Los Angeles, **Apr. 6-8.**

IEEE, Region 3 Meeting, Region 3 of IEEE; Robert E. Lee Hotel, Winston-Salem, N.C., **Apr. 7-9.**

Electronic Components International Exhibition, FNIE, SDSA, Parc des Expositions (Fair Grounds), Paris, **Apr. 8-13.**

IEEE Region 6 Annual Conference, Region 6 of IEEE; Nuclear Rocket Development Station, Las Vegas, **Apr. 13-15.**

Telemetering National Conference, AIAA, IEEE, ISA; Shamrock-Hilton Hotel, Houston, Tex., **Apr. 13-15.**

Electronics Instrumentation Conference and Exhibit, IEEE, ISA; Cincinnati Gardens, Cincinnati, **Apr. 14-15.**

Biomedical Sciences Instrumentation National Symposium, ISA; Statler-Hilton Hotel, Dallas, **Apr. 19-21.**

Call for papers

Human Factors in Electornics National Symposium, HFEG/IEEE; Boston-Sheraton Hotel, Boston, May 6-8. **Feb. 1** is deadline for submitting papers in final form to James Degan, MITRE Corp, P.O. Box 208, Bedford, Mass.

IEEE Annual Communications Convention (Including GLOBECOM VII), CIG/IEEE; University of Colorado, Boulder, Colo., June 7-9. Deadline is **Feb. 15** for submitting 4 copies of both 200-word abstract and manuscript to W.F. Utlaut, Chairman, Technical Program Committee, IEEE Annual Communications Convention, National Bureau of Standards, Boulder, Colo.

Rechargeable battery or line powered
100 μv full scale null sensitivity
1 PPM resolution for all input ranges
Large, six-digit readout, automatic decimal
Universal package for bench or rack mounting

Stability and temperature coefficient of reference element and precision resistors are often the "hidden" parameters of voltmeter design.

For Models 881AB and 883AB, Fluke processes each zener diode reference to prove ±0.0015% per year stability; ratio stability of critical Fluke-manufactured resistors is ±0.001% per year. Temperature coefficient of the reference and critical resistors is ±0.0002%/°C and ±0.00015%/°C, respectively. This provides more than ample margin for long-term drift and temperature deviations within the overall DC accuracy of ±0.01% of input plus 5 μv for the 881AB and 883AB.

"B" suffix of model number indicates operation from either rechargeable batteries (30 hours on full charge) or AC line (50-440 cps). Severe common mode problems are eliminated by battery operation, as unit is completely isolated from line.

Null detector maximum sensitivity is 100 μv full scale, and maximum meter resolution is 1 ppm of range for all input voltages. Six-digit in-line readout is obtained by four decade switches plus high-resolution interpolating vernier. Input ranges are 1, 10, 100, and 1000 volts, with 10% overranging for 0-1100 volts overall capability.

Stable, solid-state AC to DC converter of Model 883AB is specified from 20 cps to 100 KC, with basic accuracy of ±0.1% of input +25 μv applicable from 1 mv to 1100 VAC and 30 cps to 5 KC.

A single mechanical configuration is ideal for portable field use, bench mounting (tilt-up bale), half-rack mounting (7-inch panel), or side-by-side rack mounting. Mil-spec shock, vibration, and temperature testing were included in development, assuring years of dependable performance under adverse conditions.

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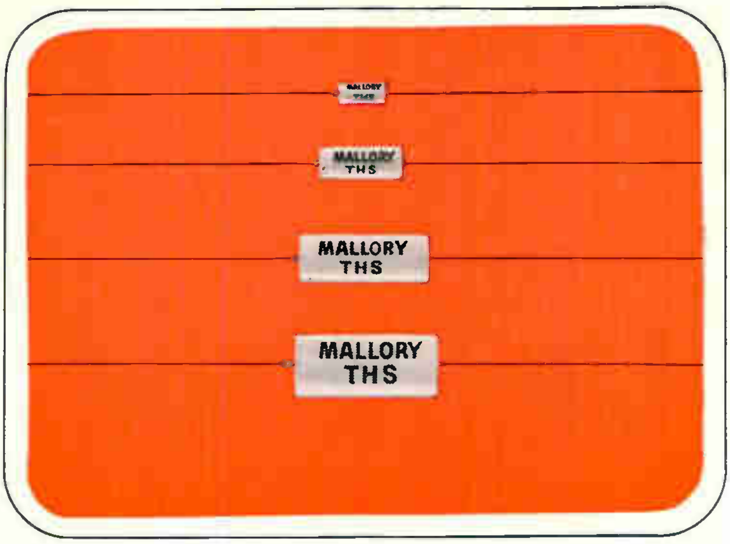

New solid tantalum capacitors for 200°C service

VOLTAGE DERATING CHART

WVDC @ 25°C	WVDC @ 200°C Continuous Duty	WVDC @ 200°C 50% Duty Cycle*
6	2.4	4.8
10	4.0	9.0
15	6.0	12.0
20	8.0	16.0
25	10.0	20.0
35	14.0	28.0
50	20.0	40.0

*Based on a duty cycle of 2 hours on Voltage @ 200°C followed by 2 hours off voltage @ 25°C.

STANDARD CAPACITANCE AND VOLTAGE RATINGS DC WORKING VOLTAGE AT 25°C

CASE SIZE*	6VDC	10VDC	15VDC	20VDC	25VDC	35VDC	50VDC
D—.125 L—.250	.0047 to 4.7MFD	.0047 to 3.3MFD	.0047 to 2.7MFD	.0047 to 1.5MFD	.0047 to 1.5MFD	.0047 to 1.0MFD	.0047 to .68MFD
D—.175 L—.438	6.8 to 33MFD	4.7 to 22MFD	3.9 to 15MFD	2.2 to 10MFD	2.2 to 6.8MFD	1.5 to 4.7MFD	1.0 to 3.3MFD
D—.279 L—.650	47 to 100MFD	33 to 68MFD	22 to 47MFD	15 to 33MFD	10 to 22MFD	6.8 to 15MFD	4.7 to 15MFD
D—.341 L—.750	150 to 220MFD	100 to 150MFD	68 to 100MFD	47 to 68MFD	33 to 47MFD	22 to 33MFD	

*uninsulated.

The first solid electrolyte tantalum capacitors to be rated for 200°C, the new Mallory Type THS line, was originally developed for use in oil well instruments which are subjected to high temperatures during deep-hole surveys. These miniature capacitors are hermetically sealed in tin-plated cases with gold-plated leads. Uniform high quality is assured by 100% screening tests at 200°C.

Four different case sizes are available from 0.125″ diameter by 0.250″ long, to 0.341″ diameter by 0.750″ long (uninsulated). Teflon* insulating sleeves can be supplied. Nominal values cover the range from 220 mfd, 6 VDC to 15 mfd, 50 VDC. For complete details, write or call Mallory Capacitor Company, Indianapolis, Indiana 46206—a division of P. R. Mallory & Co. Inc.

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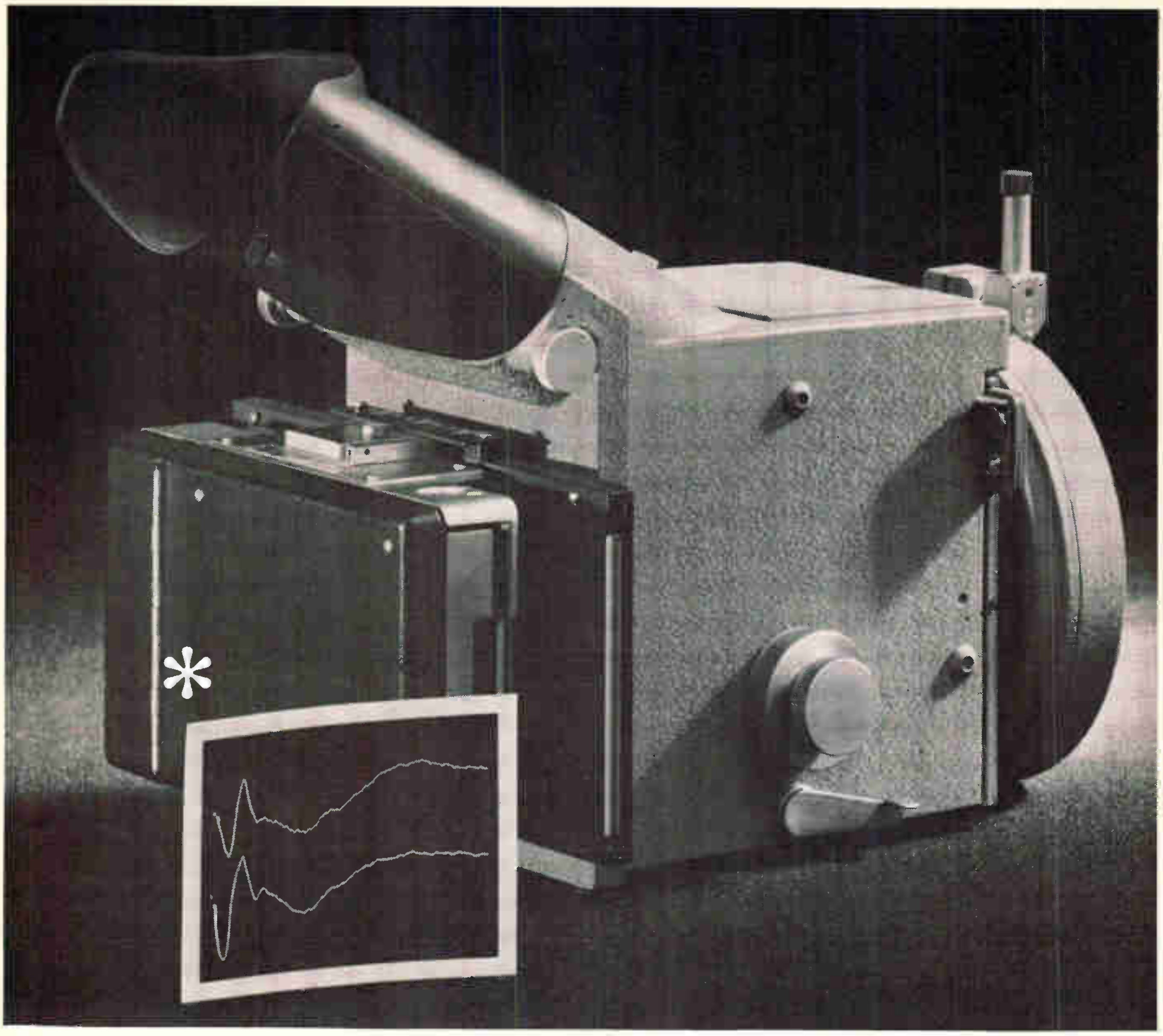
MALLORY

WET SLUG, FOIL AND SOLID TANTALUM CAPACITORS



FAIRCHILD SCOPE CAMERA AIDS EYE RESEARCH

Use as clinical tool illustrates versatility of Type 450-A camera; Polaroid Land Back and Film provide immediate record

Electroretinography is but one of the scientific frontiers where Fairchild Oscilloscope Cameras are providing high precision recording of displayed phenomena. Among the features which contribute to this high performance are: • helical rack and pinion mechanism for pinpoint focusing and image reduction • heavy duty synchro-shutters • jam-proof lever for positive tripping of shutter. • Object-to-image ratio is continuously adjustable from 1:1 to 1:0.85, permitting recording of full 6 x 10 cm field on Polaroid Land film in 0.9 actual size. With the new Polaroid Land Film Pack Adapter prints — developed outside the camera — are available in 10 seconds. • Accessories include data chamber for writing in test identification for recording simultaneously with CRT display. If your work requires precision recording of oscilloscope displays, call your local Fairchild Field Engineer or write for complete data on the Type 450-A and other Fairchild Oscilloscope Cameras.

Fairchild Scientific Instrument Dept., 750 Bloomfield Ave., Clifton, N.J.

("Polaroid"® by Polaroid Corp.)

*** Traces show reaction of human eyes to a short light stimulus. The retinae electric potential is picked up with contact lens electrodes, fed to scope and recorded by Fairchild Oscilloscope camera fitted with Polaroid Back. Sequence is initiated by synchro-shutter of camera. Polaroid print is reproduction of one of thousands made at New York Medical College by G. Peter Halberg, M.D., Associate Clinical Professor of Ophthalmology.**

FAIRCHILD

DU MONT LABORATORIES

SCIENTIFIC INSTRUMENT DEPARTMENT

Editorial

We're not getting the word

At last the government is beginning to act on the most perplexing challenge posed by its research activities. That challenge is to increase the trickle of useful knowledge that flows from these projects into the civilian sector of the economy.

In the House of Representatives, the Select Committee on Government Research has published a report entitled "Documentation and dissemination of research-and-development results." The committee clearly implies that government agencies are impeding rather than helping the flow of technical information. Duplication of activities and a confusing maze of procedures bottle up data rather than release it.

Other leaders, from Vice President-elect Hubert Humphrey down, are asking with growing impatience why the information explosion yields so little civilian fallout.

More than two-thirds of the United States' best scientists and engineers work full-time on research and development in national defense, the space effort and atomic energy—all fields closely allied to the electronics industry. The government pays $13.2 billion for more than 80% of all research and development carried on in the U. S.

This new technology could launch thousands of new products and boost the gross national product to even greater heights. Why aren't civilian engineers getting the word?

We think there are two fundamental reasons: censorship and bad writing.

Nobody doubts that information essential to the national safety should be safeguarded. But most classification is motivated by a desire to enhance somebody's political status or to hide somebody's mistake.

Sometimes a project is classified until it can be announced by an important congressman. Often security officers adopt the philosophy that "What the public doesn't know it won't complain about." Maybe that's why the design of the control system for World War I torpedoes is still classified.

One Pentagon official declares: "It takes more courage for a career officer to declassify a document than to go into combat."

The only general declassification of military information in this century came in 1954, when President Eisenhower ordered all classifications dropped one level.

Classification should be used the way it was intended: to protect the country, not the bureaucrats.

Bad writing is an equal deterrent to the spread of knowledge—and, we suspect, sometimes just as deliberate as improper censorship.

Often, technical writing can be understood only by the author's close associates. True, some of this fuzziness is a result of inadequate training in English composition. But more frequently, we fear, it's a smokescreen behind which the writer hopes to enhance his prestige. He thinks that if nobody can understand what he has written, everybody will assume it must be of a high technical level.

Regardless of the reason, many technical articles are undecipherable to civilian engineers: others are so dull the reader can't stay awake long enough to finish them.

The federal government spends somewhere between $385 million and $500 million a year to publish scientific and technical information. Then why isn't the word getting around? Take a look at the publications and you'll know.

Much of the material is technical gibberish, written for a tiny "in" group. Some is technical minutia that never should have seen the light of print. And a lot is astonishingly out of date.

In its Nov. 20 issue, U. S. Government Research Reports carried an abstract entitled "The maser: a new type molecular amplifier for microwave radiation." The same report was published Oct. 25, 1957—seven years earlier—by Science, the journal of the American Association for the Advancement of Science.

If the information gap is to be narrowed, several people and organizations have a job to do. The President and other government officials have to declassify material that has nothing to do with the national security. Editors of technical publications have to start editing, so their articles can be understood by somebody besides the author. And engineers and scientists, individually and through their professional societies, have to start demanding, and producing, intelligible articles and reports.

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CLIFTON PRECISION PRODUCTS
DIVISION OF LITTON INDUSTRIES
Clifton Heights, Pa. Colorado Springs, Colorado

Electronics Newsletter

December 28, 1964

Record output for argon laser

A blue-green laser, using ionized argon for continuous-wave operation, has delivered nearly seven watts of power at Raytheon Co.'s research division, the company announced.

The laser used a 12,500-watt power supply and operated at an efficiency of 0.053%.

Blue-green lasers offer great promise in biological research because their unfocused beams can cause changes in cells and tissues.

Raytheon says it is now building a 100,000-watt power source in an effort to get out 15 watts in light power. The company hopes to generate 100 watts in light power in 1965.

Hi-fi designers see need for FET's

Manufacturers of high-fidelity equipment appear more interested in designing with field-effect transistors than with integrated circuits.

Daniel R. Von Recklinghausen, chief engineer at H.H. Scott, Inc., a major hi-fi producer, says, "The real need at present is for low-cost field-effect transistors for tuners and audio stages." And Robert Furst, chief engineer at Harmon-Kardon, Inc., another big hi-fi producer, which is a subsidiary of the Jerrold Corp., says, "Field-effect transistors are certain to break into consumer electronic products in the near future, but integrated-circuit hi-fi equipment is a long way off."

Some integrated circuits are available but so far haven't replaced conventional tubes and transistors in hi-fi sets because integrated circuits are difficult to cool, are more expensive and don't provide a high enough power output.

Integrated circuits developed specifically for hi-fi use are made by two manufacturers: Motorola Semiconductor Products, Inc., a subsidiary of Motorola, Inc., and the Westinghouse Electric Corp. [Electronics, Nov. 30, p. 17].

Warning system's cost reassessed

A proposed warning system to detect missiles launched by submarines has been halted at the acquisition stage for cost-effectiveness studies of alternative solutions [Electronics, June 1, p. 17].

The studies, ordered by the Defense Department, are being made at the Air Force Electronics Systems division, Hanscom Field, Mass. Alternatives include modification of coastal radars or a completely new system similar to the phased array radar at Eglin Air Force Base in Florida, which is used to track space vehicles.

Automated circuit making

The Stewart-Warner Corp. has entered the already-crowded integrated-circuit market with an automated plant in Sunnyvale, Calif. The plant is operated by a subsidiary, Stewart-Warner Microcircuits, Inc.

At full capacity, the plant is designed to produce two million circuits a year. The company hopes that process automation will increase efficiency so it can reduce prices and sell in the highly competitive radio-television and industrial electronics field, as well as to military and space customers.

Push buttons and solenoids, instead of the usual stopcocks, control gas flow in the reactor that grows and dopes epitaxial material; a controller-computer sets thermal profiles in the diffusion furnaces, and a tape-programed system with a 480,000-bit disc memory tests each circuit in 5 milliseconds.

The plant will apparently serve as a proving ground for process equipment to be sold commercially. The reactor, designed by Stewart-Warner, will be sold through the Kulicke & Soffa Mfg. Co.

Air Force's role in space cut

Military efforts to get a separate manned space-flight program appear to be stymied. **Defense Secretary Robert S. McNamara won't give the Air Force the green light to proceed with the $1-billion manned orbiting laboratory (MOL) program, although he assigned the program to the service almost a year ago, when he canceled its Dynasoar program.**

Over the past year, the Air Force has spent nearly $8 million in studies on MOL and has long been ready to start the project.

McNamara withheld approval for two reasons. The two-man MOL offers little technical advance over the National Aeronautics and Space Administration's three-man Apollo spacecraft that is due for earth orbital tests in 1967—ahead of MOL. Cost is the second factor. NASA is pushing a manned space laboratory using the Apollo spacecraft; the project is known as Apollo-X. Although the Apollo-X project is still on paper, it has won attention from McNamara and Congressional leaders. **And the Pentagon and NASA have now agreed to coordinate space laboratory programs more closely. This is expected to mean dropping MOL and concentrating on a joint military-NASA Apollo-X program.**

While the MOL program will be delayed, additional Air Force participation in NASA's Gemini and Apollo projects seems certain, including some entirely military manned flights.

Work progresses on NASA center

The National Aeronautics and Space Administration is moving ahead with plans for its electronics research center in Cambridge, Mass.

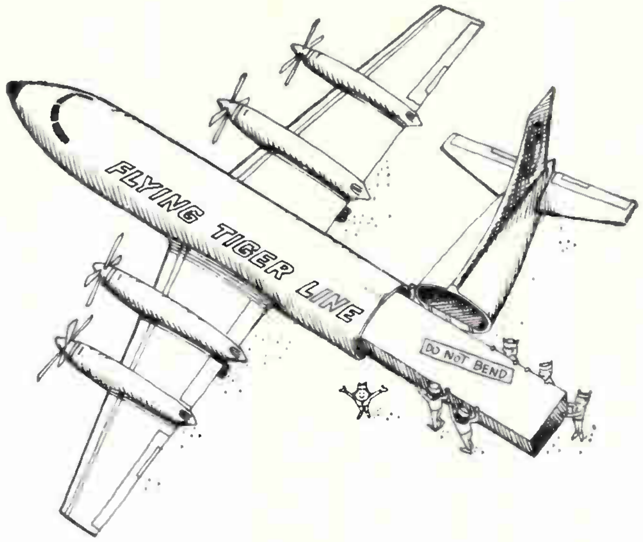
Lester C. Van Atta, chief scientist of the Lockheed Missiles & Space Co., a subsidiary of the Lockheed Aircraft Corp., was named to direct the center's research in electromagnetics, microwaves and optics. W. Crawford Dunlap, Raytheon Co.'s director of solid-state research, will head research in component technology, including solid state, materials and standards' qualifications.

In addition, Edward Durrell, the architect, was named to design the $60-million center, and the first of $5 million in research grants to be made in the next year has been awarded. The Moore School of Electrical Engineering at the University of Pennsylvania received $40,000 contract for a survey of microwave research in the 10- to 0.1-millimeter region.

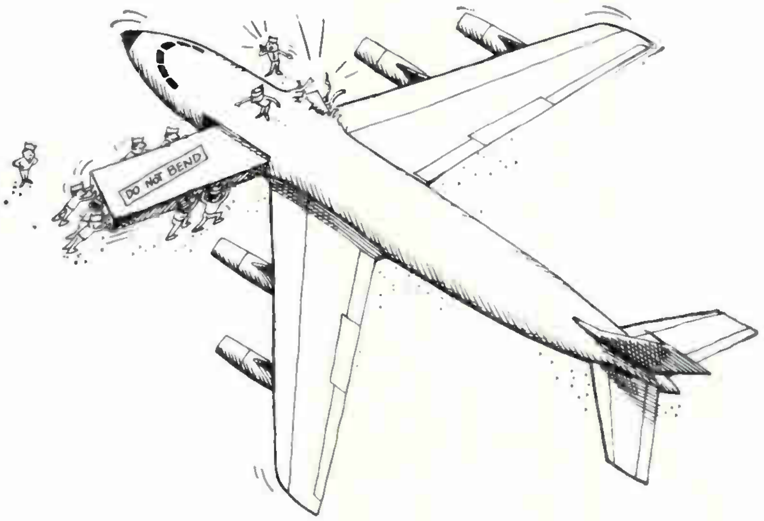
Military computer dons civvies

The Burroughs Corp.'s military computer has a new number, D82, and a civilian job with an airline in Canada.

The computer will be used by Air Canada to provide information on passengers and cargo. Burroughs is furnishing a pilot system of one computer and a disc file. The system may be expanded eventually to handle automatic ticketing and gate check-in operations, with a network of interconnected computers that will be able to "talk" to each other. In its military role, the computer a D825, is used for command and control.



WE'LL BREAK OUR BACK TO TAKE OUTSIZE CARGO



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the airfreight specialist **FLYING TIGER LINE** *design ideas for the OEM engineer . . .*

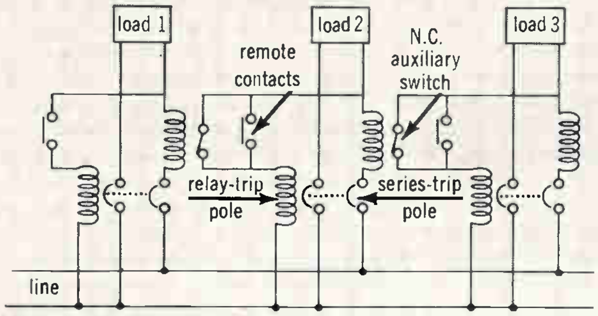
USE HEINEMANN CIRCUIT BREAKERS FOR BOTH PROTECTION AND CONTROL

Heinemann hydraulic-magnetic breakers get the nod from many OEM engineers who rate them as excellent protective devices. A growing number of equipment designers are aware of another important fact: our breakers make excellent and economical control devices. With a little ingenuity and one of our special internal circuit forms, you can often get the job done with fewer components and a simpler circuit. In addition to the basic series-trip internal circuit (coil and contacts in series), Heinemann breakers are available with shunt-trip, calibrating-tap, relay-trip, dual-rating, auxiliary contacts, and other special internal circuits.

The examples here are typical of what's being done. Together with a variety of internal circuits, the Heinemann line features current ratings from 10 milliamps to 200 amperes in any integral or fractional value, models that range from subminiature to larger panelboard and switchboard sizes, and multi-pole breakers to six poles. All use the proven hydraulic-magnetic principle which guarantees temperature-stable ratings and trip points.

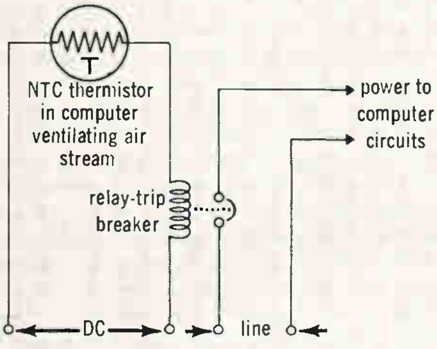
For more information, request a copy of the Heinemann Engineering Guide, Bulletin 202.

goof-proof circuit for sequential startup and shutdown



The three two-pole breakers in this circuit can be turned on only in the sequence 1-2-3, and off only in the sequence 3-2-1. Proper sequencing is guaranteed by the relay-trip pole in each ganged pair. Typically, if breaker #2 is switched on out of sequence, its relay-trip pole is tripped by the line voltage "seen" through the N.C. auxiliary switch on breaker #1. If breaker #2 is turned off out of sequence, its own auxiliary switch closes, causing breaker #3 to trip. The relay-trip coils can also be actuated from remote contacts if desired. Overload protection is furnished by the series-trip poles in each pair of circuit breakers.

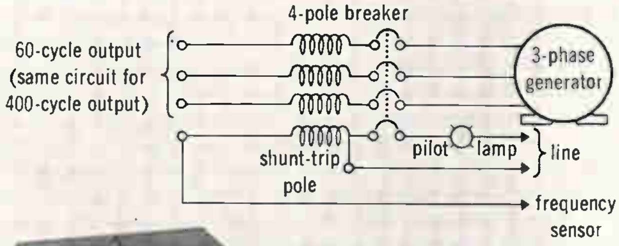
high-temperature limit control with manual reset



Here, a relay-trip breaker is paired with a NTC thermistor to protect semiconductor circuits in a computer from over-heating. Temperature rise in ventilating air will drop thermistor resistance, raise breaker coil voltage, and cause instantaneous tripping. Breaker contacts open power lines to semiconductor circuits, prevent burnout. Design was chosen as the most economical means of providing high-temperature cutoff with manual reset.

Because of the electrical isolation of the coil and contacts, a relay-trip breaker can control one circuit from another that uses an entirely different voltage or current. Relay-trip is one of the most versatile special circuit forms in our line.

protecting a diesel generator from frequency drift



A compact, portable, diesel-driven generator needed protection against frequency drift for its 60- and 400-cycle three-phase outputs. A lightweight, economical solution was effected by adding a fourth shunt-trip pole to each of the generator's three-pole output breakers. (Diagram shows one of the two output circuits.) Should frequency drift, a separate frequency sensor delivers a "jolt" of voltage to the shunt-trip coil, tripping all four poles. Use of shunt-trip trip poles saved the weight and cost of two separate three-pole contactors.

Though breakers are usually current-rated, Heinemann can supply voltage-rated models if voltage is the easier variable to monitor.

HEINEMANN ELECTRIC COMPANY

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Trenton, N.J. 08602

SA2951

December 28, 1964

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Manufacturing

Rubber-stamp circuits

Major manufacturers and users of integrated circuits are trying to get out of a costly rut: the use of individual packages for one or two integrated circuits. This makes the package more costly than the circuits and multiplies the number of failure-prone mechanical connections in a microsystem.

Most companies are heading down a familiar path: using thin metal films or foils, etched to form microminiature printed circuits that interconnect groups of circuits on a single slice of silicon, or joining arrays of circuit chips on a common substrate.

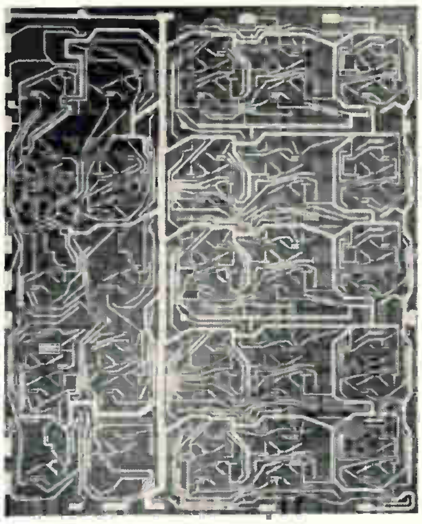
Two approaches. Production and packaging researchers at the Westinghouse Electric Corp.'s Aerospace division in Baltimore are studying two other approaches: using patterns made of sintered metal powders or conductive chemicals that could be printed on the arrays. This would be the equivalent of rubber-stamping.

Such techniques, they believe, will prove more flexible and economical than usual methods.

Why not flatpacks? Many companies are working hard on techniques for mass interconnection of circuits, seeking gains in cost, reliability and flexibility.

Some integrated circuits cost only about \$2, but the average is now probably 10 times that. In 1965, the average price for a packaged circuit is expected to drop to around \$10 and may fall to \$7 or \$8. In comparison, an unpackaged chip costs about 25 to 50 cents in mass production. So, major users of integrated circuits want interconnection and packaging methods that will add little to the cost per chip—a dime per chip is one target.

At the same time, they hope to improve reliability by eliminating most mechanical connections. An individually packaged chip now requires at least three bonded, welded or soldered connections for each terminal on the chip—chip to lead, lead to package pin and pin to external wiring. This is already being overcome economically on a small scale by interconnecting four or six identical logical circuits on a single piece of silicon with thin films, then putting the array in the same type of package that held one or two chips.



Logic subsystem on a single slice of silicon. This thin-film connected array was designed by Westinghouse for use in a satellite that had to operate a year without failure.

Too expensive. Large arrays have also been made by this method, but they are costly because it is difficult to obtain silicon slices with sufficiently large groups of flaw-free circuits. Westinghouse's Molecular Electronics division, for example, has made arrays of dozens of logic circuits for applications where the gain in reliability has outweighed additional cost.

This approach doesn't work when a variety of specialized circuits are required and if discrete components must be mixed in to obtain special circuit functions or the tight tolerances needed in analog systems. Nor do system producers want to turn over subsystem assembly to their vendors.

The most popular solutions to these problems are to make microminiature printed circuits with thin films, screened and fired thick films, or etched foil, and then attach the chips and components. But getting the parts mated and bonded to the wiring is tricky work.

Rubber stamps. Maurice Nelles, head of manufacturing research at Westinghouse's Aerospace division, thinks chemical conductors may prove cheaper and more versatile than the traditional metal conductors. Organic-metal compounds could be applied by printing processes. Their conductivity would be lower than metal, but this could be tolerated because signals would have to travel only tiny distances in multichip arrays. Or, Nelles adds, the array might be coated with a compound that will decompose and leave metallic tracks in a pattern determined by a chemical or thermal method that triggers the decomposition.

If studies of materials and methods warrant development, a chemical technique would come into use in 1966, Nelles thinks.

Silk screen. Another idea being studied is the use of sintered metal powders. The powder pattern would be printed by electrostatic methods, or through silk screens—now used to print etching-resist inks that are bonded by resins.

Nelles, however, wants to develop an all-metal "ink," tiny metal sphere coated with a metal that bonds to itself by diffusion when heated. The heat would substitute for the pressure now used to make diffusion bonds, as when two halves of a transistor are cold welded.

Avionics

Look, Ma, no hands

Into the approach pattern at Washington's Dulles Airport, the United Airlines two-engine jet Caravelle wheeled and headed for a landing on Dec. 8. As the plane descended, then "flared" and finally touched down, the pilot and copilot took both hands off the controls and held them up in the air for network-television cameramen who were photographing the test of an automatic landing system. The "no hands" landing was letter perfect.

Almost continuously since 1949—when the Air Force successfully operated an all-weather cargo schedule between the East Coast and Ohio—major United States airlines have sought an automatic landing system that would bring flights in on schedule regardless of the weather or visibility. Mostly, the Federal Aviation Agency has pushed the studies. But this month United Airlines took the bit in its teeth and did a little experimenting of its own.

Following ILS. With the new system, a joint development of Lear Siegler Inc., and Sud Aviation of France, the plane aligns itself with the runway, "locks on" to the airport's electronic ILS (instrument landing system) beam, and follows the beam down to the runway.

During the approach, airborne computers control the plane's heading, altitude, rate of descent and speed.

Just before touchdown, the system automatically "flares" the plane, raising the nose, closing the throttles, and letting it settle to the runway. The system also compensates for wind, turns the plane to a proper heading on approach, then corrects it for the proper attitude at touchdown.

Weighs 55 pounds. Instrument-failure warning devices are built into the system. The hardware, which weighs about 55 pounds, has a radio altimeter and four distinct computers (lateral, longitudinal, thrust and instantaneous vertical velocity), one throttle servo actuator with individual capstans for each engine, one air-speed transducer, and one air-speed selector and a radio altimeter. Information from the computers are fed to an autopilot, which in turn transmits roll, yaw and pitch commands to the aircraft's ailerons, rudder and elevator.

The radio altimeter, manufactured by Telecommunications Radioelectriques Telephoniques in France, uses an electronic beam to measure the airplane's height above ground.

In the Lear Siegler-Sud system, the pilot is an integral part of the landing system. He monitors it and always has the final word.

Carrier landing. Though many commercial pilots may cringe at the thought of automatic landings, Navy pilots on some aircraft carriers make them every day. They use a system developed by the Bell Aerosystems Co., a division of Textron, Inc.

But the system on the carriers is far different from that demonstrated at Dulles Airport. Position data is calculated by an analog computer on the ship and position error signals are radioed to the aircraft's autopilot. Patterns for a perfect landing are stored in the computer. Radar tracks the aircraft and compares its position to that stored in the memory.

Bell has just delivered its 12th system to the Navy and next year will ship systems to the carriers Constellation, Forrestal and Coral Sea.

British version. In Britain, which is plagued by year-round heavy fog, automatic landing has been a prime research project. One system that has been flown extensively was developed by the Smiths Aviation division of S. Smiths & Sons, Ltd., England.

Like the Lear Siegler-Sud system, success in the British no-hands landing system requires that highly accurate altitude data and ILS signals be fed to air data computers that can then furnish attitude, heading and throttle-control information to an autopilot.

The British unit is larger—it weighs about half a ton—and is redundant. To replace the present SEP-5 duplex system, Smiths is developing a triple-redundant system (SEP-6) that will be completely solid state and have no moving parts.

The pilot in the Smiths "autoland" system does not take part in the landing program after the "flare" point has been reached. He has no override option.

Airline posture. Airline operators are now wondering when a certified completely automatic landing system will be available. William A. Patterson, chairman of United Air-lines, Inc., predicts the company's aircraft will have a system installed by 1967. But it will not be fully automatic. It will reduce the ceiling limit from the present 300 feet to 100 feet. Pilots will still handle the final 100 feet of landing.

Before 1970, Patterson says, hands-off landings will become routine.

Military electronics

California far ahead

In the battle for military contracts, significant ground was gained in fiscal 1964 by Connecticut, Massachusetts, Missouri, Texas and Florida. But New Jersey and Ohio lost a little.

These and other defense contract statistics were released this month by the Pentagon.

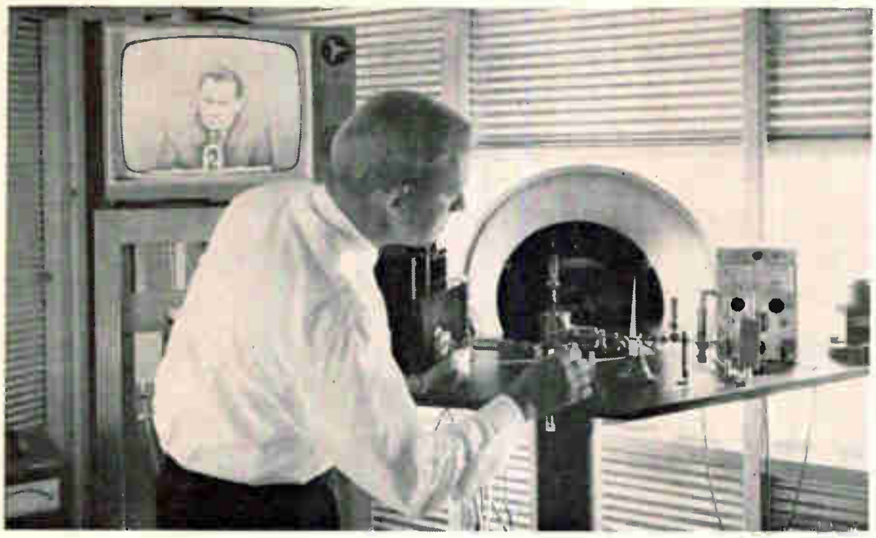
Spending inches downward. Total prime contracts for the year declined $700 million from 1963, to $27.4 billion. And research and development declined $400 million, to $5.8 billion.

California maintained its top position in dollar volume of contracts, and New York held onto second place. Missouri jumped into 3rd from 10th a year earlier, largely because of heavy buying of F-4 fighter planes from the McDonnell Aircraft Corp. of St. Louis. Texas climbed into 4th place from 5th, and Connecticut moved up into the 5th spot. New Jersey and Ohio tumbled from the top five.

The leaders for 1964, their sales and their percentages of the total are as follows:

California, $5.1 billion, 21%; New York, $2.5 billion, 10.2%; Missouri, $1.4 billion, 5.5%; Texas, $1.3 billion, 5.3%; and Connecticut, $1.1 billion, 4.6%.

Ups and downs. California also


Engineer compared performance of television signals over 3-millimeter television link and f-m link in program to improve communications on small-wavelengths.

dominated research-and-development awards by a wide margin. Massachusetts pushed New Jersey out of second spot, and Florida and Texas moved up substantially to tie for fifth among the leaders.

The new rankings:

California, $2.3 billion, 39.2%; Massachusetts, $0.4 billion, 7.1%; New York, $0.4 billion, 6.8%; New Jersey, $0.3 billion, 5.4%; and Florida and Texas, $0.26 billion, 4.5%.

Among individual contractors in R&D, North American Aviation, Inc., which ranked fourth in fiscal 1963, headed this year's list with awards totaling $568 million. The General Dynamics Corp. retained second place with $432 million. The Lockheed Aircraft Corp., which ranked first in '63, fell to third place with $342 million.

The Western Electric Co. moved up from sixth place to fourth with $318 million, and the Boeing Co. retained fifth place with $313 million. The Martin Marietta Corp., which was third in '63, dropped to sixth place with $281 million.

The Defense Department has not yet compiled the top contractors.

Communications

Millimeter-wave video

A unique scheme for evaluating performance of communication systems that operate on millimeter-size wavelengths is being used by engineers at the Aerospace Corp., El Segundo, Calif.

Researchers have set up a 12-mile line-of-sight television link between the plant and a mountain top. Television transmissions from local stations are picked up at the top of the mountain and the video portion retransmitted over the three-millimeter link to a receiver at the plant. Here, the signals are compared with signals received on a standard television set. Differences in the two signals show up phase distortion and multipath effects, if any. Results will be noted for varying weather conditions.

Little data. One of the biggest problems in millimeter waves has been the lack of information on their performance. Research has been conducted in development of millimeter-wave sources, detectors and other equipment, but there has not been enough time to develop statistical data on behavior of systems over widely varying atmospheric conditions.

This information is vital for developing antennas, power sources, transmission methods and detectors. Results from tests over this video link will tie system disturbances to specific atmospheric disturbances such as rain, fog, wind, temperature over the link and variations in transmission at night and during the day.

From this data, engineers hope to be able to design the best schemes for space vehicles and space-to-ground communications, high-resolution radar and very-wide bandwidth, high-speed data channels.

Aluminum antennas. Transmission is at 94 gigacycles (3 mm). Two-foot diameter antennas made of spun aluminum are used for both transmitting and receiving. Each antenna has a gain of about 53 decibels. The transmitter's output from a klystron is 0.1 watt.

Video information is sent via f-m instead of standard a-m television transmission because f-m is more susceptible to distortions caused by phase shift and multipath effects. Frequency-modulation is used for sound on standard tv, however.

The f-m transmission system has a peak-to-peak deviation of 40 to 50 megacycles. Signals received at 94 Gc are converted to an i-f of 120 Mc using a mixer that has a conversion loss of 14 db. The intermediate-frequency noise figure is only 3.5 db over an instantaneous bandwidth of 80 Mc.

Feed back error. Stability is a problem; an error signal is taken out of the receiver just following the i-f preamplifier and is converted to a d-c voltage using a narrow-band discriminator. This error signal is fed back to a klystron local oscillator as an automatic frequency control signal and is able to take care of frequency shifts of as much as 120 Mc. A manual tuning control is also provided on the local oscillator to handle any increases in frequency that exceeds 120 Mc.

Designers of the system have allowed a margin of 10 db for the required f-m improvement. That represents the minimum allowable signal-to-noise ratio for good reception.

New job for Syncom

Satellite relays may soon provide airliners with reliable radio communications while they're over the ocean.

Currently, high-frequency radio communication between a plane and a land base is unsatisfactory. Weather and other natural causes often block all radio contact.

Successful tests were conducted late last month on one-way transmission from the Syncom III. The satellite, in synchronous orbit with the earth, is above the Pacific. Very-high-frequency signals from the satellite were received by a modified Bendix Radio Corp. receiver, aboard a Pan American World Airways plane. The signals drive a teleprinter at 50 words a minute.

Two-way talk. Next month airline officials plan to test two-way communication with the satellite. If this part of the program is successful, officials hope to be ready to try voice communications by early 1966.

But before the voice test is possible, several problems must be worked out: signals must be strengthened and antennas, preamplifiers and receivers must be redesigned.

In last month's tests, signals were sent from the Army's Camp Roberts in California on about 148 megacycles. The signals were received by the satellite and retransmitted on 136.47 megacycles to the aircraft. Engineers had pasted four aluminum foil Yagi-array antennas to the inside of the Boeing 707 radome housing the weather radar. An operator on the plane switched from vertical to horizontal polarization, using the strongest signal available.

Seek improvements. Initial talks have already been held with the Communications Satellite Corp. to provide improved circuits and higher power for voice communications on relay satellites it plans to place in orbit. But plans for the first Early Bird satellites, to be launched next year, are too far advanced to include provision for the new service. Hughes Aircraft Co., however, is reported to be already at work on in-house models of satellites that will accommodate aircraft communications.

Currently, several government groups, including the Federal Aviation Agency, are studying the technique, hoping to improve navigation and air-traffic control.

Advanced technology

Laser measures wind

Wind speed can be measured well enough by vane anemometers, which are little wheels with scoop-like paddles that rotate in the breeze. But engineers at the Sperry Rand Corp. decided there is a more accurate tool to do the job: lasers.

They take advantage of a theory of French physicist Augustin Fresnel, who proved 150 years ago that light propagating through a moving, transparent medium undergoes a change in velocity.

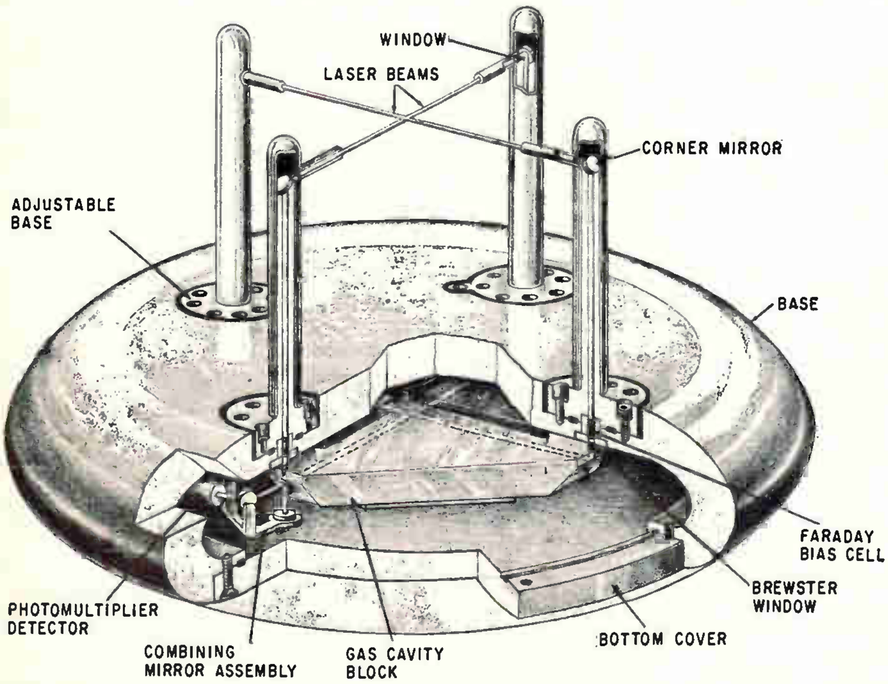
Measuring zephyrs. The Sperry researchers have set up a system of two vertical ring lasers in such a way that a wind passing through an open space will change the velocity of one or both laser beams, and from this the beams' direction and velocity can be determined, they say, to within 0.001 foot per second. Such an anemometer can measure faint breezes or the wind speed of a hurricane.

Engineers have measured the motion of carbon tetrachloride and other substances. They say the device could be used as a flow meter for toxic substances, or for fuel-flow measurement in rockets.

While the system will be much more expensive than mechanical instruments, there are certain applications where its extreme sensitivity and accuracy will make it vital. One is the determination of air currents atop a missile gantry before launching, to determine any necessary corrections.

Check the beats. The two laser rings produce two counter-rotating beams of light, each beam being set to a specific frequency. Any motion of air through the open part of the ring slows down one beam and speeds up the other, producing a beat frequency that is detected and measured.

To prevent the two beam frequencies from locking together, a "biasing" arrangement produces a known and constant difference between them, which exists even when there is no wind. Motion of air then simply raises or lowers the frequency.



Prototype laser anemometer accurately measures a zephyr or a hurricane. It works under the principle that light propagating through a moving, transparent medium undergoes a change in velocity.

Wide, wide magnet

Scientists examining subnuclear particles in high-field magnets have had two problems: lack of elbow-

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  1/2 rack: LH 119, 122, 125, 128—$5\frac{3}{16}''$ x $8\frac{3}{8}''$ x $15\frac{7}{16}''$

Model	Voltage Range	CURRENT RANGE AT AMBIENT OF: (1)				Price (2)
		30°C	50°C	60°C	71°C	
LH 118	0-10VDC	0-4.0A	0-3.5A	0-2.9A	0-2.3A	$175.00
LH 119	0-10VDC	0-9.0A	0-8.0A	0-6.9A	0-5.8A	$289.00
LH 121	0-20VDC	0-2.4A	0-2.2A	0-1.8A	0-1.5A	$159.00
LH 122	0-20VDC	0-5.7A	0-4.7A	0-4.0A	0-3.3A	$260.00
LH 124	0-40-VDC	0-1.3A	0-1.1A	0-0.9A	0-0.7A	$154.00
LH 125	0-40-VDC	0-3.0A	0-2.7A	0-2.3A	0-1.9A	$269.00
LH 127	0-60VDC	0-0.9A	0-0.7A	0-0.6A	0-0.5A	$184.00
LH 128	0-60VDC	0-2.4A	0-2.1A	0-1.8A	0-1.5A	$315.00

(1) Current rating applies over entire voltage range. DC OUTPUT Voltage regulated for line and load.

(2) Prices are for non-metered models. For metered models and front panel controls, add suffix (FM) to model number and add $25.00 to the price. For non-metered chassis mounting models, add suffix (S) to model number and subtract $5.00 from the non-metered price.

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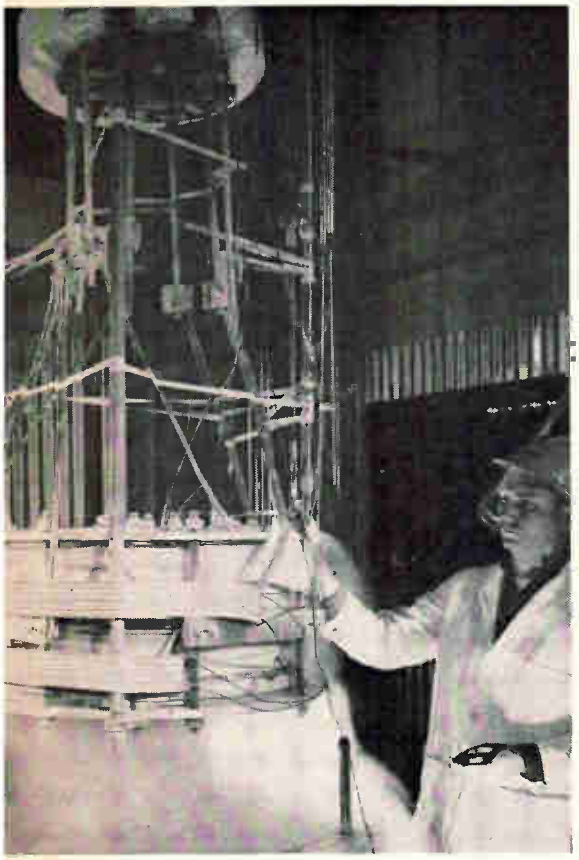


Wide-bore magnet provides elbow-room for scientists conducting research on subnuclear particles. This magnet, developed at Argonne National Laboratory, has an 11-inch bore and provides 42,000 gauss.

room inside the coils and the need for enormous amounts of power to maintain a strong field.

Researchers at the Atomic Energy Commission's Argonne National Laboratory say they've solved both problems with a cryogenic high-field magnet that has 11 inches of working space within the coils and needs little power. The magnet provides a field of 42,000 gauss. And by adding a third inner coil, the field is boosted to 67,000 gauss, although the bore is trimmed to seven inches, which is still larger than other supermagnets.

Smaller opening. The Radio Corp. of America, for example, previously developed a 107,000-gauss superconducting cryogenic magnet, but its bore is less than an inch.

Conventional high-field magnets, such as the 250,000-gauss instrument at the Massachusetts Institute of Technology's National Magnet Laboratory [Electronics, Nov. 30, p. 24], require vast amounts of current—enough to power a small city. Most of this power is wasted as heat, and elaborate water-cooling equipment is needed. Such gear is bulky and weighs several tons.

The Argonne magnet weighs only 800 pounds and is one foot high and eight feet in diameter. Its coils are bathed in liquid helium at —452° F, a temperature low enough to make the coils superconductive so that the magnet, once charged, can maintain its high-intensity field without additional power.

Special design. Physicists first will use the magnet's two outermost coils around a 10-inch hydrogen-helium bubble chamber for experiments with Argonne's 12.5 bev zero gradient synchrotron. A 6-inch bubble chamber is being designed for the smaller bore.

The magnet will also be used for experiments into controlled thermonuclear fusion, where extremely hot gases that melt any known container, must be contained.

Argonne scientists also expect to use the magnet to study magnetohydrodynamic generators that produce electricity directly from hot gases by passing them rapidly through the magnetic fields.

Computers

Bigger, but faster

The ceramic circuits that the International Business Machines Corp. will be using in its System 360 computers next year are faster than the speediest logic circuits now available as monolithic silicon integrated circuits.

Michael Flynn, of IBM's Data Systems division, said at the Symposium on Microelectronics and Large Systems, in Washington, that some of the circuits are now running at an operating rate of 300 to 500 megacycles a second. That's equivalent to 2 or 3 nanoseconds switching speed. The inherent delays in the circuits are only 1 to 2 nanoseconds and transition times vary from 1 to 1½ nanoseconds.

Integrated-circuit manufacturers are developing circuits with speeds down to 2 nanoseconds, by reducing size and improving isolation, but such circuits are not yet available. Par is now about 5 to 7 nanoseconds for special circuits.

Seven nanoseconds "or less" is the fastest circuit speed in the Radio Corp. of America's new Spectra 70 computers [Electronics, Dec. 14, p. 23]. RCA is making some of its own circuits and buying others from the Fairchild Semiconductor division of the Fairchild Camera & Instrument Corp. and from Westinghouse Electric Corp.

Ace in the hole. The computer industry was puzzled when IBM decided to use circuits made of metallic films fired on ceramic, with attached transistors and diodes, instead of the much smaller integrated circuits. Some people assume that IBM chose an older technology to play it safe and to save money by making the circuits in IBM plants.

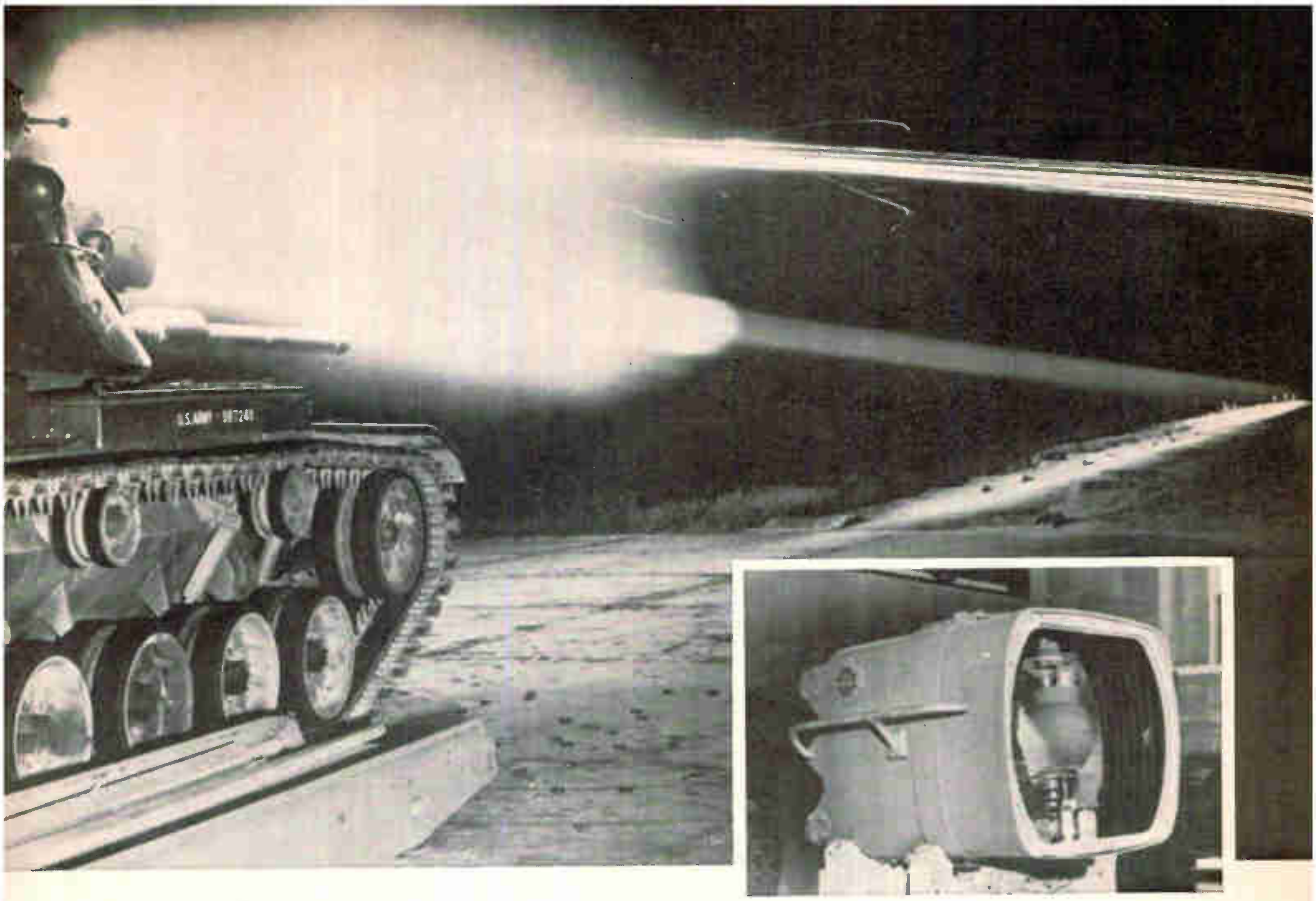
When IBM introduced the 360 computers early this year, the top speed of their Solid Logic Technology circuits was about 5 nanoseconds [Electronics, Apr. 20, p. 101].

The way the ceramic circuits' speed has been revved up may well prove to be IBM's ace in the hole in the coming battle for the microcircuit computer market. Logic speed is a major factor in computer speed, and the faster the computer, the more it is likely to be worth to the customer.

More powerful. Besides the gain in speed, the ceramic circuits give IBM a power advantage at little or no sacrifice in system size.

Flynn said that at frequencies of hundreds of megacycles, printed transmission lines, rather than printed wiring, are needed for interconnection. Transmission lines require higher driving power, and that is easier to get with bigger components. Heat is also more readily dissipated by the ceramic circuits. As as result, IBM can use 300 milliwatts of power per module.

Just as dense. IBM figures 4 to 8 lines are needed between pins on the circuit packages, for interconnection. To avoid fabrication and traffic problems with the printed



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Using Motorola's New High Current Rectifiers

Motorola's multi-cell silicon power rectifiers are providing DC in tank searchlights — dependable "seeing eyes" that pinpoint targets on the blackest nights. Giving tactical choice of visible or infrared light, the 70-million candle power searchlights — which could be seen on the moon with an ordinary pair of binoculars — are manufactured by Varo, Inc., Garland, Texas, and utilize Motorola 160-amp multi-cell rectifiers.

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MR1210-	80		2000	
MR1220-	160		3600	
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MR1240-	400		8000	
MR1260-	650		12000	
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Circle 27 on reader service card

11-45B12

circuits, 100-mil pin spacing is required. IBM gets 125-mil spacing with its circuits. Other companies that have used integrated circuits in transistor cans have had to spread out the pins, increasing the net size of circuits.

In its latest packaging designs, IBM puts four circuits in a small metal can, puts 72 of these cans on a 7-by-4½-inch printed-circuit card, and puts 18 cards on an 8-by-12-inch motherboard. That's a grand total of 5,184 circuits in less than one-fourth cubic foot.

Not only that, the modules are economical to assemble. As the circuits are stacked in the module, they are interconnected by pins inserted in the ceramic. The module can is not hermetically sealed—a major cost in integrated-circuit production. And the can plugs into the card like a miniature relay, so the connections can be dip-soldered all at once.

Parallel approach

Satellite telemetry equipment and other high-speed data-gathering apparatus has made the Air Force's computers overwhelmingly big, complex and expensive.

Rather than accept this situation as inevitable, the Air Force's Rome Air Development Center has built an experimental computer with an unusual parallel arrangement of logic modules that cuts the computer's cost and size and yet keeps it as fast as the supercomputers.

Most computers are the serial type, where operations are done sequentially. In these computers, speed is maintained by using expensive, ultra-fast logic circuits.

Saves money. On the other hand, parallel computers—where operations are handled concurrently—can theoretically use slower, less-expensive circuits and still maintain a relatively fast total execution time.

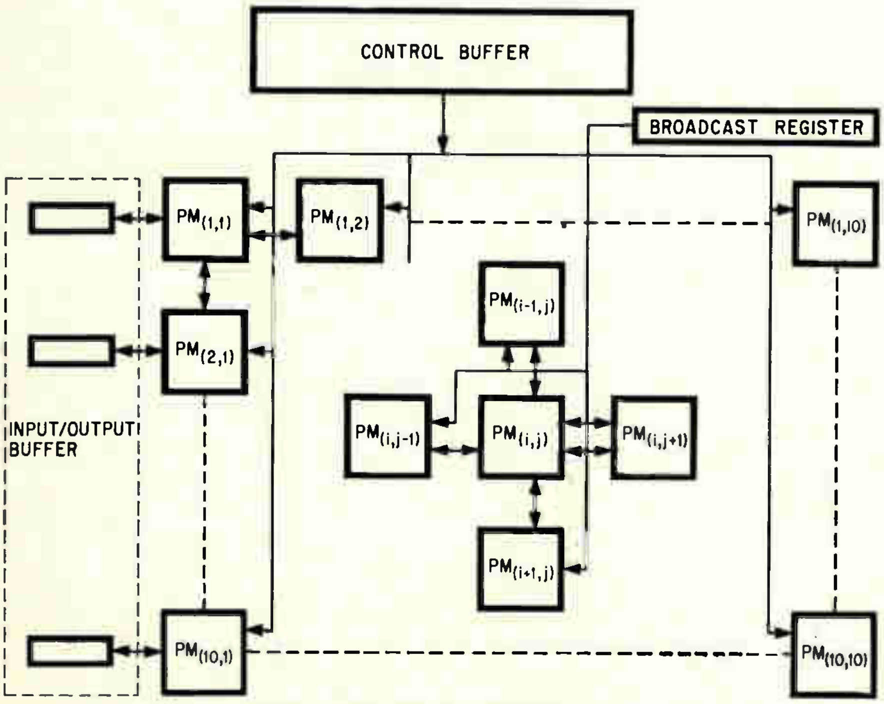
The new instrument is called a Centrally Controlled Iterative-Array Computer. Its heart is 100 interconnected identical processing modules arranged in a square matrix. Connected to this iterative array is a broadcast register that is a processor which can simultaneously supply instructions to all 100 modules and can also solve problems that do not lend themselves to parallel solution. Each processing module performs the same operation, in parallel, with its own unique data. The array can perform, 100 simultaneous operations.

Interconnected sections. Each processing module consists of a 24-bit accumulator and a storage element capable of storing 1,512 pieces of memory information. Each module is crossconnected with the broadcast register and with its adjacent modules. Thus it can perform logic operations on data stored in its own memory and accumulator, or on data stored in one of the connecting accumulators or in the broadcast register. Routing information for this operation is contained in the second half of the instruction word that comes from the control unit. Routing from the adjacent accumulators, the broadcast register or the module's own accumulator to its arithmetic unit, is the same for all 100 processing modules during any instruction cycle.

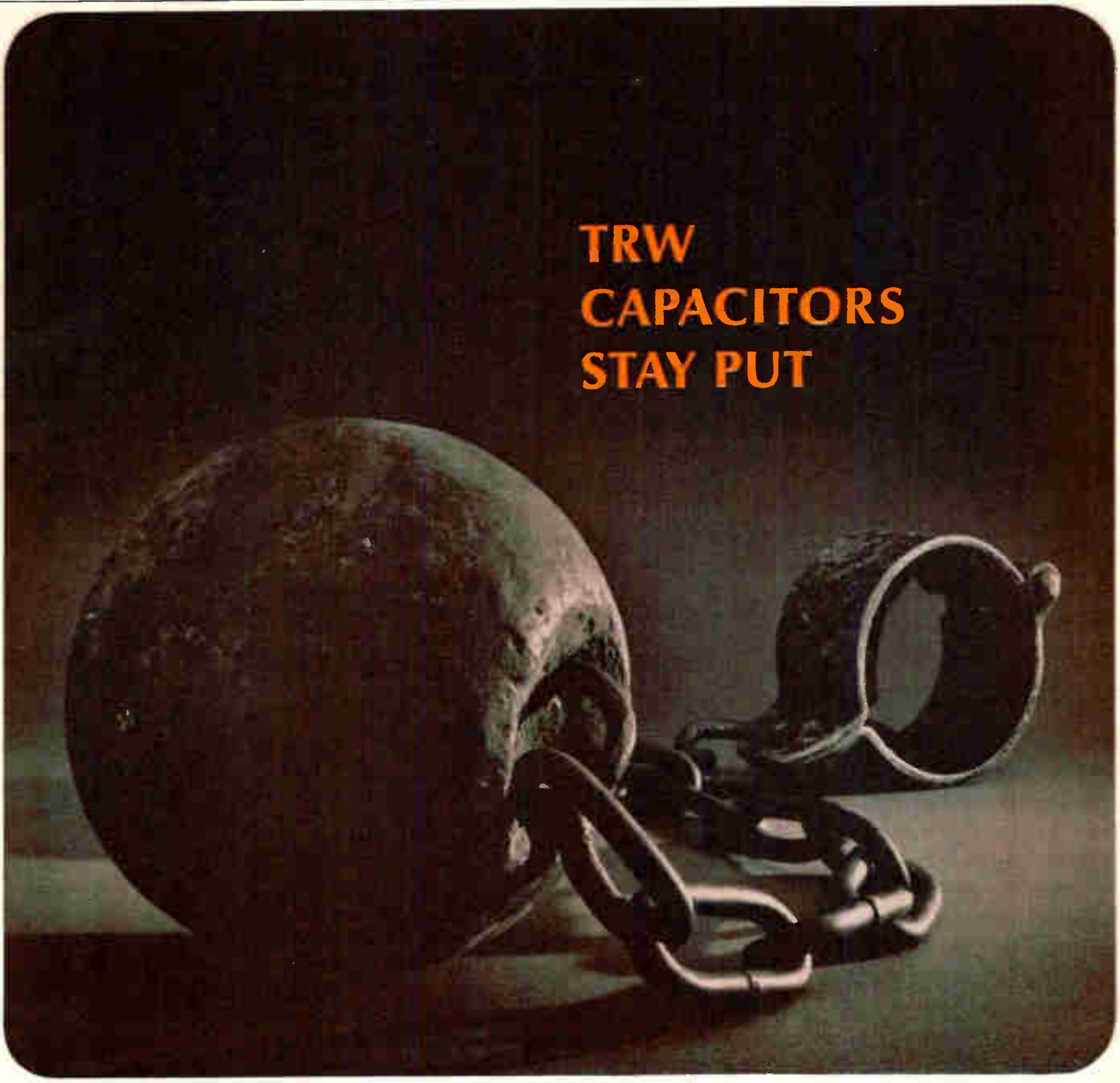
The broadcast register is also used to add in constants, perform comparisons and save duplication of data words. With the broadcast register, the array can simulate an associative memory of 100 parallel search words with storage up to 6,300 words. Each word has complete arithmetic and logic capability.

Integrated circuits. Except for the drivers, which are discrete transistor circuits, all electronic circuits in the iterative array's processing modules are integrated circuits. The accumulator and storage elements are magnetostrictive delay lines. Self-test and fault-locating features are built into the computer.

At present, the center's Intelligence and Information Processing division is using the computer to study applications of parallel processing. The evaluation studies, which are being conducted by Morris Knapp, task engineer, are expected to continue for about two years. The researchers expect to use this information to design future parallel and series-parallel computers.



Interconnection of computer modules in parallel array. The computer, designed by the Air Force, is being studied for future parallel and parallel-series machines.



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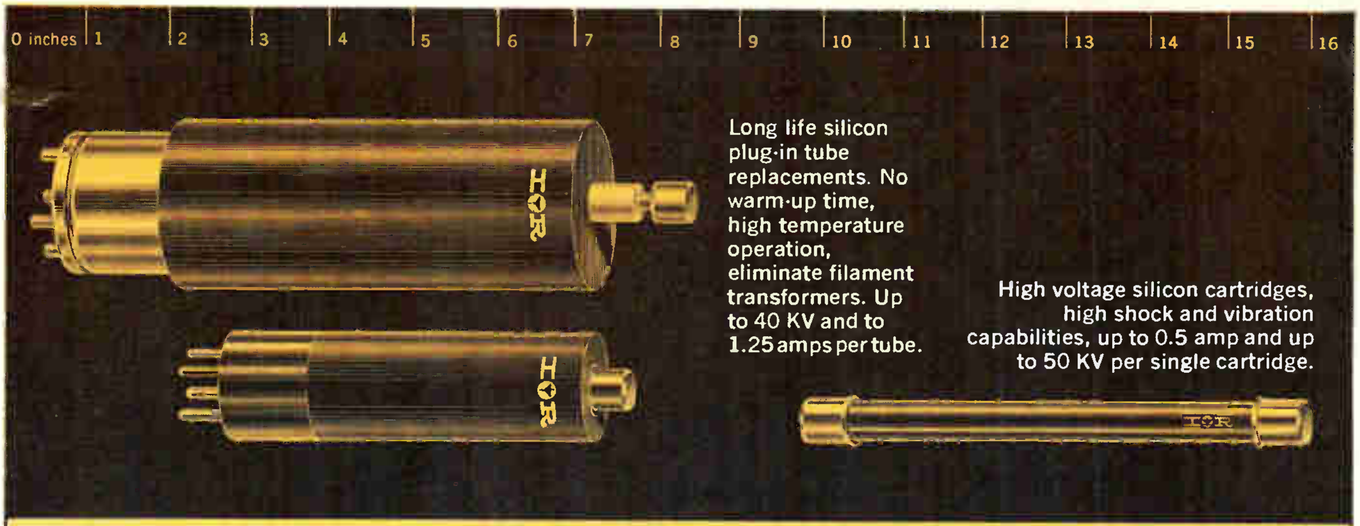

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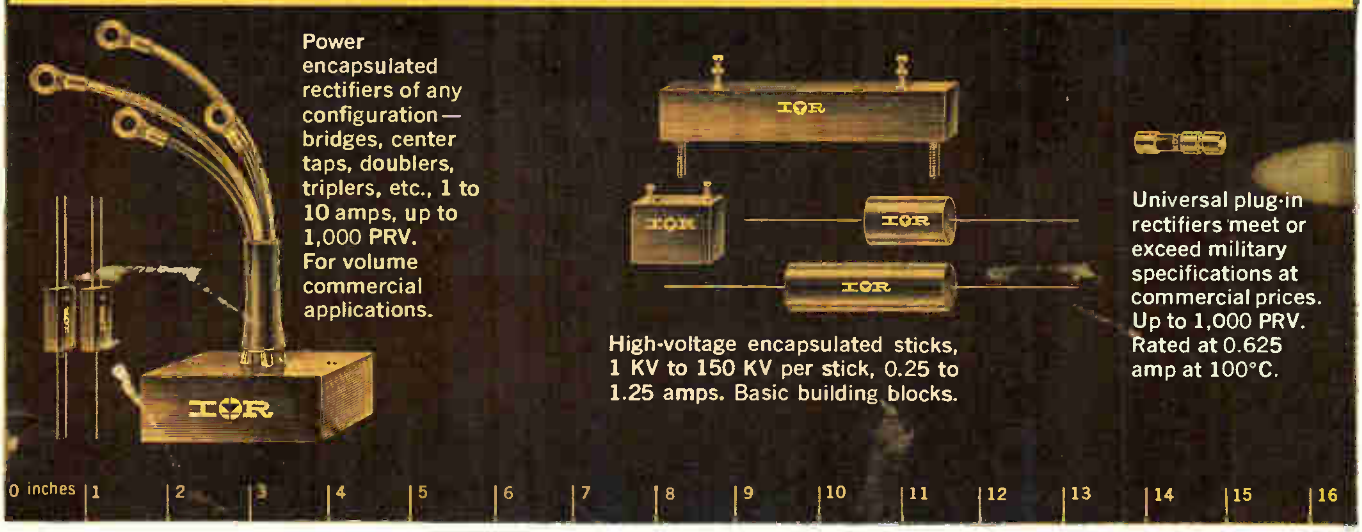


Washington Newsletter

December 28, 1964

Pentagon pushes weapon exports

The Defense Department wants United States electronics companies and other makers of military equipment to get the lion's share of the expected growth in foreign demand for defense goods.

Military equipment exports totaled $1.5 billion in the last two years. In 1965 alone that figure should rise to $1.9 billion and within a few years the total should climb about 50%.

Among the reasons for wanting U. S. producers in a strong bidding position: **American and Allied defense systems would be coordinated and production facilities of U. S. contractors would remain better tuned to military production.**

Pentagon officials believe that about 70% of the exports will go to well-heeled major Allies capable of pay-as-you-go and routine credit arrangements.

About 10% of the sales, however, will be to emerging nations, with no international credit standing. To aid them, the Pentagon is willing to participate directly in financing, by making about $1.5 billion available over the next 10 years. The remaining 20% is expected to go to nations that have international credit, but still require special financing assistance. **To help such countries, Defense and other government agencies are now working quietly with private banks in an effort to make a total of $3 billion in credits available.**

The $1.5 billion to finance the 10% of U. S. exports going to underdeveloped nations will come from an authorization voted by the last Congress.

Soviet stressing military research

United States intelligence information indicates that the Soviet Union is shifting its military emphasis from hardware to research. Reinforcing this information is the recent announcement that Russia's military budget for next year will be 4%, or $555 million, below this year's.

Partly, as a result, Defense Secretary Robert S. McNamara will continue to keep some new weapons off the production line. These delayed items include a new bomber, the Nike-X antimissile missile, a follow-on intercontinental missile and a new interceptor aircraft. This policy should keep the defense budget below $50 billion in fiscal 1966 and the research-and-development portion close to this year's $5 billion.

But critics say McNamara is creating a "technological Maginot line" by doing away with any of the weapons programs, even in R&D phase.

Pentagon burns over data release

Pentagon officials and the Bell Telephone Laboratories, Inc., prime contractor for the Nike-X antimissile system, are upset by what they consider premature release of technical details on the giant computer for the Nike-X. A general description of the supercomputer [Electronics, Nov. 30, p. 23], to be built by the Univac division of the Sperry Rand Corp., was presented at the Symposium on Microelectronics and Large Systems in Washington on Nov. 17.

While the use of the computer was not identified at the symposium, a four-alarm flap started when Aviation Week, a McGraw-Hill publication, said the size of the computer clearly identified it as being intended for use in the Nike-X system. Univac has a $17-million contract to build the Nike-X computer. The computer described in the paper is organized to handle many problems simultaneously with 25 independent processors and programs stored in 64 memories—specifications that fit into the scanty details made public on the antimissile system.

Washington observers now predict a Pentagon crackdown on clearance of technical papers.

Can foe stymie U.S. missiles?

Judging by the projects in the works, **the Defense Department is becoming increasingly worried that United States weapons could be immobilized by electronic methods.** Here are some ways the U. S. is combatting the danger:

The Air Force plans to study ways of inducing large electromagnetic fields in the ground. The aim is to simulate the electromagnetic pulse resulting from a nuclear detonation. Though defense officials are tight-lipped about the project, it appears that they want to explore the effects of a ground nuclear blast on hardened missile sites.

The Navy is planning to investigate ways of increasing the resistance of torpedo homing systems to acoustic countermeasures. A major industry study is in the offing, including the construction of laboratory equipment, devices and breadboard circuits.

And the Army is requesting proposals for a study to determine the vulnerability of the Nike-Hercules missile system to electronic countermeasures. The system, which includes high- and low-power acquisition radar, missile-tracking radar and target-ranging radar, is designed to shoot down enemy tactical missiles.

Avionics system stalled over cost

The Navy continues to have trouble getting Defense Department approval of a proposed integrated avionics system for helicopters. The project has won approval from the Defense Research and Engineering Office and Teledyne, Inc., has won the competition for development. **But the Comptroller General's office is questioning the $27-million cost.** The comptroller considers this amount excessive, unless other applications can be found.

The Army is considering the system for use on planned helicopter or fixed-wing vertical-takeoff craft, but no commitment has been made.

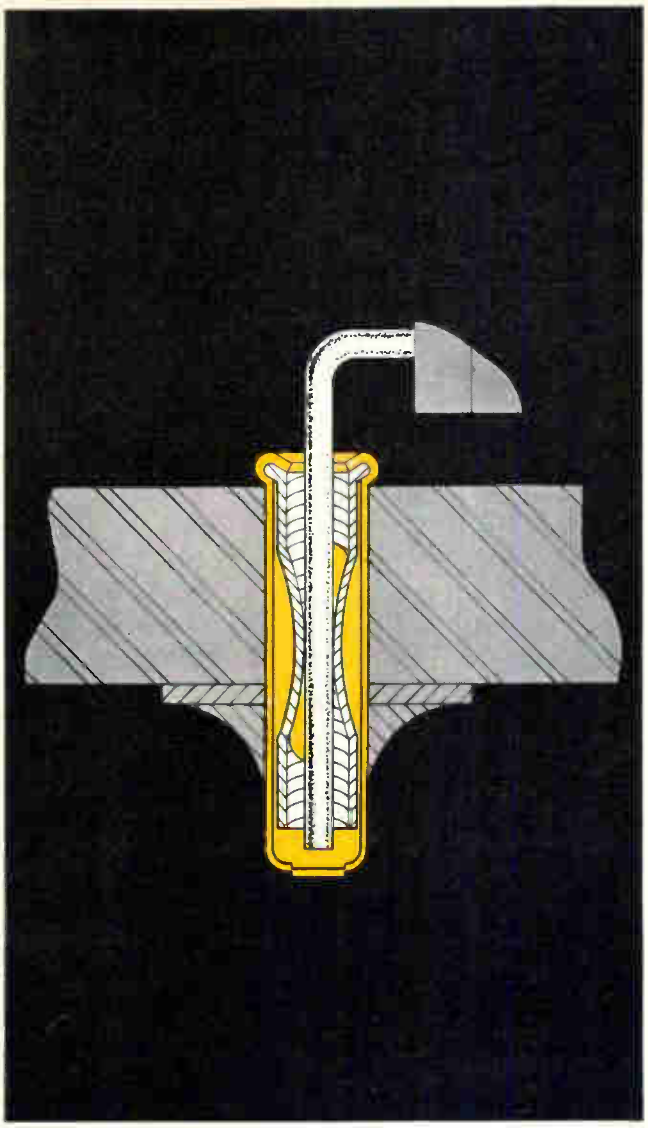
Weather stations for the oceans

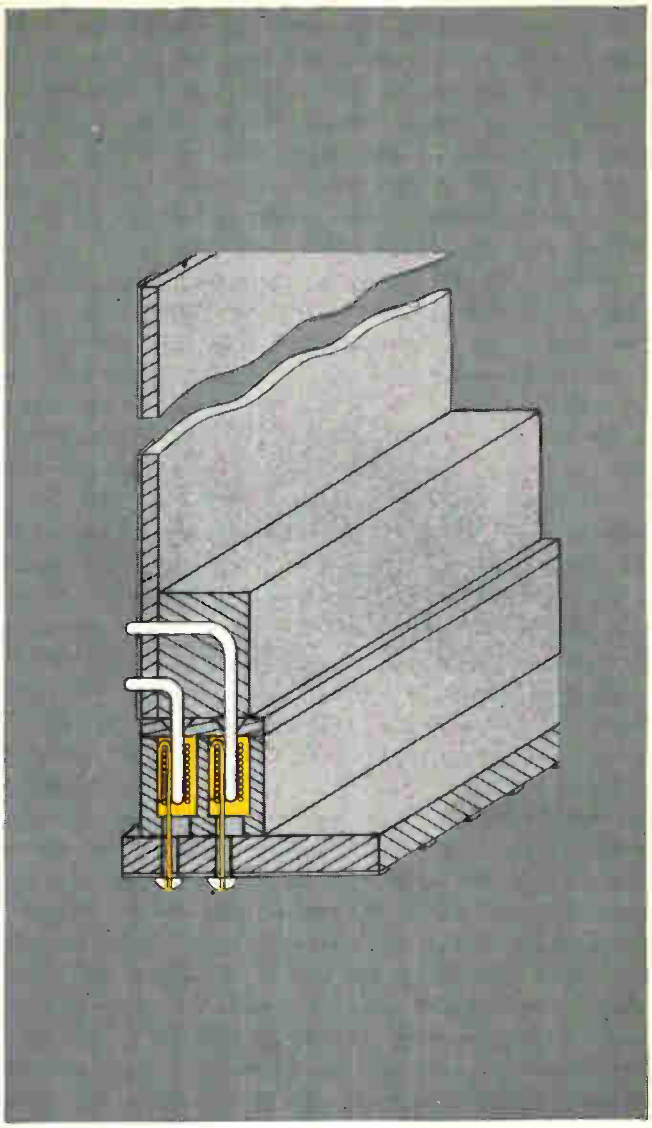
Wanted: automatic meteorological buoys to be monitored by satellites.

The United States Weather Bureau, as agent for the United Nations' World Meteorological Organization, wants 362 of them and figures the price should be between $5,000 and $7,000 each. The buoys should be able to monitor and transmit data on wind direction and velocity, air temperature, sea-surface temperature, barometric pressure, condition of the sea, storm configurations, and tensions in the buoy's mooring line.

Addenda

The Defense Communications Agency has issued a classified request to select companies for proposals on an advanced satellite communications system including satellite and ground stations. **This will be a follow-on system beyond the experimental communications satellites being developed by the Philco Corp.**





More density? Pack 'em in with these two new miniature interconnectors

The new A-MP* miniature spring socket

This new miniature socket from AMP handles single leads, multiple leads or solid wire pins in a wire diameter range from .010" to .020".

It features an inner spring that firmly holds leads even under strong vibration and a covering eyelet with a special "knockout" bottom.

The A-MP Miniature Spring Socket offers a number of design possibilities. It can be used as a memory frame bussing connector with a header-mounted pin or with jumpers running between frames. It can be used in multiple printed circuit boards with single-pin connectors. And in soldering operations, the knockout bottom prevents wicking.

Beryllium copper inner spring and copper eyelet both are available unplated or plated in tin or gold. Wire size range from 24 to 30 AWG. Minimum spacing with eyelet is .060" . . . without eyelet, .050". Socket meets MIL-G-45204 Type II and MIL-T-10727 Type I.

The new A-MP helical spring contact

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Contacts are set in brass eyelets (flanged or unflanged) or in dielectric housing. Tab ends, right-angled or straight, can be made in any length and of any metal. The helical spring assures firm contact and wiping action.

Pins can be inserted in both ends of the contact or through a number of stacked contacts.

The new A-MP Helical Spring Contact fits pin diameters .016", .020", .030" and .040".

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Circle 33 on reader service card

(ADVERTISEMENT)

New Printed Circuit Process Announced by Photocircuits

Glen Cove, N.Y.—A completely new process for the manufacture of printed wiring boards has been announced by Photocircuits Corporation, Glen Cove, N. Y. and Anaheim, Calif., world's largest printed circuit manufacturer.

The patented process, known as "CC-4", is "additive" in that the desired circuit pattern is *added* to the bare insulating base rather than selectively etched from foil clad material. The CC-4 process, developed by the Photocircuits R&D laboratory, utilizes chemical deposition of ductile, fine-grained copper on non-conductive, catalytic adhesive inks which have been selectively applied to an insulating base. The deposited copper has excellent bond strength to the base insulator and is extremely solderable. The thickness of the copper can be suited to the application—as thin as .0001" or up to .060" or more. Research on CC-4 began in 1955 when Photocircuits saw a future need for a lower cost method of manufacturing printed circuits. Various additive processes such as die stamping, electroplating, powdered metal fusing, metal spraying and vacuum deposition were investigated but discarded because of high tool and set-up costs or poor electrical and mechanical characteristics.

The CC-4 process is compatible with artwork and tooling of conventional etched circuit boards, with costs substantially lower since the raw material used is unclad. In addition to cost savings, the new technique offers many advantages not possible with conventional printed wiring. Besides the commonly used base materials such as XXXP, G-10 and polyester glass mat, CC-4 copper circuitry has been applied to flexible films, ceramics, molded plastics and epoxy coated metals. Plated-through holes can be made at very little additional cost with the new process. One or two sided copper boards with plated holes provide low cost printed circuits for commercial applications that have superior solder joints and greatly improved repairability characteristics.. Evaluations by large volume users of printed circuits have shown that the superior solderability of CC-4 copper compared to foil results in savings in board assembly.

For further information on the CC-4 process: Photocircuits Corporation in Glen Cove, N. Y. or Photocircuits of California in Anaheim.

First Announcement Made at National Electronics Conference

Announcement of the CC-4 process was made by Photocircuits in a technical paper and company exhibit at the National Electronics Conference in Chicago, Ill.

The paper was co-authored by Robert L. Swiggett, Executive Vice-President, and Frederick W. Schneble, Director of Research and Development. Mr. Swiggett is a member of the Board of Directors and is also a Past-President of the Institute of Printed Circuits.

Robert L. Swiggett

Frederick W. Schneble

CC-4 Process Offers Striking Cost Reductions

The new Photocircuits process resulted from research on substantial cost reduction in printed circuits. Robert L. Swiggett, Executive Vice-President of the firm, pointed out that this breakthrough in manufacturing technology can provide significant dollar savings. "The management of firms with captive printed circuit facilities must re-evaluate 'Make or Buy' decisions to be sure they are not investing in uncompetitive, obsolete techniques" he noted.

A substantial portion of the savings provided by Photocircuits' new process results from the elimination of the cost of applying copper foil to the base laminate. Typically, the difference in price between XXXP clad with one ounce copper and the same grade of material unclad is 22c-25c per square foot. Since raw materials and chemicals in the printed circuit process can run as high as 60-65% of the sales price in large quantity requirements, this difference is quite significant. With the CC-4 process, Photocircuits can produce the finished circuit patterns applied to insulating backing at a total cost equal to that paid for the raw material alone by users of older processes.

Wide Use Seen in Flexible Circuitry

Photocircuits is presently investigating the commercial application of the CC-4 process to the manufacture of flexible circuitry. Glass cloth has been impregnated with CC-4 ink and holes punched in the material. Application of a reverse mask to both sides and CC-4 copper deposition produces a flexible circuit with plated-through holes. The excellent bond strength of the adhesive and the plated-through holes solve a common problem associated with flexible circuits—lifting of terminal areas or destruction of the support material during soldering. Tests have shown CC-4 flexible circuits can be easily soldered and repaired.

CC-4 Licensees Include Western Electric, Grundig

Manufacturing information and patent licenses have been granted by Photocircuits on the new CC-4 process. In the United States, Western Electric Company has a licensed CC-4 facility in operation at Kearny, N. J. Facilities have been installed by several of Photocircuits' foreign licensees such as Ruwel, Fuba, Grundig and Telefunken in Germany and Lares in Italy. Other foreign licensees include Autophon in Switzerland, Cromtryck in Sweden and Mathias and Feddersen in Denmark.

Technical Articles

New use for the 'scope—measuring signal-to-noise ratio: page 36

An accurate measurement of signal-to-noise ratio frequently depends on the kind of instrument used. And the results can vary with interpretation. A new method with no such limitations uses a standard oscilloscope and requires only a basic understanding of the statistics associated with noise.

The field-effect transistor, Part 3 page 45

More applications of the field-effect transistor

I. Analog switching circuits use field-effect devices

II. FET modules simplify design of complex switching functions

III. FET integrated circuit logic for aerospace

IV. A warning: Space radiation affects MOS transistors

Designing against space radiation: page 61

As space projects increase so do the problems of making circuits safe against radiation. One approach is a special version of ceramic tubes. Part 1 of a 2-part article.

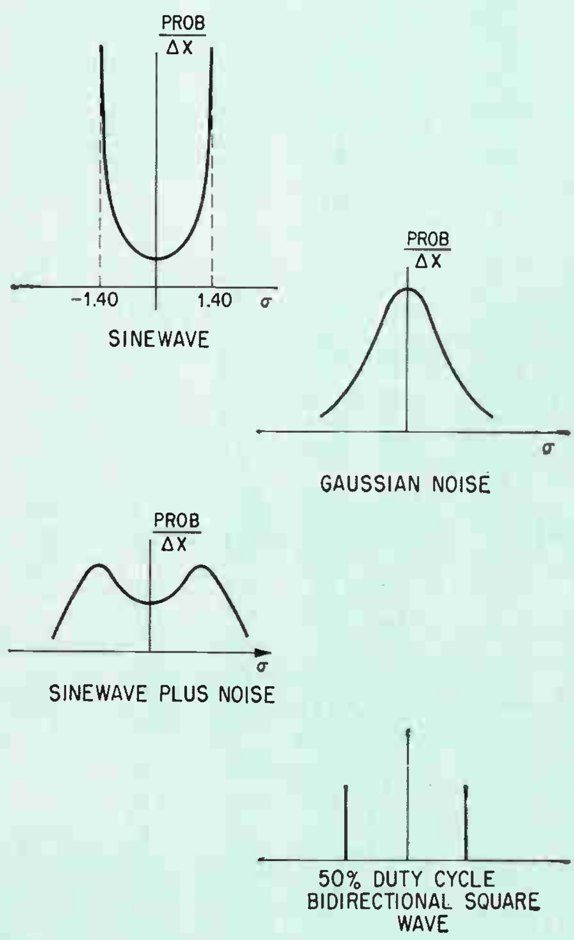
Coming January 11

- **What's ahead in 1965**
  Electronics' annual survey on the outlook for military space industrial and consumer electronics
- **Designing very-low-frequency antennas**
- **More on radiation-proof circuits for space**

A new use for the oscilloscope: measuring signal-to-noise ratio

Measurements with a new technique are as good as the observer's ability to determine the point of peak intensity of a displayed waveform

By J.W. Eberle,
Dept. of Electrical Engineering, The Ohio State University, Columbus



Probability density functions for common waveforms. Knowledge of these characteristics is required to interpret scope presentation.

The most common way of evaluating the quality of a communication channel, or a portion of it, is in terms of the signal-to-noise ratio. But, because of the random nature of noise, it is extremely difficult to make signal-to-noise ratio measurements. At some point in the measurement process a statistical approach, in which a mean or mean-square value is sought, is necessary.

Most laboratory instruments are designed for use with sinusoidal waveforms. The specific instrument used determines the technique for the measurement of noise and the interpretation of the results. This can lead to confusion among engineers when a signal-to-noise measurement is required.

To overcome this, a method has been developed that uses an oscilloscope to measure signal-to-noise ratio. Only a basic understanding of the statistics associated with noise is required to make SNR measurements of reasonable accuracy. The accuracy of the measurement depends on the observer's ability to determine the point of peak intensity of the displayed waveform.

Signal and noise

Signal-to-noise ratio involves two terms that are fundamentally different in character. Noise, which is a random waveform, requires different measurement techniques from those used for the signal, which in many cases is a deterministic type of signal. (Deterministic means that one can determine ahead of time what the waveform will be, as it is periodic.) As a result of this basic difference, the signal-to-noise ratio can be defined in several ways, depending upon how the amounts of signal and noise are rated. Because of the random nature of the noise, its rating or measurement is based usually on the mean-square value of the noise present. The signal can be measured in several ways: peak value, average value, mean square value, etc.

Hence, where signal-to-noise ratio is specified, it must be further clarified, since there is no universal definition of the term. The choice as to how the signal is measured depends upon the particular situation of interest. In many cases, such as in pulse modulation, the value of the peak signal is of primary interest; in other cases, the amount of average or mean square signal might be of more importance.

Ideally, the amount of signal present is measured with noise absent; the amount of noise present is measured with the signal absent. In any receiving system, the noise is easily measured with no signal present; measurement of the signal with noise absent is difficult or impossible. However, the same results are obtained if the signal is measured in the presence of noise, as long as the receiving system is linear. This applies specifically to the mixing stages in the receiver, where the local oscillator injection must be sufficient to insure that the statistics of the noise do not change in passing through the mixers. Since the measurement of signal-plus-noise involves a random waveform, specific instruments like those needed for measuring noise alone must be used to measure the random waveforms.

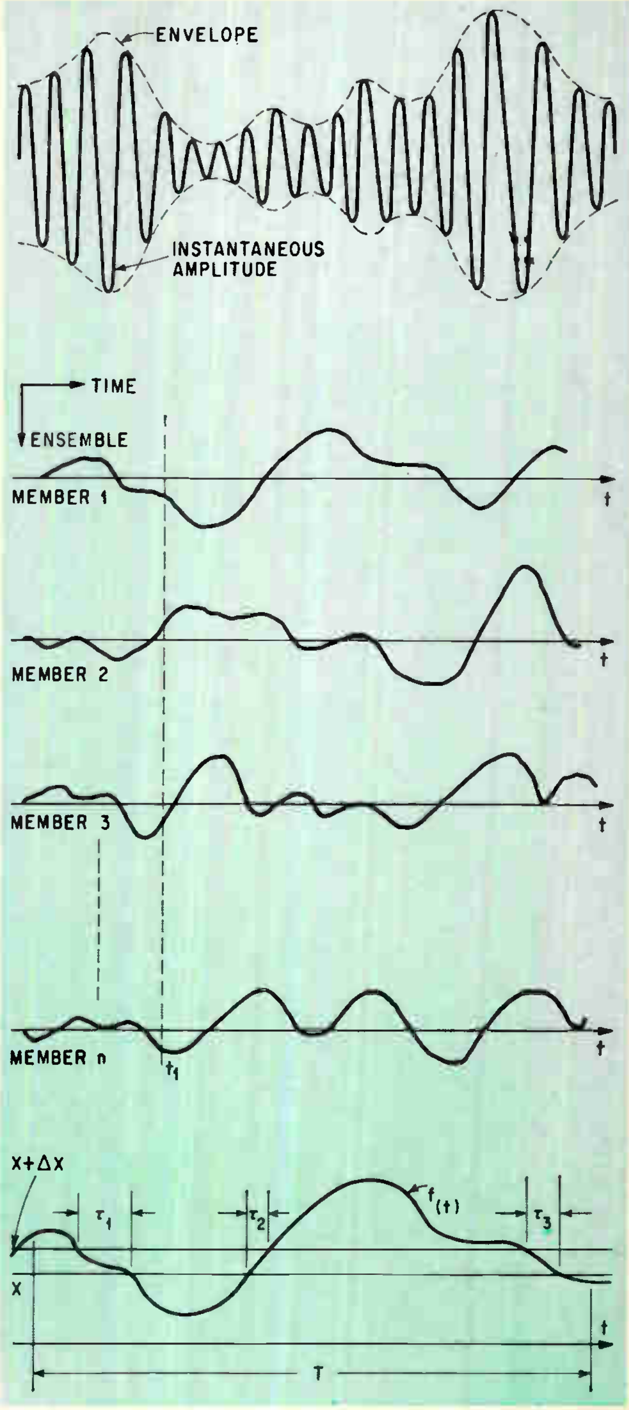
Conventional measuring instruments

The three types of voltmeters designed for the measurement of random-type waveforms can be classified as thermoelectric, true square-law and synthesized square-law meters. The thermoelectric meter, such as the Hewlett-Packard 3400A, uses bolometers, barreters, or thermocouples. When properly biased, a change in resistance of these elements gives an accurate indication of the amount of power in the circuit. True square-law meters use a nonlinear element which follows a square-law characteristic, thus giving a reading proportional to the square of the voltage. Such meters use diode detectors, or utilize the square-law action of other active elements such as field-effect transistors. The synthesized square-law meter performs the operation of a function synthesizer, where a square-law characteristic is formed by the combined action of several nonlinear diodes. In each of these three types of meters, the electronic circuits preceding the metering circuit provide the required squaring action, and the meter movement itself provides the averaging, so that meter deflection is proportional to the mean-square value of the input waveform.

In addition, various types of multiplying circuits are available which form the product between two inputs. These can be used in conjunction with a metering circuit to provide the required square-law function. These circuits, while quite accurate, are limited in frequency to a maximum of 50 kc to 100 kc, while the frequency range of some types of root-mean-square voltmeters goes as high as 1,000 Mc. In most cases, rms voltmeters have an adequate frequency response to permit measurements in the i-f section of a receiver.

Averaging meters

Average-responding meters, which are more available than true rms voltmeters, can be used in the measurement of random-type waveforms, particularly where relative measurements are suitable, if certain precautions are taken. Since the average-responding meter does have a meter deflection proportional to the average of the input waveform, and since there is a fixed ratio between the average value and the rms value for random noise (0.7980),



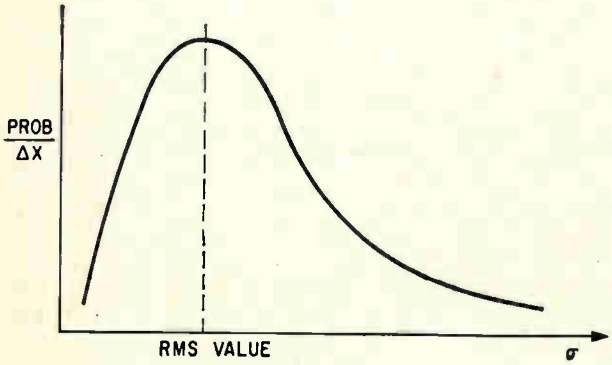
Definitions: noise-modulated carrier (top) demonstrates the different between envelope and instantaneous amplitude; measurements of the random waveforms (center) could be taken from each waveform as a function of time (time statistics) or taken at one instant over the ensemble (ensemble statistics); coordinate system (bottom) for the probability density function.

the average-responding meter deflection is also proportional to the rms value of the waveform. The difference between average-responding and rms voltmeters lies in the allowable crest factor of a waveform they can measure accurately. Crest factor is defined as the ratio of the maximum value of the waveform to the rms value. The amplifier stages for an rms voltmeter are designed to remain linear with an input about 10 times that required to give full scale deflection. The amplifiers for average-responding meters saturate with an input about 1.5 times that required to give full-scale deflection. Since random noise has a high crest factor, it is necessary to keep the meter deflection low when random noise is measured with an average-responding voltmeter. This can be done by using accurate variable attenuators at the meter input.

Random waveform statistics

By applying a knowledge of the statistics of a random waveform to the measurement problem, the engineer can devise other techniques that do not require specialized instruments but still produce accurate measurements. One such technique employs an oscilloscope to measure random noise. This approach depends on understanding the statistics of random noise.

In referring to random noise, or to a modulated waveform, one can speak of the instantaneous amplitude of the waveform or of the envelope of the waveform. The top figure on page 37, which shows a modulated carrier, demonstrates the distinction between the two terms. The waveform in the top figure could be a modulated waveform or narrowband Gaussian noise. The statistics of a random waveform, can be measured in two possible ways; that is, time statistics or ensemble statistics. The center figure on page 37 shows several random waveforms originating from identical but independent processes. The statistics could be measured on one waveform as a function of time, or could be measured at one instant of time over the ensemble. These methods of measurement are referred to as time statistics and ensemble statistics, respectively. When the statistics from these two methods are equal, the process giving rise to the waveforms is called ergodic. Random noise is an ergodic process.



Rayleigh probability density function represents the envelope of Gaussian noise measured at the output of a linear detector.

The important statistics here are known as first probability density functions. Probability is defined as the ratio of the total number of successes to the total number of trials in a given process. The bottom figure on page 37 establishes a coordinate system about a random waveform, f(t). An amplitude window is established, which is Δx wide, and the position of the window is given by the random variable x. The successes in this case are related as the amount of time the waveform resides within the amplitude window Δx, designated in the figure by τ_1, τ_2, etc. Hence probability, or probability distribution, is given by

$$P[(x + \Delta x) > f(t) > x] = \frac{\Sigma\tau(x, \Delta x)}{T} \quad (1)$$

which says that the probability that f(t) is less than $x+\Delta x$ and greater than x is given by the summation of the lengths of time the waveform resides within the amplitude window, divided by the total time of observation, T. This results in a dimensionless number. The probability density function, which is most often used, is given by

$$P\ (x) = \frac{P[(x + \Delta x) > f(t) > x]}{\Delta x} \quad (2)$$

It can be seen that the probability density function is proportional to the length of time the waveform resides at the various amplitude levels. To further illustrate this, several probability density functions are given in the figure on page 36. The functions are based on the amplitude of the waveforms plotted on a time scale. By applying equation 2 to the waveforms, the respective probability density functions are obtained. For example, the density function for the sinewave indicates that the waveform resides at the peak values for the longest period of time, and at zero level for the shortest time. These indications are obvious when a sinewave is considered as a function of time. The density function for random noise is a bell-shaped curve, referred to as the Gaussian or normal curve; hence the name Gaussian noise. This density function occurs whenever a large number of independent random events, each producing small effects, act together on the quantity being measured.

As can be seen from the figure on page 36, the density function for a sinusoid and noise is a combination of both curves taken individually. This curve and that for the noise alone are of particular concern here as they represent the situation of interest, a carrier in noise (signal-plus-noise) and the noise alone. When these two waveforms are displayed on a properly triggered oscilloscope the display will be that of the envelope of the waveform, and the probability density function of the envelope is needed to properly interpret the oscilloscope presentation.

The probability density function of the envelope of Gaussian noise (as measured at the output of a

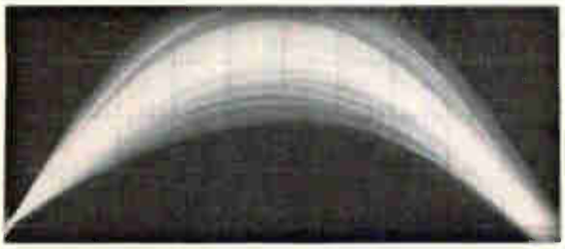
Measuring signal-to-noise ratio of a 455-kc signal

A NOISE ALONE
10 mV/CM

B SNR = 1.5
10 mV/CM

C SNR = 2.5
10 mV/CM

D SNR = 4.7
10 mV/CM

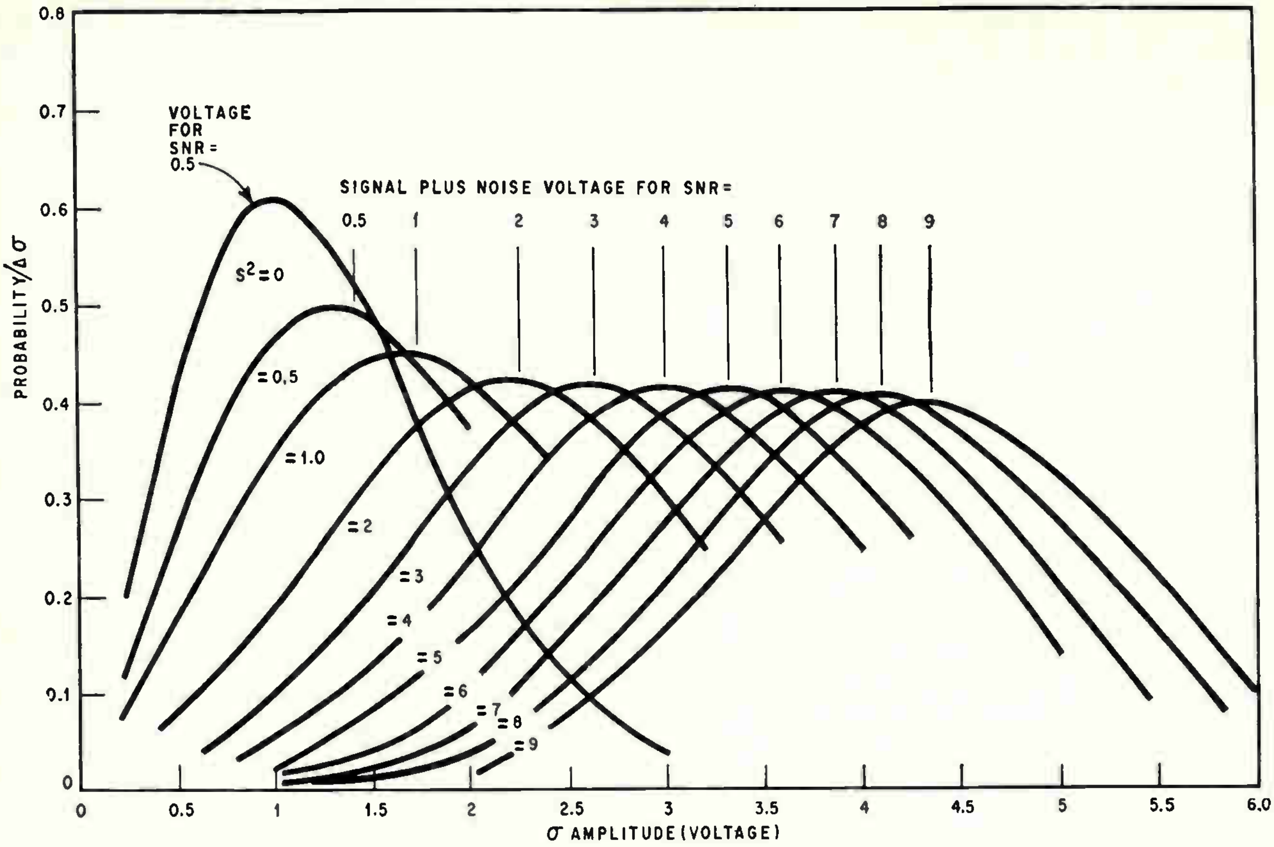


E SNR = 5.7
10 mV/CM

F SNR = 10.2
20 mV/CM

Oscilloscope display of noise and signal-plus-noise. Varying intensity in the cross-section through the peak represents the probability density function of the waveform envelope.

G SNR = 30
50 mV/CM



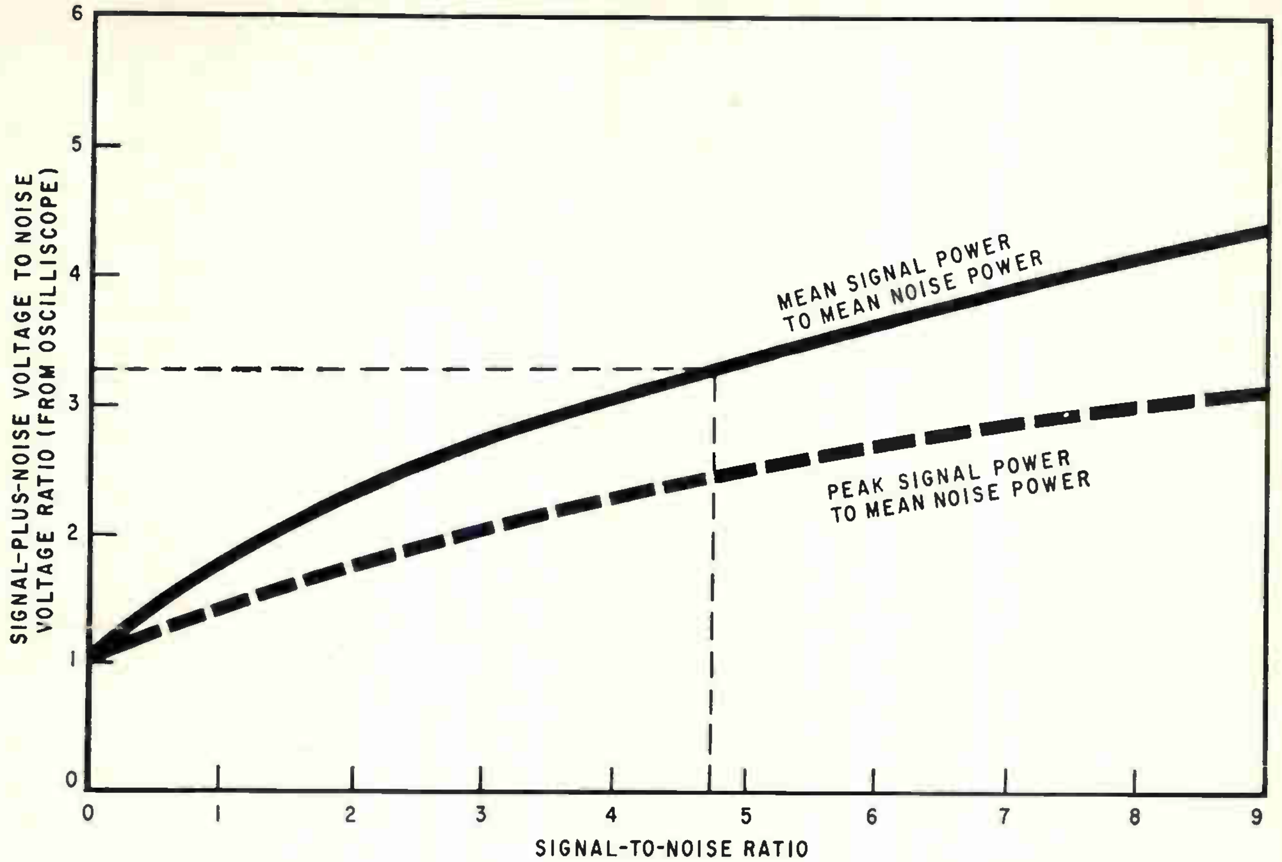
Probability density plotted against rms amplitude of sinusoidal signal plus Gaussian noise, for various signal-to-noise ratios. At low values of SNR, curve has Rayleigh shape; at higher values it becomes Gaussian.

linear envelope detector) is shown in the figure on page 38. This is known as a Rayleigh curve. Its peak represents the rms value of the waveform on the amplitude scale. The probability density function of the envelope of a sinusoid plus noise is shown in the figure above as a function of the sinusoid-to-noise ratio (SNR). For low values of the SNR, the curve has the Rayleigh shape resembling that for noise alone; for high values of the SNR, the curve becomes symmetrical about its peak value and, in fact, approaches a Gaussian curve in the limit.

Using an oscilloscope

When band-limited Gaussian noise or a sinusoid-plus-noise is displayed on an oscilloscope, and the oscilloscope sweep is triggered by the signal itself, the waveform has the appearance of a sinusoid with a frequency equal to the center frequency of the band-limiting filter (the i-f strip itself) or of the sinusoid, respectively. Oscilloscope displays of a 455-kc signal of this type are given in the figure on page 39. When the oscilloscope is adjusted so that one cycle of the waveform is displayed, the presentation consists of a number of in-phase sinusoids, each of different amplitude. This can be seen in the photographs. These sinusoids are a superposition of the individual cycles of the carrier frequency of the waveform in the top figure on page 37. Because of the triggering action of the oscilloscope, the scope trace can sweep across the oscilloscope tube at the beginning of each cycle of the carrier frequency. Thus the scope presentation consists of the superposition of an ensemble of waveforms chosen on a cycle-by-cycle basis from the time waveform, (the waveform that exists in time at the output of the i-f strip, as plotted on a chart recorder). By close examination of the oscilloscope waveforms, it can be seen that there is a varying intensity in the cross-section of the waveform taken through its peak. That is, near the base line, the population of sinusoids is small, the population increasing with increasing amplitude and then decreasing with further increases in amplitude. This intensity or sinusoid population profile through the peak of the waveform is precisely the probability density function of the envelope of the waveform. For the case of noise alone, the intensity profile has the Rayleigh shape, with the point of peak intensity corresponding with the rms value of the noise. Thus by calibrating the vertical scale of the oscilloscope, a fairly accurate measure of the noise may be obtained.

The case for a sinusoid-plus-noise is analogous to that for the noise alone, except that the intensity profile is now the probability density function of a sinusoid-plus-noise, as given by the figure above. The point of peak intensity now depends upon the signal-to-noise ratio and is, in fact, the sum of the peak signal voltage and the noise volt-



Graph for computing signal-to-noise ratio, given the ratio of the signal-to-noise voltage to the noise voltage.

age. Since the sinusoid and noise voltages are uncorrelated, the voltage at the point of peak intensity is the square root of the sum of the squares of the peak sinusoid voltage and the rms noise voltage, as given by

$$V = \sqrt{S^2 + N^2} \qquad (3)$$

where V is the voltage at the point of peak intensity, S is the square of the peak signal voltage and N is the rms noise voltage. Thus by noting the voltage at the point of peak intensity as measured with signal-plus-noise, and knowing the noise voltage as measured with the signal absent, one can solve for the signal alone. Solving directly for S will yield the peak signal voltage and from this, the rms signal voltage can be solved for. Hence the signal-to-noise ratio can be found on either a peak or rms signal basis.

One example will illustrate this procedure. Refer to A in the figure on page 39, which shows the noise alone, and to D which shows carrier-plus-noise. The point of peak intensity in A is at 9 millivolts, which is the rms value of the noise alone. The point of peak intensity in D is at 29 mv, which represents the sum of the peak signal voltage and the rms noise voltage. Since the two voltages are uncorrelated, the sum is given by equation 3. Solving this equation for S, knowing V (= 29 mv) and N (= 9 mv), gives a value of S = 27.5 mv, which is the peak value of the signal. From this, the rms value of the signal is 19.5 mv. Thus the ratio of mean signal power to mean noise power is $(19.5/9)^2 = 4.7$. This computation can be reduced to a graphical procedure by using the figure above. This graph is entered with the ratio of the signal-plus-noise voltage to the noise voltage and yields the ratio of mean signal power to mean noise power. The dashed-line curve on the graph will yield the ratio of peak signal power to mean noise power by entering the graph with the same ratio as above; that is, the signal-plus-noise voltage to the noise voltage as measured from the oscilloscope presentation. For the example given, this ratio is off the graph, at 9.4.

Acknowledgment

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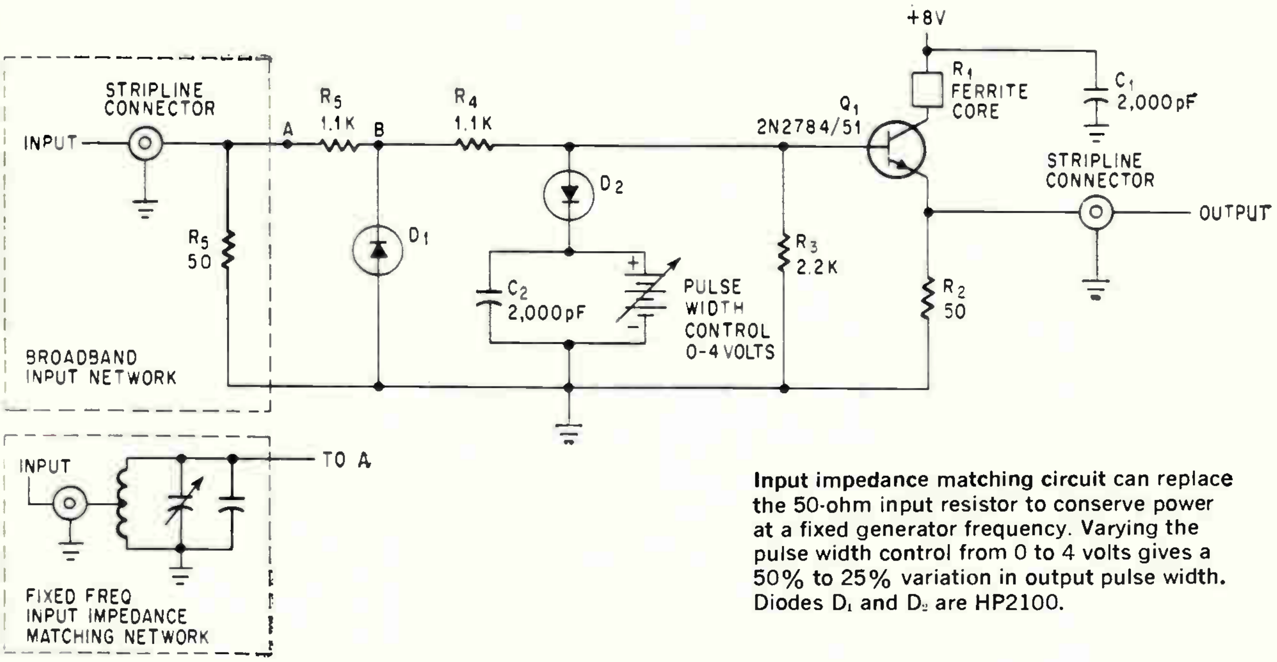
The author

Jon W. Eberle received all three of his degrees, including a Ph.D., at The Ohio State University. As assistant supervisor of the antenna laboratory, he has been working with phased arrays for satellite communications, using Echo passive satellites.

Circuit design

Designer's casebook

Designer's casebook is a regular feature in Electronics. Readers are invited to submit novel circuit ideas, packaging schemes, or other unusual solutions to design problems. Descriptions should be short. We'll pay $50 for each item published.



Input impedance matching circuit can replace the 50-ohm input resistor to conserve power at a fixed generator frequency. Varying the pulse width control from 0 to 4 volts gives a 50% to 25% variation in output pulse width. Diodes D_1 and D_2 are HP2100.

100-Mc pulse generator provides 50% duty cycle

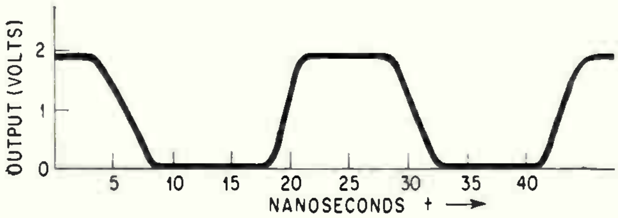
By William T. Rhoades

Hughes Aircraft Co., Fullerton, Calif.

Most commercial pulse generators are capable of only 5% duty cycle (ratio of pulse width to interval between pulses) at high repetition rates. Nearly 50% duty cycle can be obtained with the circuit shown because the input shaping network is simple, and consists of fast-recovery type diodes. The circuit uses transistors and is operated with low power dissipation. The maximum available output voltage swing is one-fourth as large as that available in most commercial pulse generators (peak-to-peak output voltage is 5 volts instead of 20 volts).

The output waveshape is completely free of ringing and has a typical rise time of 1.5 nanoseconds and a fall time of 3.5 nanoseconds (measured between 10% and 90% of peak amplitude of the waveshape leading and trailing edges). Voltage spikes have been eliminated at the end of each pulse with fast-recovery diodes and by operating the output transistor in the nonsaturated mode.

The generator input is a sine wave that determines the amplitude and frequency of the output pulse. The variable d-c source controls the width and also the amplitude of the output pulse. The usual procedure is to adjust the generator input and then adjust the variable pulse width control,



Output pulse shape shown for 50-megacycle sine wave input. Typical rise time at output pulse is 1.5 nanoseconds. Fall time is typically 3.5 nanoseconds.

repeating in that order until the desired output amplitude and pulse width are obtained.

Note that although the input and output impedance levels are 50 ohms, terminating the output in a purely capacitive load of 500 picofarads does not affect the rise and fall time adversely.

Point B of the circuit must not exceed +15 volts (the reverse breakdown voltage rating of diode D_1). For square-wave operation, this limitation typically results in a maximum output voltage amplitude of about 4 volts. The maximum amplitude can be increased but the pulse shape deteriorates. An inverting transformer would be necessary at the output to obtain a negative pulse.

For fixed frequency applications, power can be conserved by replacing the 50-ohm resistor (R_5) with an impedance-matching network as the input termination. The component values in the impedance-matching network depend on the fixed input frequency. In this network, a 15-turn coil that is tapped 3¾ turns from its ground side, gives a 20:1 step-up in voltage from input to output. A snap-off diode circuit added to the output will produce narrower pulses, if required.

R_1 is a ferrite core used as an r-f resistor. Its purpose is to suppress ringing in the output circuit.

Electronically controlling auto's engine spark

By A.R. Hayes

Royal College of Advanced Technology, Salford, England

The ignition-advance system in an automobile controls the time at which the spark occurs in a cylinder in relation to the position of the piston. The timing of the spark is a function of engine speed. Automatic ignition advance is usually controlled by a mechanical system of rotating weights and aneroid capsules incorporated in the engine design. An electronic method of automatic spark advance would be simpler and more reliable and would perform better.

With the exception of the spark-distribution system, it is possible to build a completely electronic automobile ignition system, including spark generation and automatic advance.

The block diagram above shows that ignition timing is controlled by engine speed. Trigger inputs A and B shown in the illustration are obtained from inductive pickups on the engine crankshaft. A trigger at either A or B generates a spark. Trigger A occurs at a fixed crankshaft angle that is greater than any ignition advance required by the engine. The crankshaft angle is related to the topmost position of each piston during its stroke (generally referred to as BTDC—before top dead center).

Trigger B occurs at the lowest advance angle required by the engine (engine turnover). The ignition system is designed to operate in either of two modes—at normal running speeds or at start and idle speeds.

At running speeds, input A triggers the delay circuit whose output generates a spark. The delay is controlled by the spark repetition rate which is a

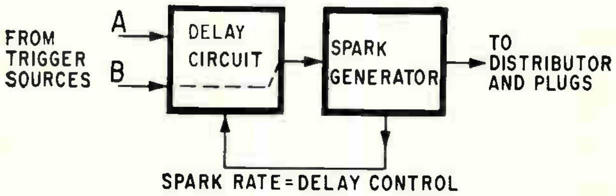
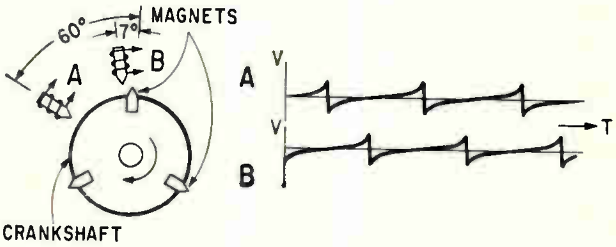
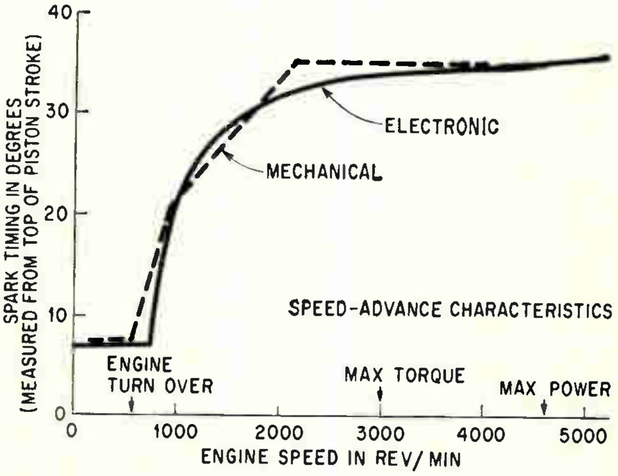


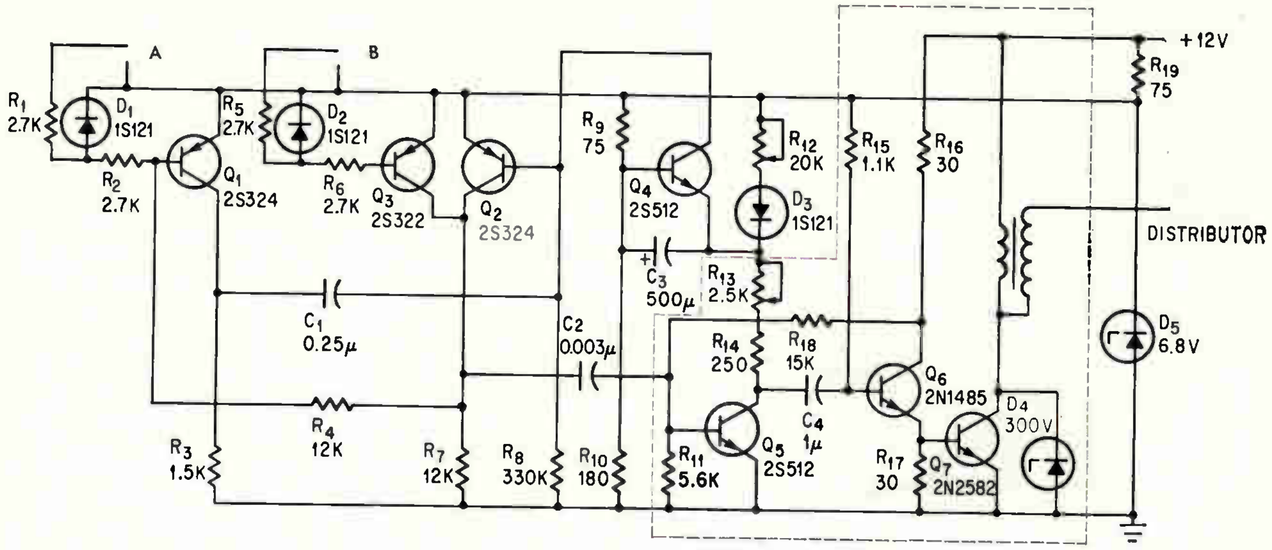
Diagram of electronic system for controlling spark repetition rate in an automobile. System is superior to mechanical technique.



First step in controlling ignition firing time. Equally spaced magnets on crankshaft rotating at engine speed, induce voltage in trigger coils A and B.



Electronic ignition advance is better than mechanical ignition advance. Curve shows that the electronic system advances more smoothly than mechanical systems.



Automatic advance transistor ignition circuit. The circuit contained within the dashed lines is similar to the commercially available Delcotronic. Ignition advance response time is dependent on the value of C_3 and the spark rate.

direct function of engine speed.

At start, input A again triggers the delay circuit, but in this mode the delay is terminated by input B, which triggers the spark generator and resets the delay circuit.

In the automatic advance transistor ignition circuit shown above, each input trigger occurs three times per revolution due to the rotating magnets fixed 120° apart at one end of the engine crankshaft.

Transistors Q_1 and Q_2 are a monostable pair in the delay circuit; the delay is controlled by the value of capacitor C_1 and the collector current of Q_4. The delay begins with input trigger voltage A turning on Q_1, and ends with either the discharge of C_1 or input trigger voltage B turning on Q_3, whichever occurs first.

The circuit contained within the dashed lines (Q_5, Q_6, and Q_7 and associated components) is similar to a basic Delcotronic spark generator. Q_5 and Q_6 form a monostable multivibrator in which Q_5 is normally off and Q_6 is normally on, supplying current to the ignition coil through the amplifier Q_7. A positive trigger from the collector of Q_2 to the base of Q_5 causes Q_5 to conduct for a period determined by the R_{15} C_4 time constant. While Q_5 conducts, the ignition coil current decreases to zero. The voltage supply to Q_5 is held constant by the zener regulator D_5 and Q_5 is fully saturated when it conducts—therefore, the average collector current of Q_5 is a function of the triggering rate, which is directly proportional to the engine speed. After smoothing by C_3, part of the Q_5 collector current passes through Q_4 to the delay circuit, and an approximately constant amount of current leaks away through D_3 and R_{12}.

Circuit component values are chosen to insure saturated mode operation of the switching circuits and to enable fast recovery of timing capacitors.

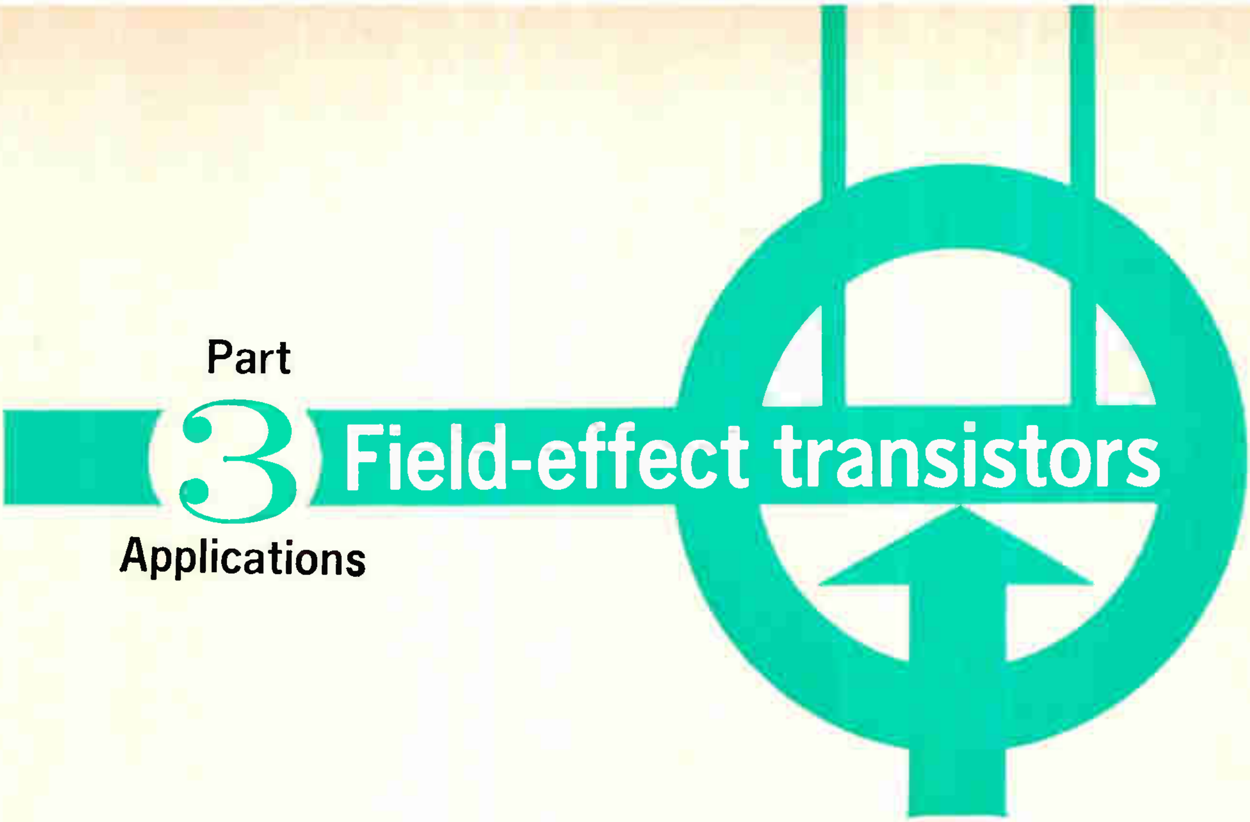
The speed-advance performance is controlled by resistors R_{12} and R_{13}. Resistor R_{12} is adjusted at low engine speed and R_{13} is adjusted at high engine speed, alternately, until the required delay is obtained at each speed. (1,000 and 4,000 revolutions per minute are suitable speeds.)

The speed-advance performance of a mechanical system and this electronic advance system are compared on the graph (p. 43). The electronic system performance is approximately the same as the mechanical system, but the ignition advance is continuously variable with engine speed.

Variations in the 12-volt supply caused negligible effects on the timing due to the zener regulator D_5. Temperature variation from 0°C to 70°C caused advance variations of less than one degree at high engine speed and less than three degrees at low engine speed.

The response time of ignition advance to change in speed is dependent on the value of C_3 and on the spark rate. With $C_3 = 500\ \mu f$, a change in speed from 1,000 to 2,000 rpm, gives a response time of less than 1 second. Higher speed changes give a time response much less than 1 second. This lag in response is not of importance in most engines. It has the effect of retardation while accelerating, and advance while decelerating, but in either case its effect is negligible.

This unit was designed for a particular six-cylinder engine, but the basic circuit is suitable for any engine having an even number of cylinders.



Analog switching circuits use field-effect devices

Transformerless circuitry with junction FET's simplifies design, offers flexibility and high-speed delivery of accurate signals

By Mark Shipley Sr.
Siliconix, Inc., Sunnyvale, Calif.

When the field-effect transistor first appeared five to seven years ago, engineers used it mostly in linear amplifiers. Since then, the device has been improved technically so it also works well in analog switching applications. By early 1964, these improvements had opened a new area for the FET.

One big advantage in such applications is that the FET eliminates the transformer drive that is usually required for analog gate circuits that use conventional chopper transistors.

There are also other benefits. Since FET circuitry does not have input-output offset voltage, transmission at the microvolt-signal level is possible. Because FETs are compatible with integrated-circuit techniques, switches can be made much smaller. An engineer can use discrete components or build a fully integrated switch, or any combination of these. Finally, small shifts in the FET's characteristics are not critical; therefore the switch has long-term stability.

Analog switches are used in all modern data-handling systems in multiplexer, sample-and-hold, modulator, and chopper circuits, and in analog-to-digital converters and analog computers. The analog switch either transmits a signal without distortion or completely blocks it. A digital switch, on the other hand, transmits only the state of the input signal (the sense of on or off).

The use of transformerless circuitry for most analog switching applications by employing field-effect transistors simplifies circuit design and gives the designer considerable flexibility. The circuits discussed in this article use recently developed junction FETs. Still, even the latest junction FETs, developed specifically for switching, cannot provide the low on resistances obtainable with dual-emitter chopper transistors.

It is only with the recently marketed large-geometry devices with high pinchoff-voltage that drain-to-source resistances below 100 ohms are being obtained (with associated gate-to-drain capacitance less than six picofarads). By comparison, some chopper transistors provide on resistances of 10 to 20 ohms with an equivalent capacitance value. However, most circuits work as well with the higher impedance values typical of FET's. Moreover, the FET circuit is highly flexible and capable of high-speed delivery of an accurate signal.

Equivalent circuits

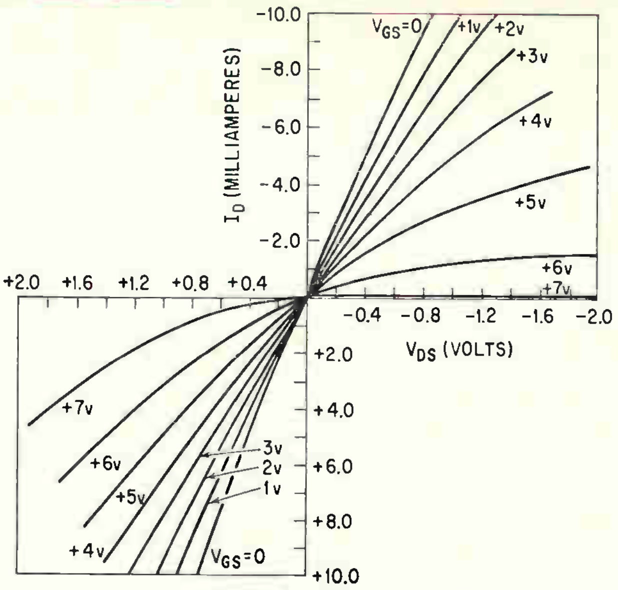
The output characteristic curves at low values of drain current I_D for a conventional p-channel FET are shown at right. When the gate-to-source voltage $V_{GS} = 0$, maximum channel conduction occurs; for large positive values of V_{GS}, the channel is completely depleted of carriers and therefore has zero conductance.

A simple on-condition equivalent circuit with no externally applied voltage is shown at right. The switch, therefore, has no offset and may be represented as a passive resistor from source to drain. The off-condition equivalent circuit shown at right indicates that if the gate voltage is positive with respect to both source and drain by a voltage greater than pinch-off voltage V_P, the ohmic connection between source and drain is opened and the only d-c imperfection in the switch is the diode reverse current from gate to source and gate to drain. The rest of the FET characteristics for voltages from $V_{GS} = 0$ to $V_{GS} = V_P$ can be described by the small-signal resistance r_{ds} between source and drain for zero V_{DS} volts.

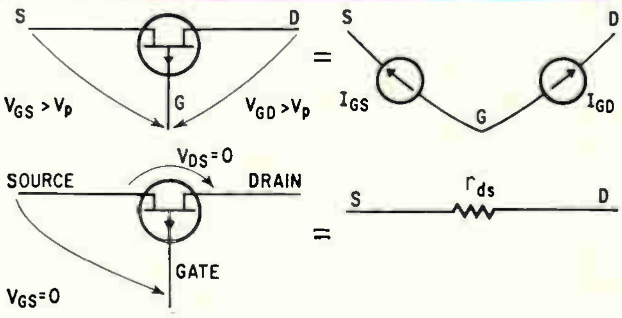
Drive circuits

The series switch shown on p. 47 forms the basis for a discussion of analog-gate circuits in a typical commutator configuration. The source is connected to an input signal and the drain to an output bus. The applied voltages are shown on p. 47. The input voltage has a range from zero to $E_{in(max)}$; the output voltage is equal to E_{in} when the switch is on, and the gate voltage is switched from a large positive value to the fixed level $E_{in(max)}$. For $E_{in} = E_{in(max)}$ no reverse bias exists on the FET. For $E_{in} = 0$ the bias is $V_{GS} = E_{in(max)}$ hence V_P must be large enough to keep the FET in conduction. The value of $E_{in(max)}$ is ½ V_P and there is a 2:1 variation in r_{ds}. The switch is turned off by $V_{GS} = E_{in(max)} + V_P + 2$ volts. The reason for adding 2 volts in arriving at a turn-off voltage is discussed later.

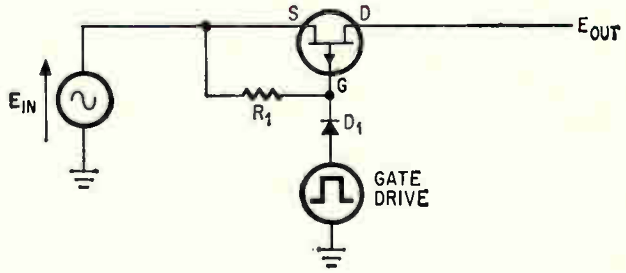
Rapid switching speeds are obtainable with this circuit since the gate may be driven directly from a fast, low-impedance switch. Fixed-gate-voltage levels may be used in many other switching circuits; for example, the drain may be connected to

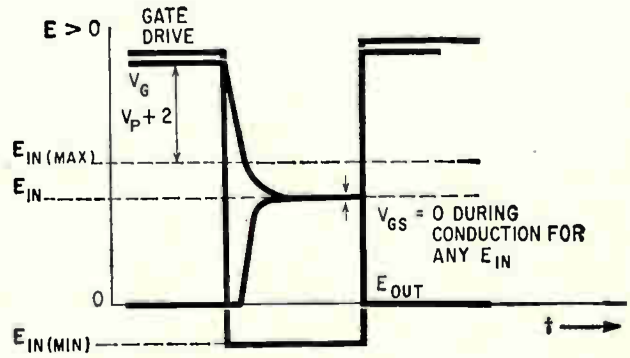


Low-level output characteristic for the 2N3386, a p-channel junction FET. Drain current is plotted for various positive gate-to-source volts.



On and off equivalent circuits. In the on condition, there is no offset voltage and the switch may be represented as a resistor.





This circuit provides a zero gate-to-source voltage for any input signal. Positive gate (see waveform) turns the switch off.

the summing junction or an operational amplifier, hence the gate drive could be exactly zero for the on condition.

A circuit that provides $V_{GS} = 0$ for any input signal is shown on p. 46. Waveforms are also shown. When the gate drive voltage is negative, diode D_1 is reverse-biased and the gate is allowed to assume the same voltage as the source; thus r_{ds} is always at the minimum possible value. Application of positive gate drive turns the switch off. The speed of the gate circuit depends on the resistor R_1 and a compromise must be made between fast gate turn-on and the amount of current fed back to the input from R_1 when the switch is off. In many cases, this simple circuit arrangement is entirely suitable, illustrating how a FET can provide dependable switching without complex gate-drive circuitry. In addition, there is no limitation on duty cycle (extremely low-frequency operation is possible).

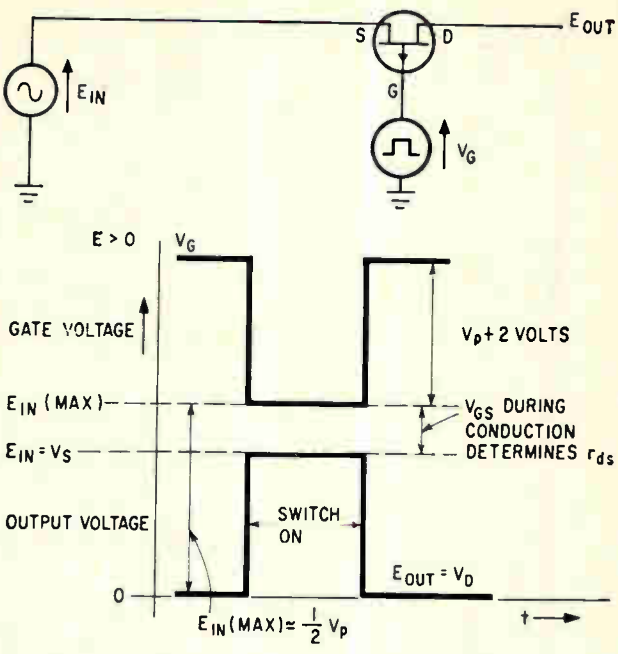
The circuit shown at right uses a coupling capacitor to turn the gate on. The value of the capacitor depends on the number of interconnected gates and the magnitude of the drive signal. This circuit is well suited for systems with fixed sampling rates and a zero clamp between samples. It can be modified easily by changing the size of the capacitor or the magnitude of the drive voltage. Components may be added to protect against overloading.

Direct-coupled switch

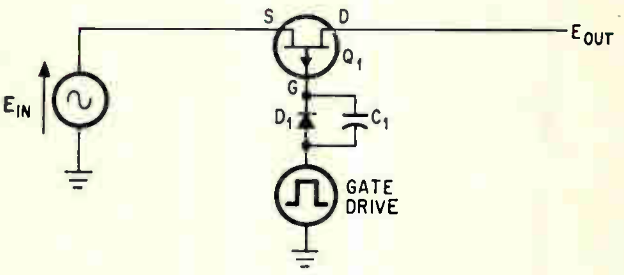
A direct-coupled switch circuit is shown at right. Q_2 replaces the previously discussed turn-on resistor for Q_1. Transistor Q_2 prevents excess current from being injected into the signal path. The drive voltage on the gate of Q_2 is sufficiently positive to hold Q_2 off and the gate of Q_1 is held positive enough to keep Q_1 off. There are two reverse-current components that flow back into the signal source from the gate-source junction of Q_1 and Q_2. Only the gate-drain reverse current of Q_1 flows into the output signal bus. When the drive voltage is negative, diodes D_1 and D_2 are reverse biased, V_{GS} of Q_2 becomes zero; hence Q_2 has a low value of r_{ds}. Transistor Q_1 is turned on by Q_2. The on channel is isolated from the driving circuitry by the two diodes D_1 and D_2. Both speed and power dissipation when the circuit is off are determined by R_1.

Transistors Q_1 and Q_2 are not necessarily the same devices. For example, Q_1 may have a higher pinch-off voltage than Q_2. A gate drive larger than the sum of V_{P1} and V_{P2} is required. This circuit can be used in integrated form to provide a high-quality switch controlled by one noncritical voltage drive. Assuming that the resistor R_1 is in the 10,000-to-30,000-ohm range, such a switch would have submicrosecond speed and a 1- to 10-milliwatt dissipation when off. Two such switches operated from one voltage drive would provide a differential channel. A differential channel has two input lines with an analog switch in each. The desired signal is the difference between the two signals.

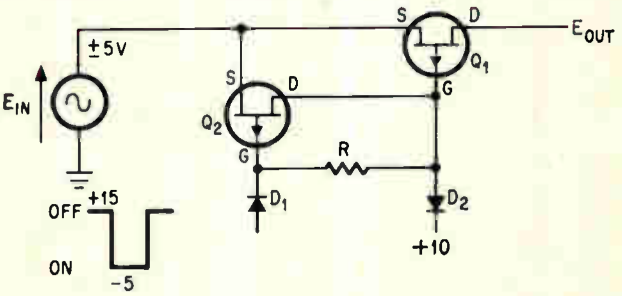
An alternate version of this switch is possible. In it two field-effect transistors are in series, with



Simple series FET switching circuit and associated waveforms. The input signal is supplied to the source. The output signal is delivered to the bus bar.



Capacitance-coupled series switch is used for systems with fixed sampling rates.



Instead of a turn-on resistor, this circuit employs another field-effect transistor, Q_2. Transistor Q_2 prevents excess current from being injected into the signal path.

D_1, D_2 and R_1 connected to turn both off together. Isolation from drive voltage is achieved at the cost of twice the on resistance in the signal path. However this alternate version works on a lower drive voltage, has lower power dissipation and is readily compatible with integrated circuit techniques.

Another circuit is shown on p. 48. It has a unity-gain buffer amplifier to absorb the turn-on current through R_1, thus providing zero V_{GS} for the on channel and complete isolation of all channels from the gate-driving voltage. Low power dissipation in the off channels can be traded for speed of response. The output signal is available either before (for very accurate signal amplification) or after the buffer amplifier, making the amplifier design flexible.

A low-dissipation version of the previous circuit in which the turn-on resistor R_1 is replaced by a bipolar transistor switch is shown at right. Saturation voltage or cut-off currents of the bipolar transistor switch do not affect signal quality in the FET portion. The circuit uses a two-phase driving voltage for each channel. An alternative method would be to return the gate of the FET to a positive voltage through a large resistor and then let the bipolar transistor pull the gate down to the proper voltage. If this method were used, only a single-phase drive voltage would be required with slightly more power dissipation in the on channel. The FET switch-buffer amplifier circuit configuration offers the widest variety of interconnections available for FET switches.

Commutator circuit

A look at a typical commutator circuit will show which FET parameters are important and how a field-effect transistor should be selected for optimum switching performance.

A commutator with N number of channels using an FET switch-buffer amplifier configuration is shown at right. The pertinent FET parameters are r_{ds}, V_P, $I_{D(OFF)}$, and C_{dgs}. The circuit condition for the commutator with channel 1 on and the rest of the channels off is shown at right. Including the signal source resistance R_s, the transmission ratio of the on channel is

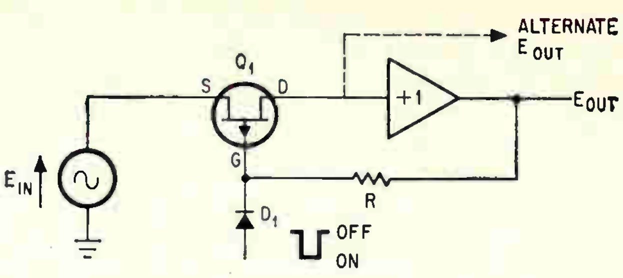
$$TR = \frac{R_{in}}{R_{in} + R_s + r_{ds}} \qquad (1)$$

Thus, $R_s + r_{ds}$ must be small compared with the amplifier R_{in}. When $E_{in} = 0$, there is an output offset voltage generated by the sum of reverse currents from all off switches.

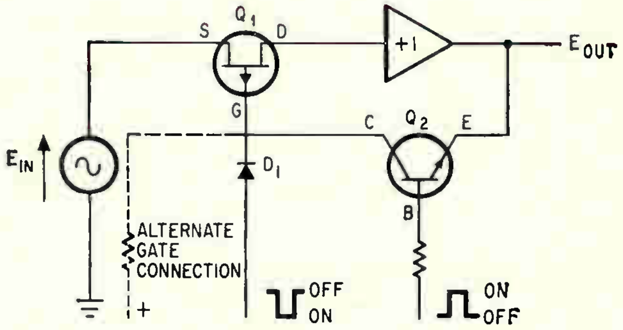
$$E_{out} = (N - 1)(I_{D(OFF)})(R_s + r_{ds}) \qquad (2)$$

The value of $I_{D(OFF)}$ varies as the square root of the applied gate voltage and doubles approximately every 11°C. For a given group of FETs, $I_{D(OFF)}$ should vary no more than 4:1 below the maximum specified. This means that the error voltage in equation 2 will have roughly the same average value for all channels. The $I_{D(OFF)}$ maximum specification guarantees both maximum off channel conductance and reverse current from gate to drain. Off channel conductance for a good switching FET should be far less than the reverse current.

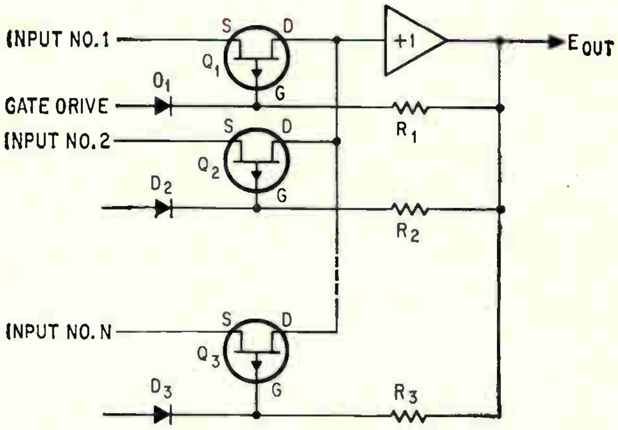
The pinch-off voltage V_P determines the gate voltage in excess of maximum signal voltage necessary to turn a channel off. In low-level applications



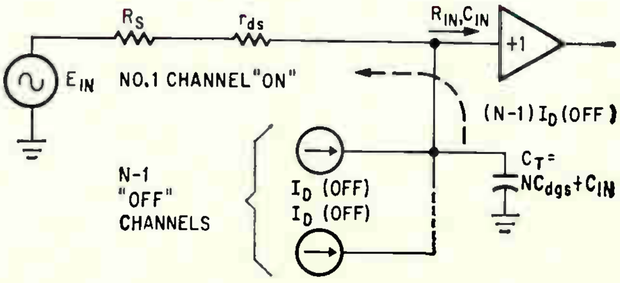
Series switch with a buffer amplifier. The unity-gain buffer amplifier provides complete isolation between the channels and the gate-driving voltage. As indicated by the alternate connection shown, the output signal may be taken at a point before the buffer amplifier as well as after it.



An alternate version of the series switch with a buffer amplifier. A bipolar transistor, Q_2 is used instead of a turn-on resistor in this circuit.



Typical commutator cricuit uses the FET switch configuration with a buffer amplifier.



Commutator network with the first channel on and the remaining channels off.

input signals of 50 millivolts or less are typical, where allowance for common-mode voltages of 5 to 10 volts is usually made.

Commutating speed is determined by the on resistance of one channel, $r_{ds} + R_s$, and the total capacitance C_T on the output bus. Capacitance C_{dgs} is defined as the capacitance of each FET drain with respect to ground for specified source and gate voltages. Thus, including the amplifier input capacitance,

$$C_T = N \cdot C_{dgs} + C_{in} \quad (3)$$

The commutated signal therefore changes levels with a time constant of τ (if it is assumed that the gate drive voltage changes state much faster).

$$\tau = (r_{ds} + R_s)(N \cdot C_{dgs} + C_{in}) \quad (4)$$

It should be noted that the transients coupled from the gate-drive voltage decay with the same time constant.

These problems of system offset, current feedback into the on signal source, and speed are common with all solid-state switches and are usually solved by breaking a large system into smaller groups and subcommutating.

Parameters for analog gates

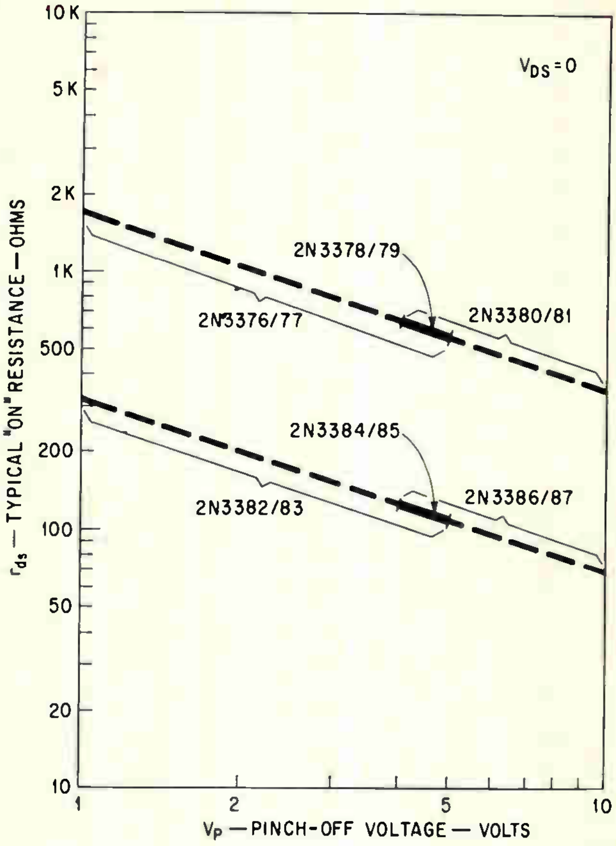
The dimensions of the conducting channel are expressed as the length, L, between source and drain contacts, the width, W, of the channel, and the channel thickness, T, measured into the silicon wafer. For a given FET geometry, T is controlled by the diffusion process, while L and W are controlled by photographic masks and are quite constant. Once L and W are determined, all reverse current and capacitance parameters are fixed. A smaller value of L is desirable to achieve lower r_{ds} values. The two series of devices (2N3376 and 2N3382) in this discussion have equally small L dimensions but different W dimensions. Variable channel thickness results in a range of r_{ds} and V_P. The FET physical mechanism causes these two parameters to be related: r_{ds} varies inversely as the 0.7th power of V_P, i.e., for a thin channel, a high r_{ds} and a low V_P result. As the channel is made thicker, r_{ds} decreases and V_P increases. This relationship is shown at the right, above.

The channel resistance r_{ds} has a temperature coefficient of +0.7% per °C. The channel conductance varies linearly with applied gate voltage V_{GS}. Thus,

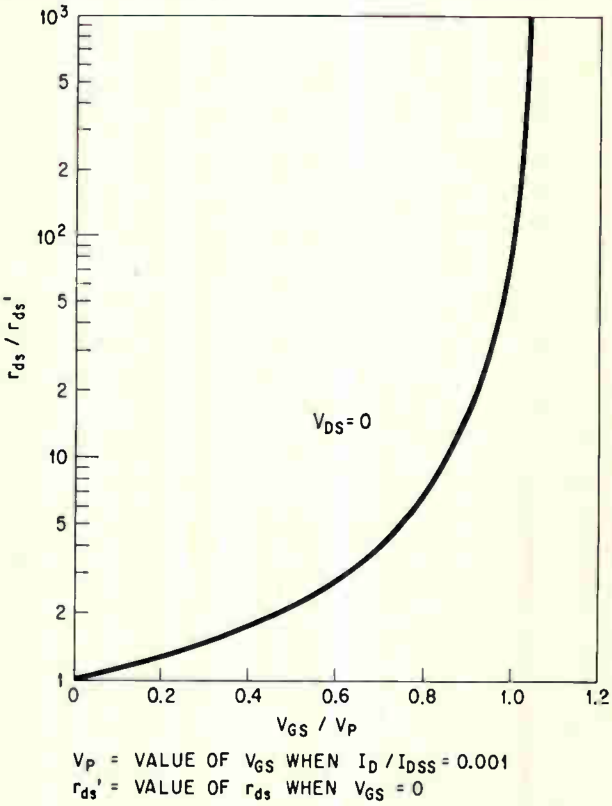
$$r_{ds} = r'_{ds} \Big/ \left(1 - \frac{V_{GS}}{V_P}\right) \quad (5)$$

where r'_{ds} = the value of r_{ds} when $V_{GS} = 0$. This relation is most useful for small values of V_{GS} in the vicinity of zero even where the gate-channel diode is slightly forward-biased. A normalized graph is shown at right.

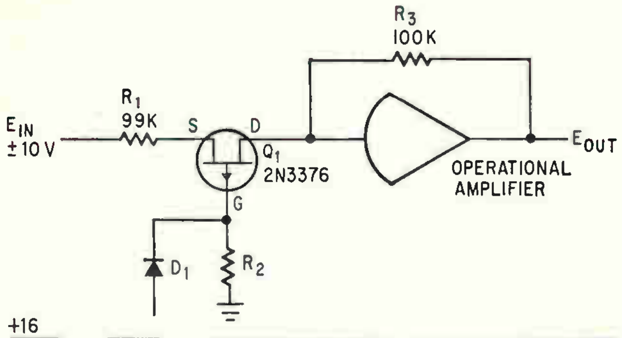
Capacitance in the FET analog-gate results from the package, the internal contact areas, and the gate-channel diode. Only the gate-channel diode



Relationship of pinch-off voltage to on resistance for various junction FETs.



Effect of gate voltage on the on resistance with a drain-to-source voltage of zero volts.



SWITCHING SPEED	R_1 VALUE
<1 MICROSEC.	10,000 OHMS
10 MICROSEC.	1.0 MEGOHM

Analog gate circuit uses a 2N3376 junction FET. This transistor has a V_P of 2 volts, an r_{ds} of 1000 ohms and an $I_{D(off)}$ of less than 0.4 nanoamperes. Output of gate is −10.0025 volts for an input of +10 volts and +9.9975 volts for an input of −10 volts.

capacitance is sensitive to voltage and temperature. For the two FET types under discussion, C_{dgs} at $V_{GS} = +10$ volts and $V_{DS} = 0$ is 3 and 6 picofarads respectively, and the total charge in the channel is 32 and 145 picocoulombs for $V_{GS} = +10$ volts. That is, if both source and drain are grounded and if the gate makes an excursion from 0 to +10 volts, then the current spike in either source or drain carries half this charge. In a practical circuit, the external capacitance affects the switching spike coupled from the gate since it is usually much larger than the gate-to-drain capacitance.

The circuit shown at left is a typical FET analog gate. The FET is connected directly to the summing junction of an operational amplifier used to effectively switch the input resistor R_2 in or out. This circuit is typical of analog-to-digital converter applications. The gate drive is either 0 or +16 volts. When the signal voltage E_{in} is +10 volts, the positive gate drive makes $V_{GS} = +6$ volts, which is sufficient to cut off all devices with

Field-effect transistors

How modules make complex design simple

4 basic switches offer flexibility

By John Gulbenk and Thomas F. Prosser*

Amelco Semiconductor division of Teledyne, Inc.
Mountain View, Calif.

In chopper and telemetry multiplex applications, there is a need for switching circuits that can handle a wide range of signals of either polarity without distortion. This is accomplished by using analog switches. When very complex multipole switching circuits are required, the design is simplified by analog switch modules as building blocks, using field-effect transistors.

A basic FET analog switch is a three-port device consisting of input, output and control terminal pairs. A typical analog switch module used as an electronic commutator is shown on page 51. The module includes an n-channel FET, a pnp junction transistor, and a junction diode.

Basic switch circuit

In the circuit, Q_1 is the analog switch transistor and Q_2 is a pnp transistor that controls the on or off state of Q_1. During the on condition, the current that flows from V_{IN} to the load resistor is:

$$I_{IN} = V_{IN}/(R_g + R_{ON} + R_L) \quad (1)$$

where V_{IN} = signal voltage
R_g = Resistance of signal source
R_{ON} = FET source-to-drain resistance
R_L = output load resistance

The on resistance is fairly constant at low source-to-drain voltages. For a typical FET, it is approximately 125 ohms for source-to-drain voltages below 0.5 volt. By using a value of R_L, which is much greater than either R_{ON} or R_g, equation 1 reduces to:

$$I_{IN} \approx V_{IN}/R_L \quad (2)$$

To insure that Q_1 remains fully in the conduction state, the gate-to-drain voltage must be kept at nearly zero for all values of the input signal. This is accomplished by placing an isolation diode D_1 in series with the gate. The diode is back-biased when

$$|V_{IN}| \leq V_{EE} - V_{CE(sat)} \quad (3)$$

where V_{EE} = Q_2 emitter bias voltage
$V_{CE(sat)}$ = Q_2 collector-to-emitter saturation voltage

When the diode D_1 is back-biased, the gate of Q_1 is isolated. The gate voltage, under this condition, directly follows the source voltage. It also follows the drain voltage which differs slightly from the source voltage because of the small drop across the channel.

Transistor Q_1 is turned off with a negative gate-to-drain voltage equal or greater than the pinch-off voltage. The pinch-off voltage is the voltage ap-

* Now with Stewart-Warner Microcircuits, Inc., Sunnyvale, Calif.

$1 \leq V_P \leq 5$ volts. $I_{D(OFF)}$ is 0.50 nanoampere for the 2N3376 with a gate-to-drain voltage of 16 volts. (Data sheet max $I_{D(OFF)}$ of 0.4 nanoampere is for $V_{GD} = 11$ volts.) When the input voltage is -10 volts, the gate-source junction has a 26-volt bias; this is within the breakdown rating of 30 volts.

The switch is turned on by dropping the voltage on D_1 to zero or lower. The FET gate is held at zero by R_1. The on resistance is 1000 ohms for a typical 2N3376 with V_P of 2 volts. The amplifier has been set up for unity gain. When the input voltage is $+10$ volts, there is a $+100$ microampere current through the FET making $V_{GS} = -0.1$ volt, i.e., the source is 0.1 volt positive with respect to the gate. Since $V_P = 2$ volts, r_{ds} is actually 0.1/2.0 or 5% lower than 1000 ohms. Similarly, for -10 volts input the source voltage is -0.1 volt from the gate, making the effective r_{ds} 5% higher. The small-signal gain of the amplifier therefore varies $\pm 0.05\%$ for the ± 10 volt input range. In terms of d-c linearity, the output is -10.0025 volts for $+10$ volts input and $+9.9975$ volts for -10 volts input (these calculated errors are about twice the actual errors since the channel voltage is distributed).

When the FET is off, the $I_{D(OFF)}$ value causes a worst-case output of 50 microvolts at room temperature. The gate-to-drain capacitance causes about 20 picocoulombs to be injected into the summing junction each time the gate voltage shifts, the effect of which will depend on amplifier response and capacitance.

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plied between the gate and the drain, which pinches the channel current down to a given level, typically one nanoampere. This forward-biases D_1 and clamps the gate to V_{CC}.

The function of Q_2 is to apply the necessary positive and negative voltages to the isolation diode to turn Q_1 on or off.

Transistor Q_1 will be maintained in the on state if

$$+V_{IN} \leq +V_{EE} - V_{CE(sat)} - V_{RD} \qquad (4)$$

where V_{RD} = voltage required to keep D_1 reverse-biased (typically under 50 millivolts)

The drain current I_{ON} for the stage is given by

$$I_{ON} \approx [V_{EE} - V_{CC} - V_{CE(sat)}]/R_P \qquad (5)$$

where $V_{CC} = Q_2$ collector supply voltage

Transistor Q_1 will be turned off if

$$-V_{IN} \leq V_{CC} - V_{FD} - V_P \qquad (6)$$

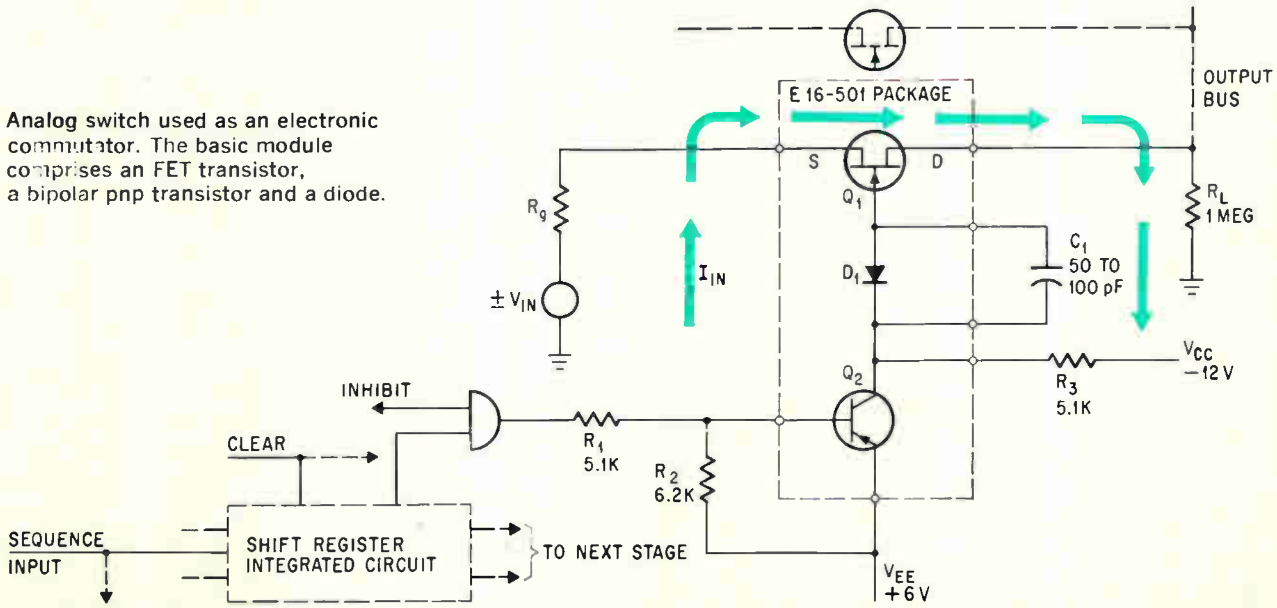
where V_{FD} = forward voltage drop of the isolation diode (typically 500 to 800 millivolts)

V_P = pinch-off voltage

In the off state, a very small drain current flows because of FET transistor leakage current. Capacitor C_1 is used as a speed-up capacitor. It helps remove the charge stored in the FET gate when the FET is cut off. A large value is chosen for the load resistor R_3 to limit the power dissipation for the stage.

Equivalent circuits

The off and on conditions may be represented by a set of equivalent circuits as shown on page 52. The upper circuit illustrates the off condition (Q_1 not conducting). Resistors R_a and R_b represent the source-to-gate and drain-to-gate resistances through which FET leakage current flows because of the reverse biasing of the gate. Capacitor C_S is the stray capacitance. Resistor R_{OFF} is the source-to-



Analog switch used as an electronic commutator. The basic module comprises an FET transistor, a bipolar pnp transistor and a diode.

drain resistance. The source-to-gate and drain-to-gate capacitances are $C_{i(OFF)}$ and $C_{o(OFF)}$.

During conduction, the lower equivalent circuit applies. Here R_C represents the path for the flow of leakage current I_L from the reverse-biased isolation diode. Its value is a few hundred megohms. Resistor R_{ON} is the source-to-drain resistance during conduction, and R_g is the signal source resistance.

In the design of analog switching circuitry, a choice must be made between the use of an FET with a relatively small value of $C_{i(OFF)}$ and a high value of R_{ON} on the one hand, and an FET with a larger $C_{i(OFF)}$ and a smaller R_{ON} on the other. The first type of FET provides a switching waveform with a faster rise time than does the second. The second is better for handling very accurate voltages.

Capacitance $C_{o(OFF)}$ shunts a part of the switching transient to ground (which is desirable), but its magnitude limits the number of switches that may be paralleled for a given switching rate.

FET analog switches may be designed in a wide variety of circuit configurations. Four configurations have been selected that can be applied in the design of complex switching functions. Six configurations are shown on page 53 because two alternate versions are included that use npn transistors in place of the pnp transistors.

Alternate versions of the analog switch modules, using npn instead of pnp transistors, allow power consumption to be held to a minimum in either the off or the on state. This is especially advantageous if the off or the on state is held for a long time.

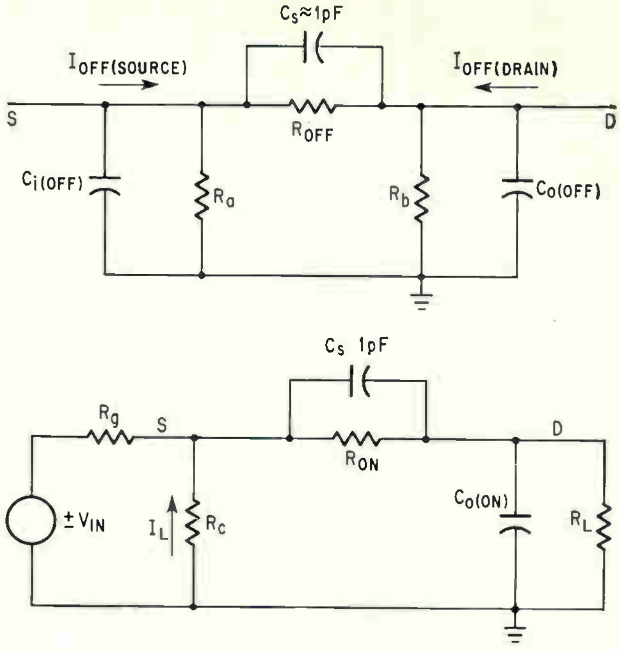
Consider a multipole commutator where the on time of the switch is very short compared with the off time. For minimum power consumption, a basic module should be used that maintains the FET switching transistor, the bipolar transistor and the drive logic circuitry when all are usually off.

The analog switch can be controlled by the binary levels of a logic element such as a gate, flip-flop or shift register.

The commutator

A single-pole multithrow switch, composed of several spst switches, can be used as a commutator in many time-division multiplexing systems. The basic spst configuration (top left circuit on p. 53) is used with control logic to form a high-level, single-ended commutator.

The output waveform for an experimental 10-channel commutator is shown on page 54. The switching rate here is 10 kilocycles per second, although megacycle switching is feasible with available devices. With this type of arrangement, it is possible to build commutators for sequential sampling of several separate data inputs (the analog output voltages of many sensors), or for data-acquisition systems where channels may be addressed directly by a computer, or advanced sequentially, or for continuous monitoring of a single channel.



Switch in the on condition (FET_2 conducting) is represented by lower circuit. Upper circuit applies for the off condition (Q_{FET} not conducting).

Voltage comparator

The voltage comparator has found widespread use in analog-to-digital converters. FET switches of the spdt type can be used with suitable logical control to switch a reference voltage (it might be ground) to successive points on a binary voltage ladder until a comparator determines that the output of the voltage ladder is equal to that of some unknown voltage. The circuit and the output waveform for a voltage comparator stage, using the basic spdt module with a pnp transistor, are shown on page 54. A sine wave and a square wave of the same frequency are applied to the two inputs.

One problem inherent in instrumentation systems using strain gauges with low-level d-c signals is the presence of ground-loop currents that tend to obscure the desired signal. This problem is overcome by breaking the ground loop and using a floating or differential signal connection between the transducer and its associated amplifier, which

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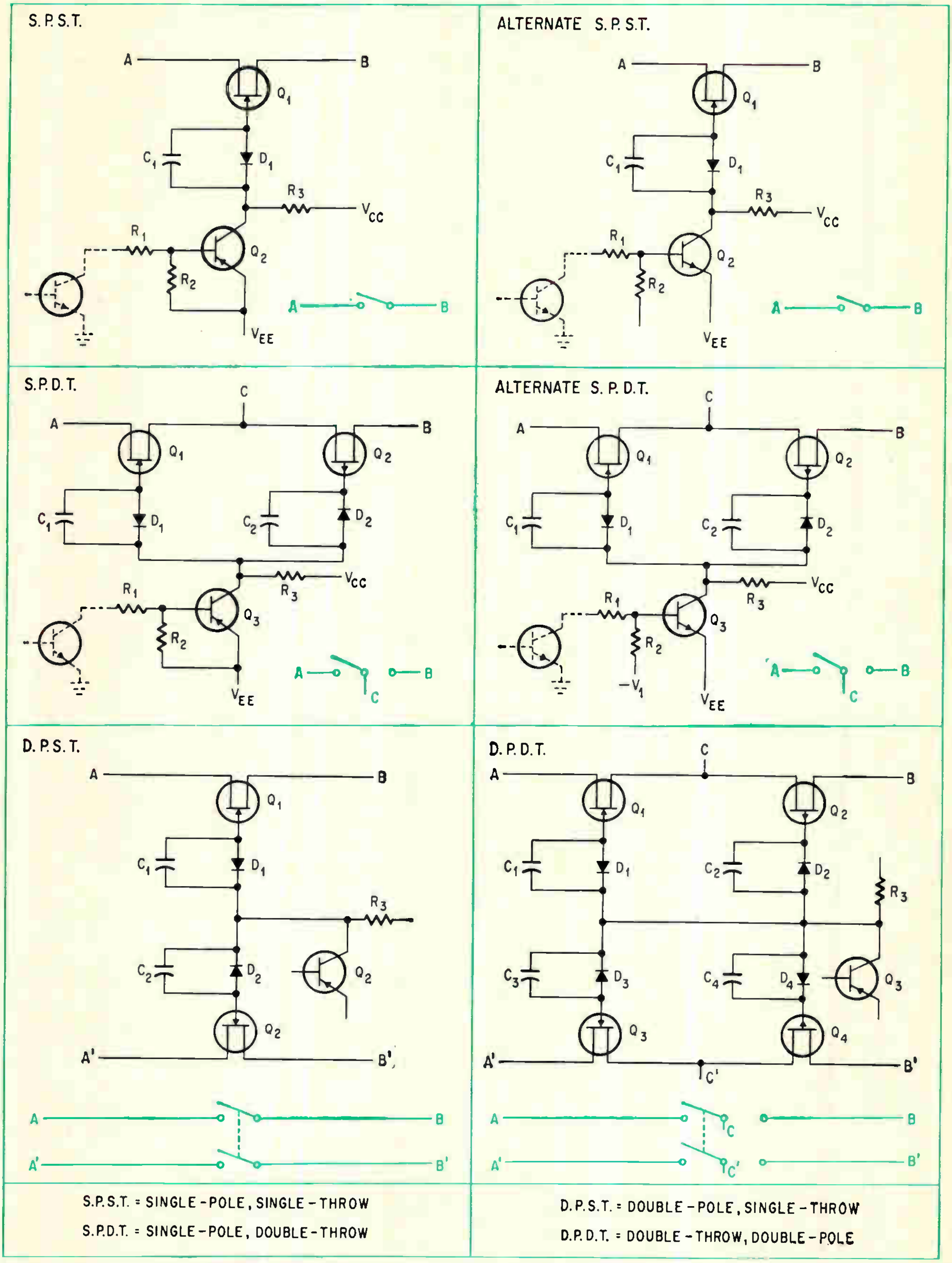
Thomas F. Prosser recently joined the Stewart-Warner Corp.'s microcircuits division as an applications engineer. Previously he was a circuit designer at the Amelco and Philco Corp.

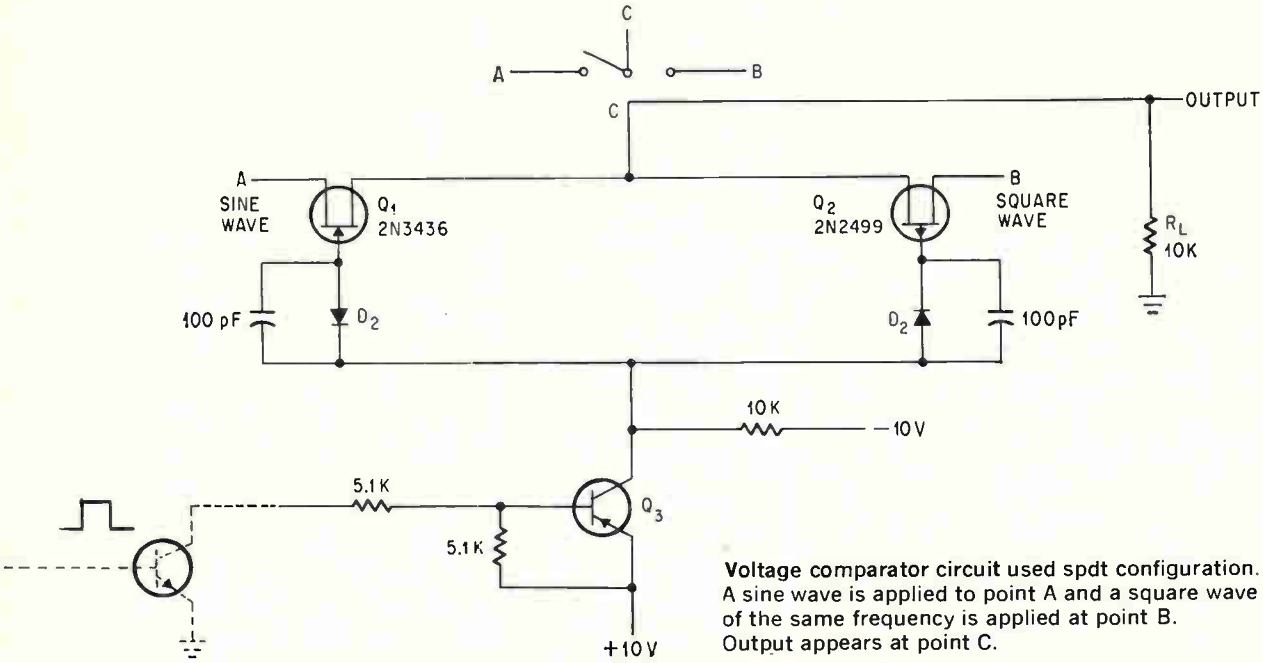
Analog switch building blocks



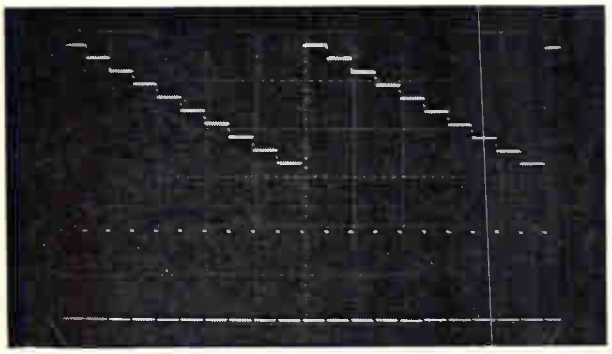
Modular analog switches allow compact design of complex switching functions. The four basic building blocks and two alternate versions are shown. The two alternate-version switching circuits substitute an npn transistor for the pnp transistor.

may be far away. The differential system tends to allow induced noise signals to flow so that they are cancelled out by virtue of their common mode while the signal is not attenuated because of its differential mode.

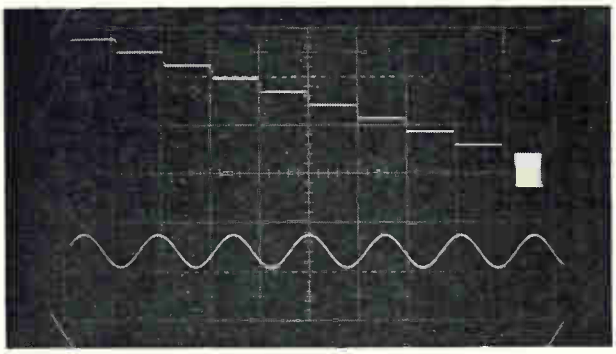
The differential system has two floating signal lines going to the transducer. If it is desired to switch several transducers into a common amplifier, the dpst FET analog switch on page 53 may be used. Because the FET contributes little noise and has no offset voltage, it is well suited for low-level differential switching.



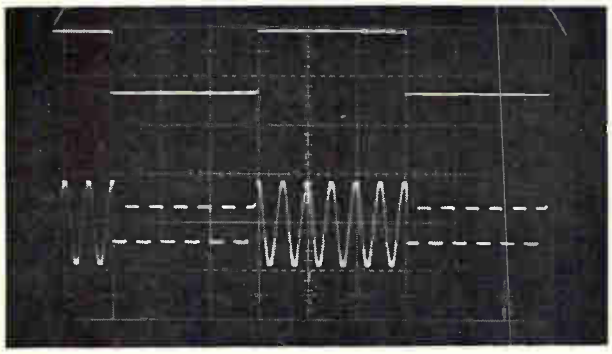
Voltage comparator circuit used spdt configuration. A sine wave is applied to point A and a square wave of the same frequency is applied at point B. Output appears at point C.



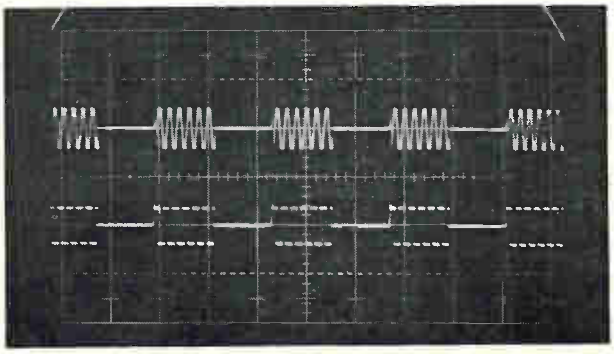
Upper trace shows two frames of a staircase waveform applied to the 10 input positions of an experimental 10-channel commutator built with spst modules. The lower trace shows the voltage applied to the logic units.



Output waveform for a voltage staircase input waveform applied to the first nine input positions of a 10-channel commutator is shown in the upper trace. A sine wave was applied to the 10th input position as shown by the bright portion at the right of the upper trace. The lower trace is the output for the 10th channel with an expanded time scale.



Upper trace represents the output waveform for the voltage comparator. Lower trace shows the control inverted waveform. The scales are: vertical, one volt per centimeter; horizontal, 20 microseconds per centimeter.



Output waveforms for a differential analog switch. the dpst module (see circuit on p. 53) receives a square wave at point A and a sine wave having the same frequency at point A'.

FET complementary integrated circuits: aerospace natural

Simplified NOR and NAND circuits built by combining p-channel and n-channel MOS field-effect transistors

By P.J. Coppen

Raytheon Co., Mountain View, Calif.

Digital logic circuits in satellites and other aerospace equipment must be small and must operate on limited power. Engineers are discovering that they can design simplified NOR and NAND circuits that have these characteristics by combining p- and n-channel field-effect transistors.

F. M. Wanlass and C. T. Sah have investigated novel logic circuits using insulated-gate metal-oxide FET's with both p- and n-channel polarities.

In this article, this complementary approach to logic circuitry is applied to integrated circuits.

A three-input circuit that performs the NOR function (shown on page 57) produces a logical zero at the output when at least one input has a logical one.

Logic circuit

This circuit has three p-channel FET's connected in series and three n-channel FET's connected in parallel. The drain leads of the n-channel units are connected to the drain lead of one of the p-channel units and the output is taken from this connection. The source leads of the n-channel units are grounded and the source lead of the first p-channel unit is connected to a positive supply voltage. Each input connection is tied to a pair of FET gates. One of the gate leads is from an n-channel transistor and the other is from a p-channel device. All of the FET's are enhancement mode types, that is, when the gate of a particular unit is connected to its substrate, there is no induced channel and the drain-to-source resistance is high, typically greater than 1,000 megohms.

When all three input positions of the circuit are connected to ground, the gates of the n-channel units are connected to their substrates. Thus the n-channel units have very high drain-to-source resistances. The gates of the p-channel units are biased negatively with respect to their substrates; if the positive supply voltage is larger than the threshold voltage for the p-channel units, they will be turned on and will have relatively low drain-to-source resistances. The output voltage will nearly equal to the positive supply voltage, as determined by the relative resistances of the p-channel units, which are on, and the paralleled n-channel units, which are off. If one or more of the input positions is connected to the positive supply voltage, then corresponding numbers of p- and n-channel units turn off and on, respectively, and the output voltage falls to nearby ground voltage. This circuit thus performs the NOR function.

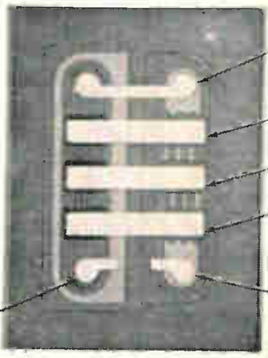
Power dissipation

The low power consumption of the circuit is a major advantage to the designer. When the circuit is quiescent in either the on or off state, the resistance between the supply and ground is about 1,000 megohms through the string of FET's. Also, if the circuit is followed by other FET circuits, the input impedance of the next stage is completely capacitive and draws no output current. Therefore, the power consumption in either quiescent state is very low. An appreciable amount of power is consumed only during a switching cycle, when the input capacitance of the next stage is charged, and when current may flow through the string of FET's. The power consumption is proportional to the switching rate, and is at a maximum when the circuit is freely oscillating.

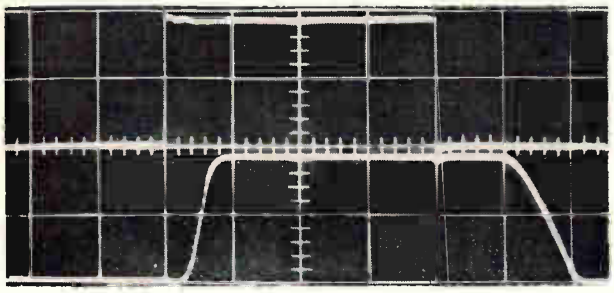
If the n-channel units had been connected in series and the p-channel units in parallel, a three-input NAND circuit would have resulted. Either the NAND or the NOR circuit can be directly coupled and the fan-out may be as large as desired. The only limitation on the number of fan-out stages is that the high capacitance caused by a high fan-out limits the switching speed.

Design considerations

For the NOR or NAND gates to be used in series, the output voltage must swing over a range as nearly equal to the supply voltage as possible. The



View of NOR integrated circuit shows the n-channel transistors on the left side and the p-channel units on the right.



Waveforms show propagation delay for a pair of NOR circuits. The upper trace represents the input pulse to the first NOR circuit. The lower trace is the output waveform for the second NOR circuit. Each vertical division (y-axis) is 5 volts. Each horizontal division is 1 microsecond.

supply voltage must sufficiently exceed the magnitude of the FETs' threshold voltage to provide an impedance change of at least 10^6 ohms between the off and on states. For operation with a supply voltage of less than 10 volts, the threshold voltage should be no more than about 5 volts. Noise immunity requirements may limit the threshold voltage. The maximum supply voltage that can be used is limited by one of several factors: the gate-to-substrate breakdown voltage, the drain-to-source or drain-to-substrate breakdown voltage of any FET in the circuit, or, for an integrated circuit, the breakdown voltage of the reverse-biased p-n substrate junction.

Switching speed

The output voltage reaches the positive supply level for the NOR circuit shown here. This output is connected to the capacitive input of the next stage. If one input is made positive by a rise pulse that is fast—compared with the switching time of the circuit—then the series string of p-channel units offers a high resistance. The high resistance occurs since one p-channel device turns off and the paralleled n-channel units offer a low resistance because one n-channel unit turns on. The output voltage falls to ground and the input capacitance of the next stage discharges through the relatively low resistance of the conducting n-channel unit. The switching-time constant is the product of the effective channel resistance of the conducting n-channel unit and the input capacitance of the next stage.

With a positive input to a NOR circuit that is being driven by the output of a similar NOR circuit, the time for the voltage of the input to become positive is comparable to the circuit's switching time. As the voltage of this particular input rises, the channel resistance of the associated conducting p-channel unit increases rapidly. This alters the impedance ratio of the p- to n-channel units and causes the output voltage to fall. However, until the input voltage has risen high enough to exceed the threshold voltage of the n-channel units, the only way for the output voltage to fall is by the discharge of the input capacitance of the next stage through the very high resistance of the nonconducting n-channel units. The output voltage does not change appreciably until the input voltage is sufficiently positive to turn on one of the n-channel units. After this happens, the output voltage falls rapidly. For fast switching then, not only should the on-channel resistance and the input capacitance for the next stage both be as small as possible, but the threshold voltages must be as low as possible (consistent with noise immunity requirements) to reduce delay in output switching, while the input is changing by the magnitude of the threshold voltage.

Switching time constant

A simple expression for the transconductance of an insulated-gate FET is:

$$g_m \propto W/Lt \tag{1}$$

where g_m is the transconductance in the saturation region (when the drain current is constant with drain voltage) W and L are, respectively, the width and length of the induced channel, and t is the thickness of the dielectric under the gate electrode. The on-channel resistance measured for low drain-to-source voltages is given by $R_{on} = 1/g_m$ at the same gate voltage. Therefore:

$$R_{on} \propto Lt/W \tag{2}$$

The input capacitance C_{in} of the next similar stage is determined by the area of the induced channel and the thickness of the gate dielectric. It may be expressed by:

$$C'_n \propto LW/t \qquad (3$$

We have then, for the switching time constant:

$$R_{on}C_{in} \propto \frac{Lt}{W} \cdot \frac{LW}{t} \propto L^2 \tag{4}$$

If L approaches zero, this time constant is very small. Also, since the width, W, of the channel does not appear in the $R_{on}C_{in}$ expression, the individual FET's may be made very small with a consequent higher yield because of the reduced probability of a pinhole in the gate dielectric. This increased yield, as well as the small size of the FET, allow the design of integrated circuits far more complex than simple NOR gates.

Although C_{in} varies reciprocally with R_{on}, stray capacitances and the capacitance associated with bonding areas and interconnections do not vary. These capacitances play a part in determining switching speeds. Once a minimum value of L, the channel length, is found, then W must be kept sufficiently large so that C_{in} is larger than the stray capacitance. With very small interconnections—possible because continuous high currents do not flow in this device—and thick oxide surrounding the activated areas, the stray capacitances may be minimized. This confirms the advisability of fabricating complex integrated circuits rather than assembling complex circuits from smaller, separately packaged, simpler circuits.

Power considerations

In fabricating the integrated circuit version of the

NOR circuit, separate p- and n-type portions of the starting wafer are required. Since the p-substrate of the n-channel units is maintained at ground and the n-substrate of the p-channel units is positively biased, the p-n junction in the substrate is reverse-biased. In parallel with this junction are the reverse-biased drain junctions of whichever FET's are turned off. The leakage currents of these FET's add up and are typically a few nanoamperes. The quiescent power consumption is, at most, a few tenths of a nanowatt.

During switching, current flows to charge or discharge the capacitance of the next stage. In a circuit designed for fast switching, as has been noted, the threshold voltages must be low, and so, as the input voltages change, the off units will turn on before the on units turn off. Consequently, for a part of the switching cycle, all units in the circuit will be on and the power supply will be connected to ground through a moderate resistance. Current will then flow momentarily through the FET's. If the threshold voltages are just larger than half of the supply voltage, then the on unit will turn off before the off units turn on. Consequently, there will always be a high resistance present and so only leakage currents will flow through the FET's. This situation represents a lower power consumption than is the case when the threshold voltage is low and switching is fast. But this lower power consumption is realized at the expense of a much longer delay time and hence a much slower speed.

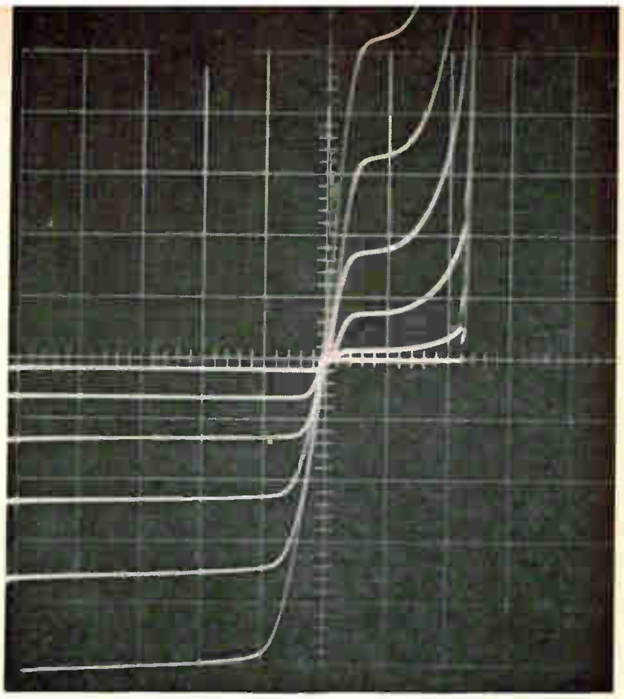
Experimental results

The n-channel units have sharp breakdown at about +12 volts. Measurements were made with a supply voltage of +9 volts.

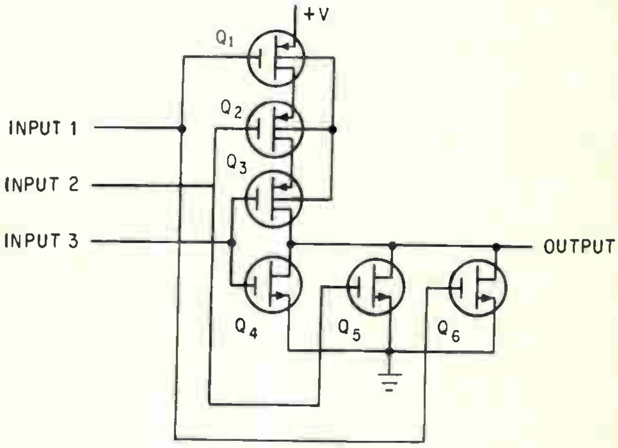
With the input voltage level at either 0 or +9 volts, and the circuit quiescent in either state, the current drawn from the supply is about 1 nanoampere. The quiescent power consumption is about 10 nanowatts.

The testing arrangement shown at right measures the propagation delay through two integrated NOR circuits. Two NOR circuits are connected here with extra capacitance added to give effective fan outs of three for each NOR circuit (the capacitance at each input is 6 picofarads). One input of the first gate is driven by a pulse generator with a 50-ohm source impedance. The scope traces obtained are shown on page 56. The input pulse is superimposed on the pulse obtained from the output of the second NOR circuit. The delay time is evident, especially as the input pulse is falling. The curve isn't symmetrical because, while the threshold voltage for the p-channel units is about 2 volts, it is about 5 volts for the n-channel units. The delay time for the rise of voltage at the output of the second NOR circuit is, therefore, less than the delay time for its fall.

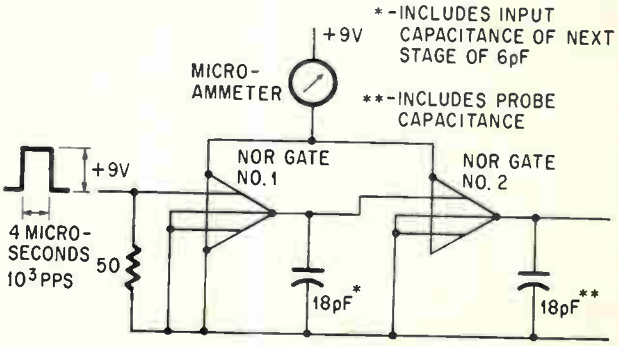
A microammeter shows a current drain of 760 nanoamperes for the circuit test arrangement, when the input pulse repetition rate is 1,000 per second. This gives a power consumption of about 3.5 mi-



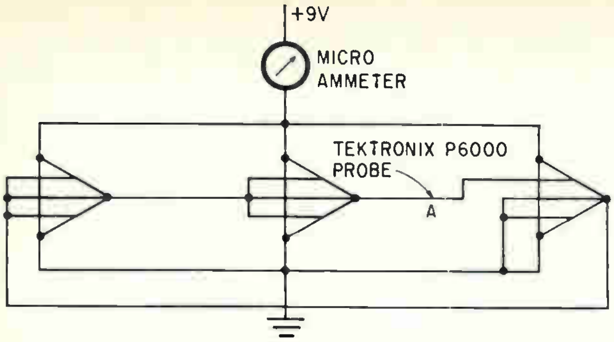
Set of oscilloscope traces shows drain characteristics for one n-channel unit and three p-channel units in series in the NOR circuit. The upper traces are for the n-channel unit. The highest trace is for a V_{GS} of +9 volts; the lowest trace is for a V_{GS} of −9 volts. Each vertical division (y-axis) represents 0.2 milliamperes. Each horizontal division is 5 volts. One-volt gate steps were used.



NOR circuit uses three p-channel MOS FET's (Q_1, Q_2, and Q_3) and three n-channel MOS FET's (Q_4, Q_5, and Q_6). Low dissipation of circuit during both on and off states makes it attractive for use in equipment where space and power are limited.



Circuit arrangement for measurement of propagation delay and power consumption for a pair of NOR integrated circuits. The simulated fan out for each NOR circuit is three.



Ring oscillator using three NOR integrated circuits is an example of how the FET's can be used. Each integrated circuit has an effective fan out of three.

crowatts per NOR circuit for 2,000 switching operations per second, with a fan-out of three.

Three integrated circuit, each containing a NOR circuit, can be connected to form a 500-Kc ring oscillator as shown at the left. A current of 540 ma was drawn, giving a power consumption of about 1.6 milliwatts per NOR circuit, when oscillating with a fan out of three. This is the maximum power consumption for this circuit with this fan out.

The results obtained have been sufficiently encouraging to justify further work. First, the effective channel length must be reduced in order to increase the speed. Very small channel lengths would change the characteristics of the FET's by

Field-effect transistors

Space radiation affects MOS FET's

Theory that the MOS FET has inherent resistance to nuclear radiation has now been disproved; this will limit MOS units in some applications

By Harold L. Hughes and Ronald R. Giroux
Naval Research Laboratory, Washington

According to a popular view, the metal-oxide semiconductor transistor is inherently resistant to nuclear radiation because of its majority-carrier nature. If this immunity to nuclear radiation really exists, the qualities of high input resistance and low input capacitance coupled with radiation resistance would make the MOS transistor ideal for many space applications.

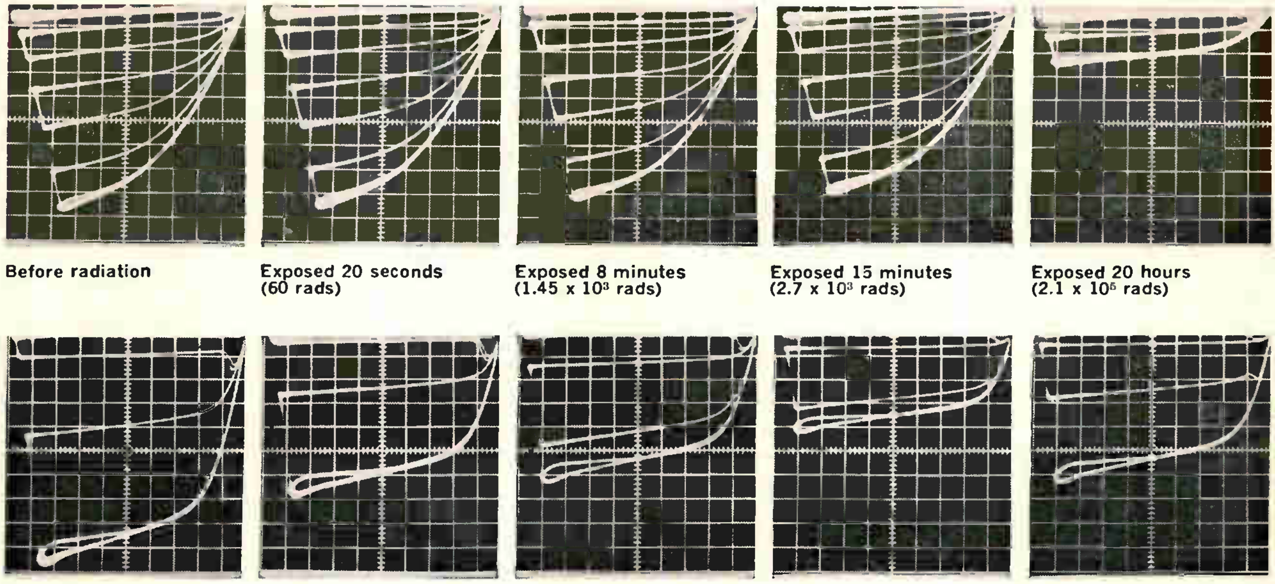
As a result of the discovery of radiation surface effects on transistors, it was decided to test new MOS devices before they were used in a radiation environment. MOS transistors of this study were to be used in a satellite electrometer circuit. Consequently, commercially available n-channel and p-channel MOS transistors earmarked for this satellite use were studied as a function of space-type radiation.

The total dose (10^6 rads) used in the experiment is approximately equivalent to the amount of radiation absorbed by the transistors after one year in space. Two dose rates (2.54×10^4 roentgens per minute and 2.07×10^2 roentgens per minute) were used to correlate accelerated radiation testing to real conditions of space radiation. For the MOS transistors to receive the dose of 10^6 rads required 45 minutes at the higher dose rate and 92 hours at the lower dose rate. The unit rad is a measure of the total amount of radiation absorbed by the material of interest. One rad absorbed means each gram of material has received 100 ergs of energy. The term roentgen refers to the total exposure to radiation; therefore, this term is used to describe the magnitude of the radiation source rather than the extent of interaction of the radiation. In the case of silicon, to convert radiation-exposure expressed in roentgens to radiation absorbed-dose expressed reducing output resistance, but this is of no consequence in switching units. Oxide-mask source-to-drain spacings of only 0.2 mil can be readily maintained with current photoengraving technology.

Induced channel area of the six FET's in the experimental circuit discussed is about 130 square mils. If L is reduced to about 0.5 microns, and if W is made small, then a shift register could be made, with six NOR circuits using a total of 32 FET's in a total active area of less than 20 square mils. The interconnection pattern of such a shift register is simple. NAND circuits, which operate very much like NOR circuits, have been made by interchanging the source-drain diffusion masks over the appropriate parts of the substrate, to connect the p-channel units in parallel and the n-channel units in series.

The author

Peter J. Coppen heads the field-effect transistor development section at the semiconductor division of the Raytheon Co.



Before radiation | Exposed 20 seconds (60 rads) | Exposed 8 minutes (1.45 x 10^3 rads) | Exposed 15 minutes (2.7 x 10^3 rads) | Exposed 20 hours (2.1 x 10^5 rads)

Exposed 20 hours (2.1 x 10^5 rads) | Exposed 43 hours (4.7 x 10^5 rads) | Exposed 64 hours (6.9 x 10^5 rads) | Removed after 88 hours (9.6 x 10^5 rads) | Three days later

Effects of radiation on two p-channel MOS field-effect transistors. Top set of curves was produced by a transistor that was not biased during exposure to radiation. The transistor represented by bottom set of curves was biased continuously during exposure. In the top set of traces, each veritcal (y-axis) division represents one milliampere. In the bottom set, each y-axis division represents 0.2 milliamperes. In both sets, radiation dose rate is 2.07 x 10^2 roentgens per minute. Each horizontal division is one volt. One-volt gate-voltage steps are used. Load is 50 ohms.

in rads, the roentgen is multiplied by 0.875.

Six commercially available p-channel (enhancement type) MOS transistors and five commercially available n-channel (enhancement-depletion type) MOS transistors were exposed to 10^6 rads of gamma radiation. Cobalt 60 was used as the radiation source. On bombarding the MOS transistors, the gamma radiation emitted by this type of source produces Compton electrons which cause ionization in the transistor. For the absorbed dose of 10^6 rads, changes in bulk semiconductor conductivity and lifetime are negligible.

It has been found that both p- and n-channel MOS transistors are very susceptible to space-type radiation. Both transconductance (g_m) and channel conductance degraded after exposure to 10^6 rads. General trends of the radiation damage can be observed from the tables of the electrical characteristics of MOS transistors before and after exposure.

The channel conductance at a given gate voltage is decreased as much as 650 times for the p-channel transistor and as much as 15 times for the n-channel transistor. This data is obtained from the columns of drain current (I_{SD}) at a given gate voltage.

Channel conductance

The decreasing of channel conductance I_{SD}/V_{SD} appears to be at least a partial cause of the large decreases in transconductance at a given gate voltage. The radiation effect of decreasing channel conductance causes the drain current at a given drain voltage to decrease, thus producing a decrease in transconductance since the transconductance naturally falls off at lower drain currents. However, considering the transconductance before and after exposure to radiation at equal drain currents, the data

Effects of space radiation on n-channel MOS transistors

Unit	Leakage Current (I_{GS})		Transconductance (g_m)		Transconductance (g_m)		Source-to-Drain Current (I_{SD})	
	V_{GS} = 10.0V, V_{SD} = 0		V_{SD} = 10.0V, V_{GS} = 0		V_{SD} = 10.0V, I_{SD} = 0.5ma		V_{SD} = 10.0V, V_{GS} = 0	
	Before Radiation (Ampere)	After 10^6 rads (Ampere)	Before Radiation (μmhos)	After 10^6 rads (μmhos)	Before Radiation (μmhos)	After 10^6 rads (μmhos)	Before Radiation (ma)	After 10^6 rads (ma)
1	1.0×10^{-12}	1.0×10^{-12}	600	200	450	200	2.1	2.1
2	1.0×10^{-12}	2.0×10^{-13}	500	160	400	160	2.0	0.9
3	3.1×10^{-12}	5.0×10^{-12}	600	30	400	20	3.0	0.2
4	2.5×10^{-12}	1.5×10^{-13}	750	40	400	60	4.7	0.9
5	2.0×10^{-12}	3.0×10^{-12}	1400	200	375	120	4.5	0.6

V_{GS} = Gate-to-source voltage V_{SD} = Source-to-drain voltage

Effects of space radiation on p-channel MOS transistors

Unit	Leakage Current (I_{GS})		Transconductance (g_m)		Transconductance (g_m)		Source-to-Drain Current (I_{SD})	
	V_{GS} = 5.0V, V_{SD} = 0		V_{GS} = 5.0V, V_{SD} = −10.0V		V_{SD} = 5.0V, I_{SD} = 1.0ma		V_{SD} = 5.0V, V_{GS} = −10.0V	
	Before Radiation (Ampere)	After 10^6 rads (Ampere)	Before Radiation (μmhos)	After 10^6 rads (μmhos)	Before Radiation (μmhos)	After 10^6 rads (μmhos)	Before Radiation (ma)	After 10^6 rads (ma)
1	1.0×10^{-14}	1×10^{-14}	1500	600	800	600	5.6	0.8
2	1.0×10^{-14}	1×10^{-14}	1300	35	500	Not measurable	5.4	<0.01
3	1.5×10^{-14}	1×10^{-14}	1700	100	600	Not measurable	6.5	<0.01
4	1.0×10^{-14}	1×10^{-14}	1700	900	1000	900	6.5	0.8
5	1.0×10^{-14}	3×10^{-14}	1025	425	1100	600	2.7	0.4
6	1.0×10^{-14}	1×10^{-14}	1250	725	750	725	3.5	0.7

V_{GS} = Gate-to-source voltage V_{SD} = Source-to-drain voltage

still indicates considerable reduction in this parameter.

Both n- and p-channel MOS transistors experienced little or no permanent degradation of gate leakage current.

It has been observed that matched pairs appear to be damaged equally up to about 2×10^5 rads of radiation. As can be seen from the output characteristics of two matched p-channel MOS transistors measured on a Tektronix 575 Curve Tracer during exposure, radiation degradation of the output characteristic has already begun at the very low dose of 60 rads (equivalent to only one half hour in space). After 2×10^5 rads (2.5 months in space) the matched nature of degradation no longer exists.

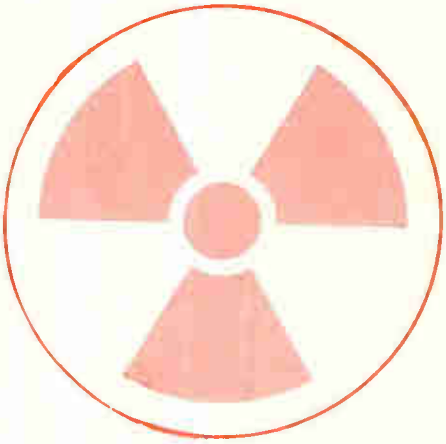
The results of exposing commercial MOS transistors to radiation indicate that caution must be exercised when utilizing this type of device for space applications. Further testing of MOS transistors is being conducted to derive a suitable model which can be used to predict the radiation damage experienced by MOS transistors.

The authors

Ronald A. Giroux has been with the Naval Research Laboratory for five years. He is currently engaged in the development of instrumentation for rockets and satellites. He is working for a master's degree at George Washington University.

Harold L. Hughes is a member of the Experimental Device Section at the Naval Research Laboratory. He is engaged in semiconductor device and thin-film research programs. He is also studying for a master's degree at George Washington University.

Designing against space radiation: Part I



More and more electronic systems are being sent through space. Engineers need to know the radiation environments these circuits must withstand

By Henning H. Lind Olesen

Reentry Systems Dept., General Electric Co., Philadelphia

The space age has confronted electronics engineers with some new words and concepts: trapped radiation, albedo protons, solar x-rays, ionization effects, fast neutrons, rads, dose rates and many more.

Planning for space vehicles that must withstand radiation exposure has introduced a new environment with which the engineer must become familiar.

Over the years, the engineer has learned to use semiconductor devices and components to reduce size, weight and power consumption. As experience with nuclear radiation has increased, it has become apparent that it affects these components drastically. Nuclear radiation has had an even greater effect on transistors than on the vacuum tubes that they replaced.

The most obvious solution—shielding—is often impossible because it adds too much weight.

To design against nuclear radiation, the engineer must know how radiation affects materials and circuit elements, and how some design techniques can avert some problems.

Part one of this article will describe nuclear environments and the interaction of radiation with the material atomic structure. In the next issue, part two will describe how this affects electronic components, and radiation-hardened circuit design techniques together with some design examples.

The author

At age 32, Henning Olesen is one of the General Electric Co.'s nucleonics experts. Educated in Denmark as an electronics engineer, he has crossed disciplines to train himself in nuclear physics. Besides heading some of GE's nuclear radiation projects, he conducts a company course on radiation effects on electronics.

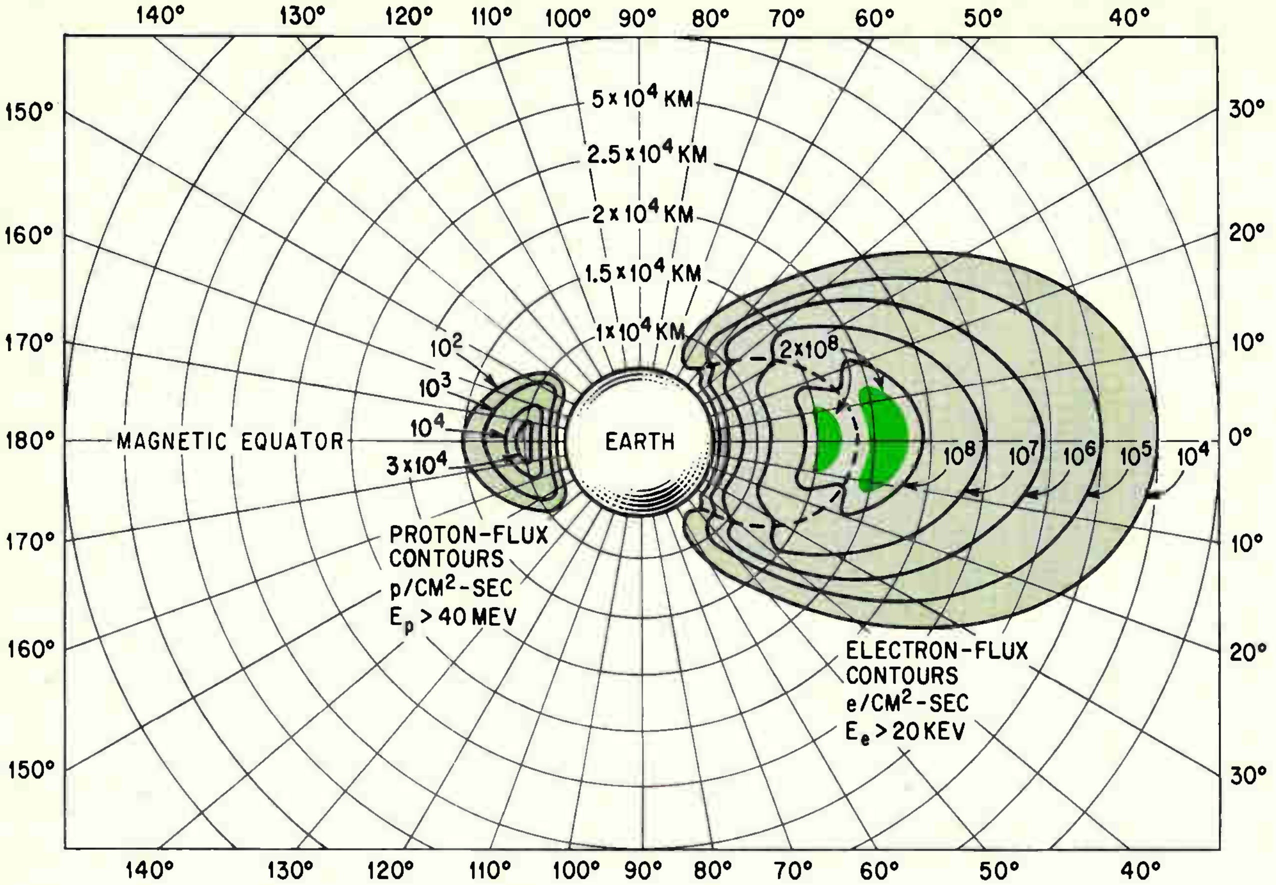
The Van Allen belts

A nuclear radiation environment can be established by any of three sources. One is the steady-state radiation of the Van Allen belts surrounding the earth, or that produced by solar flares. Another is steady-state radiation emanating from a nuclear reactor such as may be found in a nuclear propulsion system. A third is pulsed nuclear radiation produced by a nuclear weapon burst, a pulsed nuclear reactor, or other sources of short (millisecond) pulses of radiation. A combination of these may be encountered, as in the case of a nuclear-powered space vehicle passing through the Van Allen belts.

The penetrating nuclear radiation of near and solar space may be further divided into cosmic radiation, trapped radiation (Van Allen belts), auroral radiation and solar-flare radiation. Other, less important sources are solar winds, solar x-rays, neutrons and albedo protons.

Cosmic radiation consists principally of hydrogen nuclei (protons) whose speed indicates that their kinetic energy is one billion to 10 billion electron volts. It is impractical to shield against cosmic particles of such great penetration.

The cosmic-particle flux is about two particles per square centimeter per second. This flux consists 90% of protons and 10% of alpha particles (helium nuclei). The ionization dose rate attributable to cosmic radiation is about 10^{-4} rads per hour;



Trapped radiation particles from a toroid circling the earth about its geomagnetic equator. Chart shows Van Allen belt fluxes as a function of distance from the center of the earth and latitude. Colored high-level flux contours are separated by a low flux shot.

that attributable to secondaries produced by the primary particles is about 10^{-3} rads per hour. Most materials and electronic components are unaffected until an ionization dose of 10^{4} rads has been absorbed. Consequently, cosmic radiation does not pose a severe threat to the performance of electronic equipment.

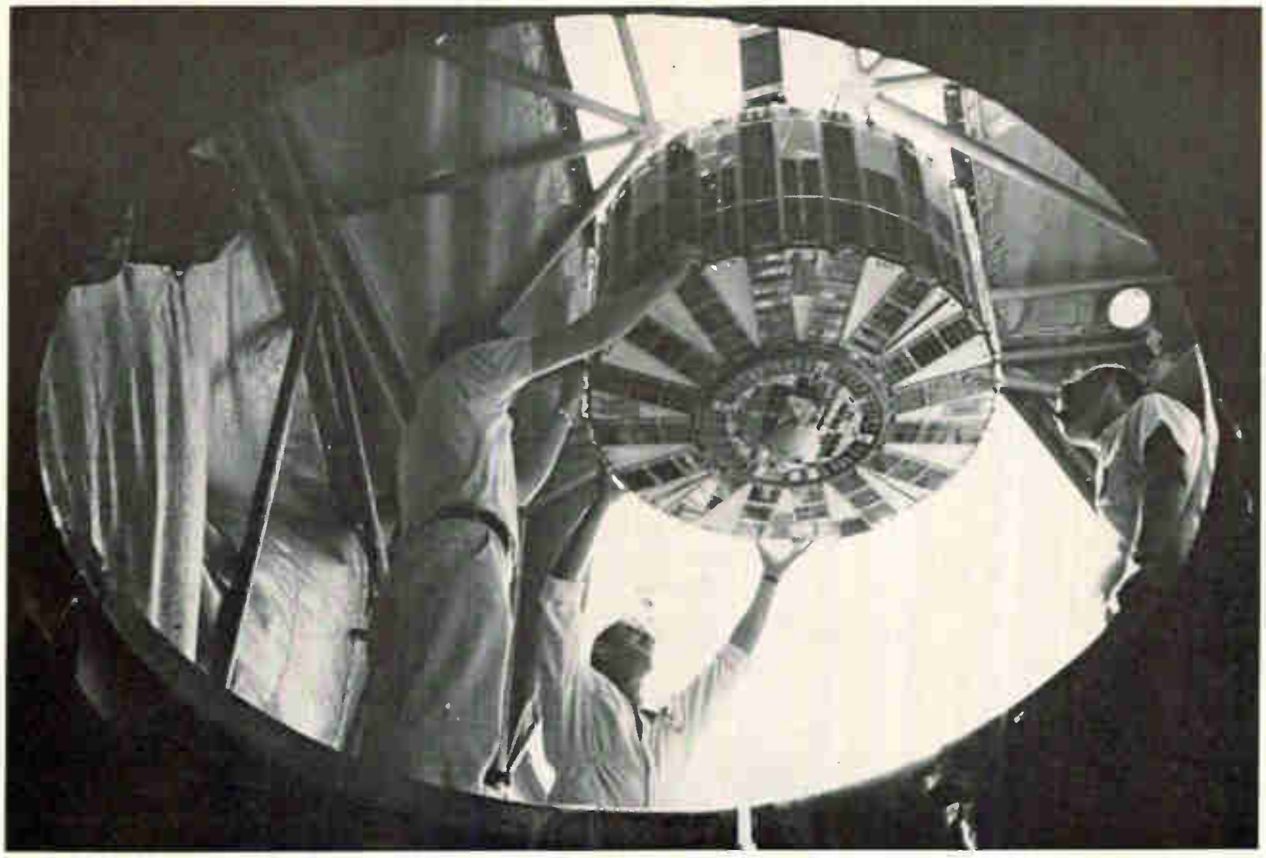
Van Allen radiation consists of a great number of electrons and protons of various kinetic energies, all trapped by the earth's magnetic field. The contour plot of the belts shows these in cross-section.[1] The particles form a toroid around the earth's geomagnetic equator. The charged particles—electrons and protons—are restricted to spiral paths surrounding magnetic field lines, and they continually drift between the southern and northern extremities of the magnetic field lines. A slight longitudinal drift is also evident; this makes the toroidal configuration complete.

The contour plot shows how the belt is represented as having an inner and outer belt. Recent data[2] shows that the toroidal volume is permeated with protons and electrons. The proton flux peaks at about 2,200 miles and the electron flux at 9,900 miles. It is postulated that the volume of low-particle flux separating the two peaks, the so-called "slot," is created by some phenomenon that reduces the lifetimes of the particles in this region.

The inner Van Allen belt starts at an altitude of 248 to 744 miles depending upon the longitude. It extends up to about 6,200 miles where it begins to overlap the outer belt. The inner belt extends from about 45° north magnetic latitude to 45° south magnetic latitude. The region of highest flux occurs at 2,232 miles above the magnetic equator. The flux is strongly directional with most particles moving perpendicular to the magnetic field. The table on page 63 lists the fluxes at various particle energies. The energy gives an indication of the penetrating capability of the particular particle.

The outer Van Allen belt begins at an altitude of about 6,200 miles near the magnetic equator and extends up to 37,000 to 52,000 miles. The upper boundary is influenced by solar activity. The flux in the outer belt changes 10 to 100 times during the peak of a solar storm.

Normally the highest flux is found 9,900 to 14,000 miles above the magnetic equator. Both the inner and outer belts were affected by the United States' high-altitude nuclear-bomb test on July 9, 1962.[3] After the detonation, the flux of both belts increased enormously, and the low flux separating the two belts was temporarily eliminated. The inner belt has regained its normal flux levels, although the average energy of the particles appears to be higher. The outer belt has returned to the intensity levels that existed prior to the nuclear explosion. Solar conditions can increase intensity of the outer Van Allen



Navy's Transit 4A navigational satellite contains circuitry designed to operate near the SNAP (systems for nuclear auxiliary power) radioisotope generator power source built by the Martin Co.

belt as much as 1,000 times.

Protons are the most penetrating type of radiation in the Van Allen belts because of their higher average energy and their large mass. Shielding against protons, therefore, is difficult.

Although the average energy of electrons in the belts allows shielding, the secondary radiation they create is more troublesome. A medium-energy electron (0.5 mev to 50 mev) expends its energy mainly by ionizing materials; this results in a secondary dose of ionization. A high-energy electron (greater than 50 mev) is ultimately absorbed by the bremstrahlung process (braking or stopping electrons) which produces x-rays or gamma rays. X-radiation is more penetrating than the electrons and causes in ionization radiation doses inside the vehicle.

Other radiation in space

Auroral radiation, associated with the aurora borealis, is encountered between 65° and 70° north and south magnetic latitudes. It affects space vehicles in polar orbits.

It is sporadic in nature, with the major flux delivered as electrons. Although an average yearly dose could run as high as 10^8 rads on the surface of a space vehicle, the secondary radiation amounts to only about 50 rads a year. Auroral protons have energies no higher than 650 kev, and a typical surface dose would be about 500 rads a year. Secondary radiation would be negligible.

Solar storms produce large fluxes of energetic protons. These arrive at the earth one hour after a flare has been observed on the sun. The proton flux generally lasts about 100 hours. If these occur about twice a year, about 10^{11} protons would be received annually in the Van Allen belts.

The protons have energies higher than 20 million electron volts. The ionizing dose caused by solar-flare radiation is approximately 10^5 rads a year for the interior of a space vehicle orbiting in the

Maximum Van Allen Belt Radiation Levels

Fluxes at various particle energies. The energy gives an indication of a particle's penetrating capability.

	Altitude	Electrons >20 Kev (e/cm²/sec)	Electrons >200 Kev (e/cm²/sec)	Protons 0.1 to 5 Mev (p/cm²/sec)	Protons >40 Mev (p/cm²/sec)
Inner Belt	(2,232 mi)	$\sim 2 \times 10^9$	$<10^8$	$<10^6$	$\sim 4 \times 10^4$
Outer Belt	9,900 mi	$\sim 10^{11}$	$<10^8$	$\sim 10^8$	$<10^2$

outer Van Allen radiation belt.

Other types of space radiation are solar wind, solar x-rays, neutrons produced by cosmic rays, and albedo protons. None of these produce enough internal ionizing radiation in the space vehicle to be of concern to the designer of electronics systems.

Nuclear propulsion systems

Radioisotope generators are being used to provide power for some space vehicles. These generators have low output per unit mass and are, therefore, restricted to applications requiring power levels of less than one kilowatt. The electronics designer must be concerned with gamma radiation from these sources.

The flux level and primary gamma energy depend upon the type of isotope involved. Generally the gamma-dose rate for an radioisotope source is low enough so that the threshold for damage by ionizing radiation will not be exceeded in electronic equipment.

As power requirements in space vehicles increase beyond the kilowatt level, the radioisotope source becomes costly and difficult to produce. It also becomes difficult and hazardous to transport the power plant. Nuclear power reactors become more attractive when power levels from 100 kilowatts to many megawatts are required to operate for months or years. Nuclear reactors also can be used directly for propulsion. For direct propulsion, however, higher power levels are required—1,000 megawatts and up. These are still far from ready to be used in flight.

Although the operation of nuclear reactors in these two applications differs somewhat, the emission of highly penetrating nuclear radiation is common to both. It is desirable to examine the radiation environment created by such a power plant.

To the electronic-equipment designer, two important types of penetrating radiation emanate from a nuclear reactor beyond the confines of the reactor core. One consists of ionizing gamma radiation of fluxes of about 10^4 rads (carbon) an hour. The other consists of neutron particles which, because they are uncharged, can penetrate materials; when these collide with the atoms of a material they change the material's mechanical and electrical characteristics.

The neutron environment is expressed as the total integrated dose per unit area. For a typical 100-kilowatt nuclear reactor with a mission time of 10,000 hours, if some shielding is interposed between the reactor and the electronic system, the following is a typical radiation exposure for the electronic system:

- Total neutrons with kinetic energies higher than 10 kilo-electron-volts, 10^{13} neutrons per square centimeter:
- Integrated ionizing dose, 10^8 Rads(c);
- Ionizing dose rate, 10^4 Rads(c) per hour (average gamma energy—1 mev).

Because electronic systems are usually located in the vicinity of the reactor cooling system, they operate in an ambient temperature of about 250° F and the component temperature is increased further as the ionizing radiation expends its energy directly in the component materials. The nuclear reactor's design is a major determinant of its neutron and gamma leakage flux from a particular space-vehicle's reactor and of the energy spectrum of the neutron flux. Fuel elements and coolants also influence the leakage flux.

The space vehicle's design can also affect the flux reaching the electronic system. Shadow shielding—reduction of radiation in one direction—reduces the flux in the direction of the electronic system, but the reduction of radiation by the in-

Glossary of radiation terms

As the nuclear environment becomes an area of increasing concern for circuit designers, it becomes more important that the engineer understand the terminology found in specifications and literature on radiation effects.

There are two basic types of radiation that can disturb the operation of electronic equipment: electromagnetic radiation and particle radiation.

Electromagnetic radiation

These radiation terms are generally identified with the speed of light (electromagnetic) radiation.

Absorbed dose rate: The energy that a given material absorbs per unit time from a radiation field.

Absorbed dose: The time integral of the absorbed dose rate.

Photon: As the wavelength of gamma radiation decreases to below an arbitrary threshold of 0.124 angstrom or 0.124×10^{-8} centimeters, the behavior of electromagnetic radiation resembles that of particles. These particles are called photons, each with an energy in ergs equal to Planck's constant ($h = 6.625 \times 10^{-27}$ erg sec) times the frequency in cycles per second.

Compton effect: The effect resulting from a collision between a photon and an electron in the atomic structure of a material. The electron may receive enough energy to leave its atomic orbit and become a free electron, thereby ionizing the atom. The photon proceeds on a deviated course and with a lower energy.

Gamma rays: High-frequency electromagnetic radiation emitted as photons. Energy levels are expressed in million electron volts.

Million electron volts (mev): A measurement of a photon's energy, where one million electron volts corresponds to 1.6×10^{-6} ergs. For most materials, the photons' absorption probability can be assumed to be constant from about 500 kilo-electron-volts to about two million electron volts.

Ergs per gram (of material m_o): The amount of energy absorbed in the form of ionizing radiation per gram of a particular material. Carbon or water is often used as a reference. It appears as ergs/gr(m_o).

Rate of energy absorption: Ergs per gram (m_o) per second. The rate of energy absorption of material m_o. This is expressed in the literature as ergs/gr(m_o)/sec.

Photon flux: Assuming an average energy of 1 mev, this flux is often expressed in terms of absorbed dose in carbon. It is expressed as mev/cm^2/sec $= 4.5 \times 10^{-8}$ ergs/gr(c)/sec.

Time-integrated dosage: Mev per square centimeter, time-integrated dose of 1-mev photons intercepting a unit area. This appears as Mev/cm^2.

verse square of the distance can also be used to advantage[4].

Where a nuclear reactor is used directly for propulsion of the space vehicle, the comments about the nuclear power reactor still hold. However, when the reactor is to be used directly for propulsion, it is operated in different modes. When the velocity is to be changed, the reactor is programed for the required thrust, generating very high gamma and neutron fluxes during these short periods. This introduces rate or transient effects in the electrical behavior of the electronic system, caused by high ionization rates. These short-term electrical effects produce temporary degradation of performance. They can introduce false trigger signals in switching circuits, and result in a system malfunction.

Nuclear explosions

The main difference between radiation from a nuclear reactor and that emanating from a nuclear explosion is the time scale. The radiation from the explosion is delivered at high neutron and gamma dose rates, it is often referred to as pulsed radiation, as is that produced by a pulsed reactor.

Radiation levels of the magnitude given for nuclear power reactors are received within milliseconds after a nuclear explosion. The resultant transient electrical effects, produced by the ionizing gamma radiation, can cause temporary failures in electronic circuitry.

Roentgen: Often abbreviated R or r, this term specifies the amount of ionizing radiation (x-ray or gamma-radiation) released in standard temperature and air pressure. It is the quantity of radiation that produces 2.083×10^9 ion pairs per cubic centimeter of air at standard pressure, 760 millimeters, and standard temperature, 25°C or 77°F at sea level. The rate of energy release is expressed in roentgens per second.

Rad(m_o): The quantity of radiation that releases 100 ergs of energy per gram of the material. (The energy can be either x-ray or gamma-ray ionizing radiation). It is important to specify the material when this term is used. Because carbon is a common reference material, c is often found in the parenthesis.

Linear absorption coefficient (LAC) or μ: Each material has a characteristic coefficient that expresses the efficiency with which that material absorbs ionizing radiation. It can be approximated as constant for most materials between 0.5 to 2 mev's. It appears in the following equation: $I = I_o \exp(-\mu x)$
where I = dose rate or dose per unit area after penetrating x centimeters of material, and I_o = initial dose rate or dose per unit area.

Rep: A term seldom used with respect to electronic circuits. It is an acronym for roentgen equivalent physical, and expresses roentgens in terms of absorption of ionizing radiation by tissue. This absorption is equivalent to 93 ergs per gram of tissue.

Radiation Term Conversion Chart

From	To	Multiplier
Rads	ergs/gr	100
ev/gr	ergs/gr (c)	1.6×10^{-12}
Roentgen	ergs/gr (c)	87.7
Rep	ergs/gr (c)	84.6
Rad (tissue)	ergs/gr (c)	90.9
Rad (H_2O)	ergs/gr (c)	90.0
Mev/cm²	ergs/gr (c)	4.5×10^{-8}
Photons/cm²	ergs/gr (c)	4.5×10^{-8}
Photons/cm²	rep	5×10^{-10}
Rep/hr	neutrons/cm²/sec	7.1×10^4
Rad/hr	neutrons/cm²/sec	8.3×10^4
Rem/hr	neutrons/cm²/sec	8.3×10^3
(nv_o)	rad/hr	4.2×10^{-6}
Roentgen	rad (tissue)	1.036
Rep	rad (tissue)	1.074
Rem	rad (tissue)	91.29

Rem: Another tissue term, standing for Roentgen equivalent mammal. It corresponds to the quantity of radiation that produces biological damage equivalent to one roentgen of x-radiation.

The radiation-term conversion chart at the right relates the various terms to each other.

Particle radiation terms

These terms specify particle radiation. Neutron terms predominate because neutrons in their uncharged state threaten great damage to electronic systems. Neutrons can travel farther from the source, and penetrate deeper into materials, than any other particle of comparable energy.

Neutrons per square centimeter: Total of neutron particles that cross each unit of area during exposure to a radiation source; > E kev. The energy in kilo-electron-volts is a measure of kinetic energy that the neutrons possess, and is therefore a measure of their penetrating power and ability to create displacement damage in materials. Dosimetry convention calls for the energy to be given as the lower limit of a spectrum. Other particles could replace neutrons in this term; for example, protons per square centimeter, without changing the concept.

Neutron dose rate: Neutrons per square centimeter per second, > E kev.

nv_o: The total dose of thermal neutrons. These are neutrons with kinetic energies less than 0.025 electron volt or expressed in terms of their velocity, of 2,200 meters per second. This can also be expressed as neutrons per square centimeter (< E kev).

Fast neutrons: Neutrons with high kinetic energies. The energy level above which neutrons are considered to be fast is not universally established. Generally it implies energies greater than 10 kilo-electron-volts.

Kinetic energy: Expressed in electron volts, this is a measure of a particle's energy due to its mass and velocity. Since the mass is known, it is useful to calculate the velocity from

$$V = \sqrt{c^2 - \frac{c^2}{\left(\frac{mv^2}{m_o c^2} + 1\right)^2}}$$

where $m_o c^2$ = the particle rest energy (for neutrons = 931 mev)
mv^2 = particle energy in electron volts

Compton electron: An electron which, after interacting with a gamma photon by the Compton process, is removed from its atom and moves through the materials crystal structure as a negative current carrier; in the case of electrons with kinetic energy > 200 kev, it moves as a displacement-producing particle.

The integrated neutron doses result in damage to electronic systems similar to that produced by nuclear reactor neutrons. Because the gamma radiation is applied only briefly, the gamma dose from an explosion is generally less than a nuclear reactor's gamma dose at a comparable neutron dose.

Radiation effects

Before considering nuclear-hard circuit design techniques, it is important to know how radiation interacts with materials. From a radiation standpoint, an electronic system is only a collection of many materials. If the electronic designer understands the interaction of radiation with these materials, he will be better equipped to design circuits and systems to meet a specified radiation requirement.

Radiation energy may be supplied in two forms: as electromagnetic radiation, such as x- and gamma-rays, or as particle radiation. The velocity of electromagnetic radiation is equal to that of light, and its energy can be determined by Planck's law (Energy = hf). Gamma radiation is the most penetrating form of electromagnetic radiation because of its high frequency.

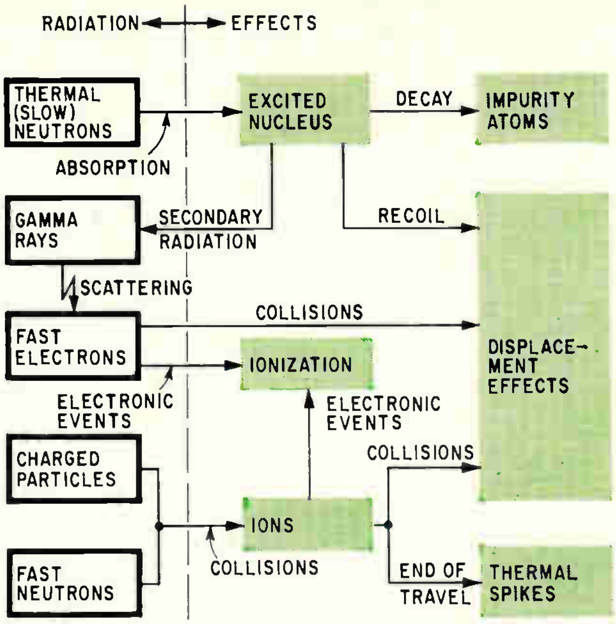
The second basic form of radiation energy includes all particles moving at speeds slower than that of light. The particles may be positively charged protons, negatively charged electrons or uncharged neutrons.

The specific nuclear environment determines the type of radiation that may be encountered. The table above compares the various environments with types of radiation. As shown, a specific type of radiation may appear as primary radiation in one environment and as secondary radiation in another environment produced by the primary radiation.

High-energy electromagnetic radiation—x- or gamma-rays—interacts mainly with the orbiting electrons that surround the nuclei of the atoms of the material upon which it impinges. There are three dominant interactions: the photoelectric effect, the Compton effect and the pair-production effect.

The photoelectric and pair-production effects result in the complete absorption and ultimately in the disappearance of the gamma photon. The Compton effect causes a reduction of gamma photon energy which, after one or several Compton interactions, is absorbed by the photoelectric effect.

In a photoelectric interaction, the gamma photon gives all of its energy to an orbital electron. The



Effects to be expected from different types of radiation

electron is raised to an orbit of higher energy, or attains enough energy to be ejected from the atom and to appear as a free electron in the conduction band of the material. The ejected electron's energy is equal to the difference between the interacting gamma photon and the electron-binding energy; the latter ranges from 2 to 25 electron volts, depending on the material involved.

The linear absorption coefficient is the sum of the three interactions. Gamma energies of 0.1 mev are the major causes of photoelectric effects. Gamma energies from 0.7 to 2 mev produce Compton effects, and these energies are predominant in a nuclear reaction. Higher-energy gamma rays (greater than 2 mev) are those that cause pair-production.

Gamma radiation interacts primarily with a material's electrons, removing these from the atomic orbits. In so doing, it creates a radiation effect of major concern to electronics designers—the ionization or transient effect.

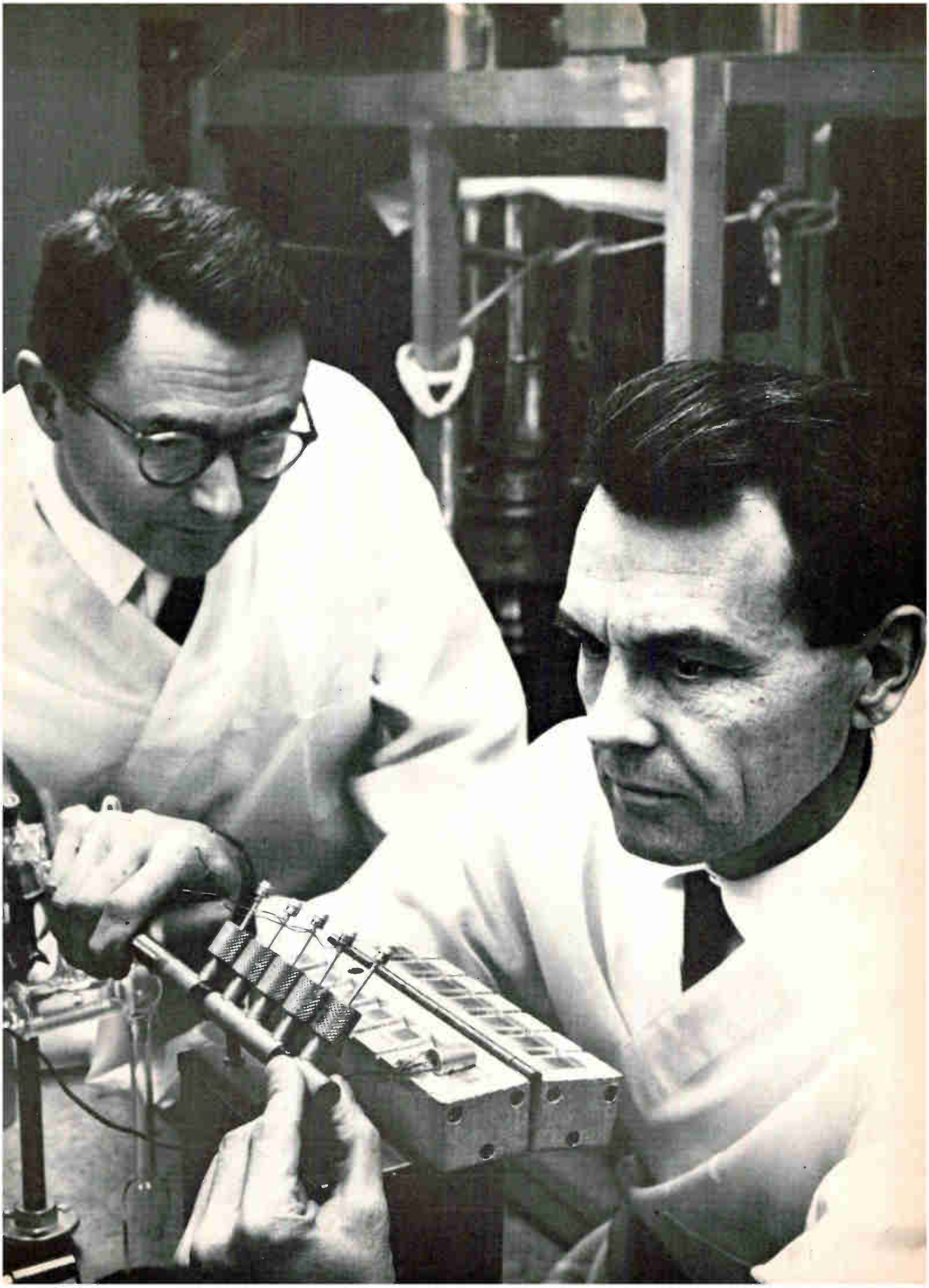
Ionization effect

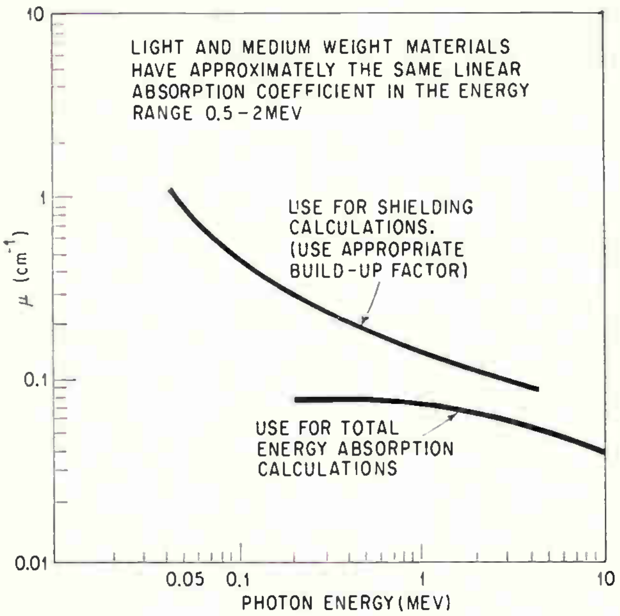
By ionizing a large number of atoms in the materials of electronic components and circuits, gamma

Solid-state pn-junction diode radiation detectors for Telstar I are shown being prepared by engineers at Bell Telephone Laboratories, Inc.

Nuclear Environment vs. Radiation Type

Environment	Gamma	Xray	Electrons	Protons	Neutrons	Cosmic
Outer Space		Primary		Primary		Primary
Van Allen Belt		Secondary	Primary	Primary	Secondary	
Nuclear Reactor	Primary	Secondary	Secondary		Primary	
Pulsed Reactor	Primary	Secondary	Secondary		Primary	





Linear absorption coefficient (LAC) of aluminum is a measure of the efficiency with which the material absorbs ionizing radiation.

photons provide many free electrons. When the circuits operate with all voltages applied, these electrons are attracted to positive potentials and spurious current begins to flow; the amount depends upon the rate at which gamma radiation is applied.

Summarizing, ionization or transient radiation effect is a short-term electrical effect associated with fast application of gamma- or charged-particle radiation. It momentarily interrupts operation of an electronic systems, but rarely causes any permanent damage to the system. The electronics designer with full knowledge of the effects and their estimated magnitude can employ design techniques to prevent erratic behavior resulting from the radiation-induced currents.

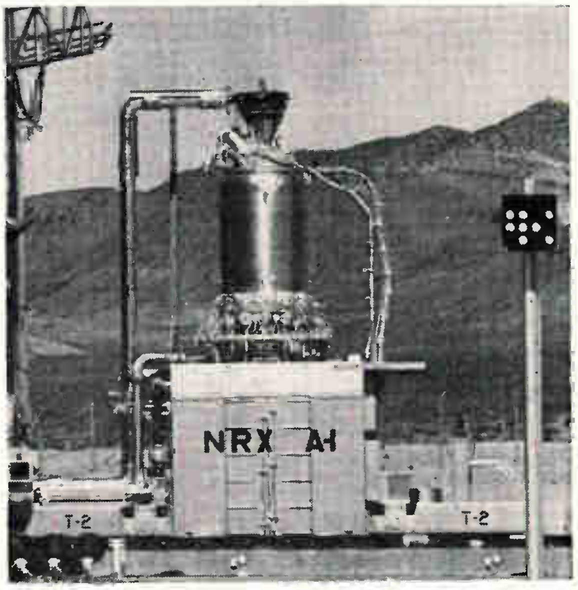
High-energy particle radiation, however, introduces permanent degradation in the operation of an electronic system. In this case, electronic components and circuits are damaged during irradiation and remain damaged when the radiation is over. This occurs when particles expend their energy by direct collision with atoms.

In materials such as semiconductors, where the bonds between neighboring atoms are weak, the affected atom receives enough energy to be removed from its normal lattice in the crystal structures.[5] This is called the displacement effect.

Displacement effect

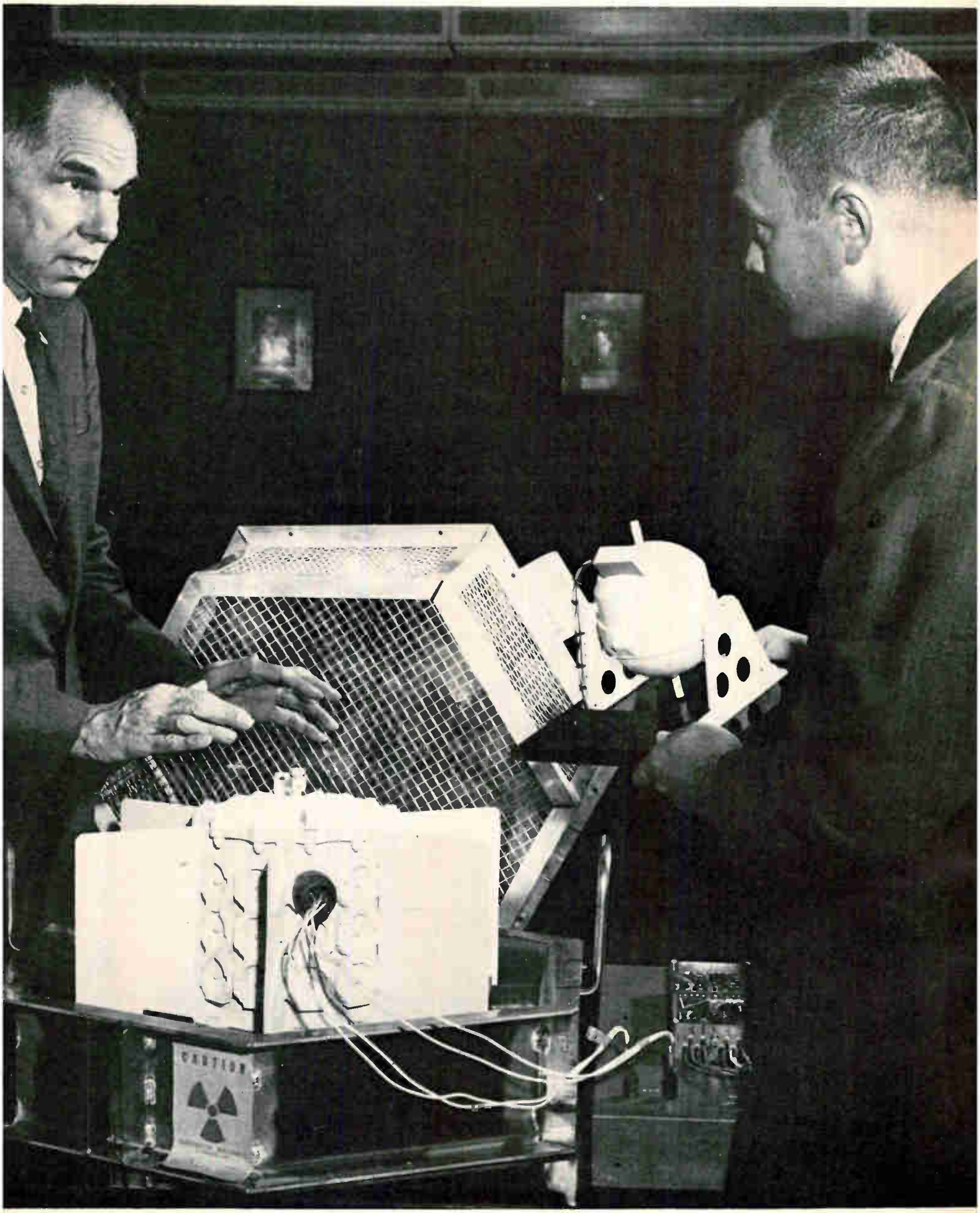
A displaced atom and the vacancy it created corresponds to the introduction of an impurity into a crystal structure. In electronic components, where electrical behavior is a function of the degree of crystal purity in component material, a large number of radiation-induced displacements can completely change the behavior of the particular component. Semiconductors are the most sensitive in this respect. The quartz crystal used as a frequency

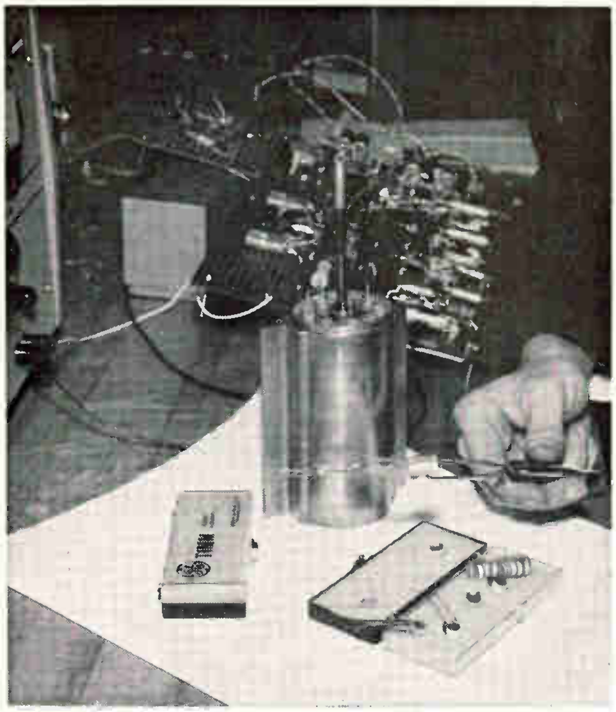
Space systems that use nuclear reactors, such as this reactor being test-fired, emit ionizing gamma rays and neutrons. Nearby circuits must be radiation-hard.



Pipe at right of nuclear reactor on test stand in Nevada contains leads attached to instruments for measuring pressures, temperatures and vibrations. Reactor controls are in building under the reactor.

Radioisotope sources, such as the SNAP-9A generator in foreground, built by the Martin Co., emit troublesome gamma radiation. Glenn T. Seaborg, chairman of the Atomic Energy Commission, at left compares the SNAP-9A with a scale model of the SNAP-3 held by Robert T. Carpenter, SNAP project engineer for the AEC.


CAUTION


Components for a radiation-hardened missile-borne amplifier undergo extensive testing at General Electric Co.'s Reentry Systems division. Metal cannister contains amplifier modules shown on the cover.

standard is also affected by imperfections in its crystal structure.

If electrons have sufficient kinetic energy they create displacements. Whether the electrons originate in the Van Allen belt or as secondary electrons produced by gamma radiation, they create the same effect. For charged particles, the interaction between the particle and the atom to produce a displacement is caused by the electrostatic force between the nuclear charge and the moving particle. A charged particle produces a displacement if it has sufficient energy for such an interaction and if it passes within the radius of the innermost (k-band) electron orbit. On the other hand neutral particles—neutrons—are required to pass within the much smaller radius of the atom's nucleus.

The electron being a charged particle, creates ionization effects. Extra current is produced by introducing free electrons into a material. Electrons must possess kinetic energies of more than 200 kev to produce displacement effects. Since electrons of energies greater than 200 kev comprise less than 10% of the total in the Van Allen belts, displacements by electrons are not of major concern.

Secondary electrons, produced by gamma-radiation processes, can attain energies in excess of 200 kev. For primary electrons with energies exceeding 40 million to 50 million electron volts, the energy is expended in materials in the form of braking radiation. This is complete conversion of the electron into gamma radiation. The threat from electrons in the space-radiation environment is more from contributions to the total ionization dose than from displacement damage.

In collisions, the transfers of energy and momentum differ vastly for heavier charged particles, such as protons, and for atomic ions with masses more than 1,000 times that of the electron. An energetic proton can interact with the material atoms in four ways:

- By collisions with atomic electrons to cause ionization.
- By collisions with atomic nuclei to cause displacements. Because of its charge, it needs only to pass inside the K-band of the atom to produce the displacement.
- By direct interaction with the atom nucleus causing transmutation.
- By creation of secondary nucleons.

The last two ways require proton energies of more than 500 mev to be important. Most displacements are caused by protons in the 10-mev region and are important because Van Allen-belt protons and solar-flare protons fall in this range. Up to 100 mev, protons also create ionization effects because of their charged condition.

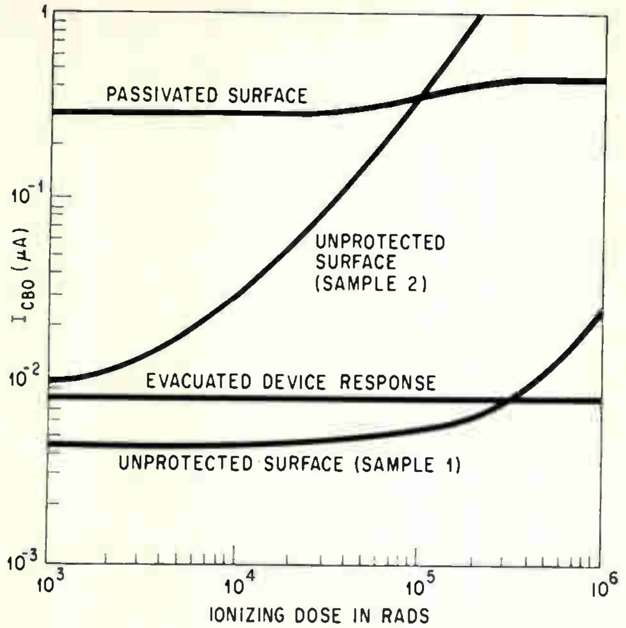
The neutron particle, because it is uncharged, can cross large distances in a material before interaction takes place. Since the neutron particle is uncharged, the interaction involves a direct encounter with an atom's nucleus. The nucleus receives a high percentage of the neutron energy during such an encounter; as a result, the atom is usually displaced from its position in the crystal structure, forming a vacancy and a shifting of atoms to where they are not expected. Quantities of neutrons large enough to produce many displacements occur in nuclear reactions. The neutrons have energies ranging from thermal energies (0.025 electron volts) up to 14 million electron volts. Neutrons with kinetic energies below about 200 electron volts cannot produce displacements in most materials. These are captured by atomic nuclei producing radioactive isotopes that subsequently emit gamma radiation.

The cross-section, or probability of displacement, for semiconductor materials increases approximately linearly with neutron kinetic energy up to the range between 200 kev and 1 mev. From 1 to 14 mev, the displacement cross-section is approximated by the square root of the energy, if it is assumed as one at 1 mev.

Neutrons greater than 10 kilo-electron-volts produce significant displacement effects. They impart enough energy to the material's atoms so that they in turn cause displacement effects on their own. Furthermore, the gamma processes may cause the material's atom to become an ion, and it behaves as a charged particle as it moves through the material.

Summarizing, the displacement effect is caused by particle radiation. It physically changes materials by changing carrier mobility and minority-carrier lifetime in semiconductor devices because of the creation of defects in the forbidden energy band, by decreasing metals' conductivity, and by changing materials' mechanical properties.

In organic materials characterized by covalent



Surface-effect response curves show the reverse current of unprotected passivated and evacuated silicon transistor devices.

chemical bonds, as in gases and liquids, the principal radiation effect is a chemical change. The chemical bond can be broken at an energy absorption of about four electron volts. The ions and free radicals that are produced react to create new compounds. These effects are minor until large amounts of ionizing radiation have been absorbed.

Teflon undergoes a process in which fluorine and other decomposition products are evolved and the polymer chains are broken. This chain-breaking causes rapid degradation of Teflon properties in a radiation environment.

However, warnings against the use of Teflon in a radiation environment have little basis. Even when Teflon is mechanically altered by radiation, it retains its basic structure. From a radiation standpoint, it behaves much better in a vacuum because the lack of oxygen eliminates one cause of degradation.

Polyethylene, another organic material with the same mechanical properties as Teflon, improves because of changes in crystal structure that are caused by irradiation. This explains the much higher damage threshold for polyethylene.[5]

Surface effect

The impact of the surface effect on the proper operation of equipment was discovered during the flights of Telstar, the first communication satellite. This effect was identified and diagnosed by the staff of the Bell Telephone Laboratories, Inc.[6] The surface effect is associated with semiconductor devices; in this family of components, transistors are damaged most. The effect is produced by any radiation source that ionizes the gas and the contaminants. The ions and released electrons are attracted to the transistor surfaces by the electric fields existing at the junction surfaces when the transistor is operating.

These ions distort the electric fields inside the transistor, causing changes in certain transistor parameters, including a rise in leakage current and a decrease in gain. The greatest effect is upon a transistor in which the junction surface is directly exposed to the gas in the transistor container, and to which bias voltage is applied. The surface-effect response curve at the right shows the reverse current of unprotected passivated and evacuated silicon transistor devices.

The radiation is applied slowly, illustrating the difference between the surface effect and the ionization effect. When a transistor has been degraded by the surface effect, it recovers only after it is removed from the radiation field, or all bias voltages are removed. However, if it is again exposed to ionizing radiation with all bias voltages applied, it returns to its previous degraded state.

After the problems of the surface effect were diagnosed, they could be alleviated. It was found that transistors with junction surfaces not directly exposed to the gas in the container—for example, devices that are protected by an oxidized layer—are not affected as severely by the surface effect. Removing the gasses within the container reduces the effects 90%. The last figure also shows the surface effect on a glass-encapsulated transistor device.

The cover
Spaceborne amplifiers, made from ceramic components, operate in a pulsed-neutron environment, giving missiles greater immunity to radiation from nuclear attack. They are the first vacuum-tube circuits to operate below 100 kc amid heavy pulses of gamma neutrons. GE's thermionic integrated micromodule components are used.

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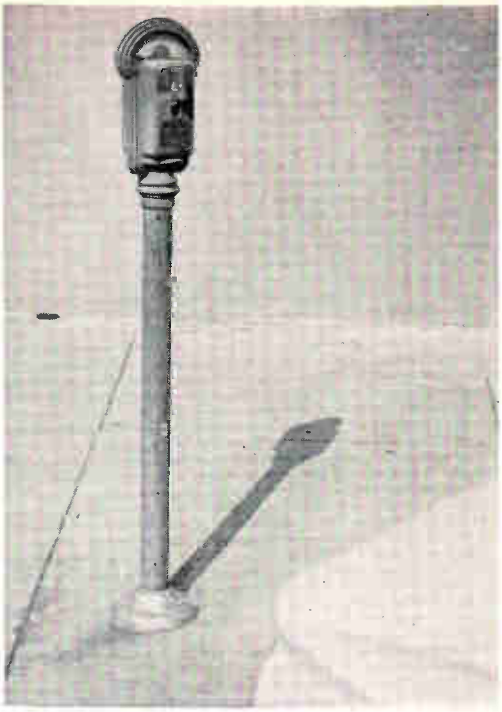
Industrial electronics

Farewell to free time on city parking meters



Device with infrared detector resets itself at zero when an auto leaves a parking space

By W.E. Osborne

Consultant, Whittier, Calif.

Whittier, Calif., is planning a counterattack against mooching motorists in search of free time on parking meters. The city has enlisted the aid of a meter whose "expired time" clock returns to zero as soon as a car pulls out of the parking space.

The meter being tested uses an infrared sensor to detect movement of a car. It operates on the same principle as a missile-tracking device.

An infrared-controlled parking meter would cost only a few dollars more than a conventional meter. Its effect on city revenues is easy to see. Not so readily apparent, but of at least equal importance, is its potential to reduce traffic congestion.

How many times have you circled the block looking for unexpired time on a parking meter?

Hot cars

Several cities have considered a system that involves a photocell placed in the roadway in front of a parking meter. When a car backs out, the change in light intensity activates a device that zeroes the meter.

This method has several disadvantages, however. It's costly to dig a hole in the street for each parking meter. Also, the system is vulnerable to spurious triggering by auto headlights, sunlight and small boys with flashlights. Dust, dirt and fog can also cause trouble.

An infrared system like the one being tried in Whittier could eliminate these troubles. Two sensing circuits have been tested: one is a straight amplifier, the other a cross between a Colpitts oscillator and a Schmitt trigger. They have performed almost equally well during trials of one week each. No false triggering occurred.

Two cars did vacate a parking space without triggering the meter. They did this by backing out in a straight line to the detection-range limit of 12 to 15 feet. However, incoming cars did zero the meter.

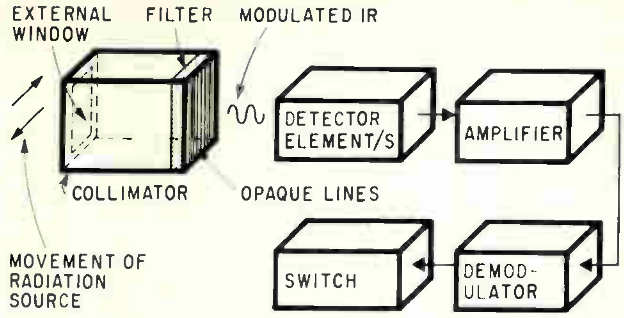
The operating temperature of an automobile engine is about 300° to 400° F. An average temperature of 350° F is equivalent to a wavelength of 6.35 microns. Although the upper response limit of an infrared-wavelength detector of lead sulfide is only 3.5 μ, about 2% of the incident energy from an auto's engine falls below 3.5 μ and provides a usable signal. The radiant energy from humans (9.3 μ at 98° F) is too weak to trigger this restricted-range receiver. But a lighted cigaret, if waved in front of the detector, will trigger the unit.

The detector

The detector, shown at the top of the next page, is mounted inside a steel pole and about two feet above the road. It is collimated for a 1° field of view of the street through a small hole in the pipe. No optical gain is provided, and the range is purposely restricted. To eliminate unwanted near-infrared radiation, filters with a cut-off at 2.5 microns are mounted in front of a 0.1-by-0.1-millimeter lead-sulfide detector. This prevents false triggering by sources of radiation, such as pedestrians walking between the car and the meter.

The filter also includes fine vertical grid lines, deep black, 100 to the inch. These lines chop the radiation produced by a car pulling out of a parking space. The chopping rate is proportional to the rate of change of the angle at which the radiation is received, the range and the number of black lines. The frequency is 10 to 25 cycles per second. This modulation component is then used to trigger a silicon switch, or unijunction transistor, that in turn activates the meter timer with a relay.

The schematic on page 73 shows the experimental amplifier with a 97-decibel gain. No re-



Detector mounts inside the pole of parking meter. Filter eliminates false triggering.

generation is used. Measured with a laboratory rig, specific detectivity, D° was 1.5 x 10^{11}. The amplifier's input impedance matches that of the lead-sulfide detector—about 500,000 ohms. Silicon npn transistors are used in all four amplifying stages. The switching stage uses a positive trigger.

How it works

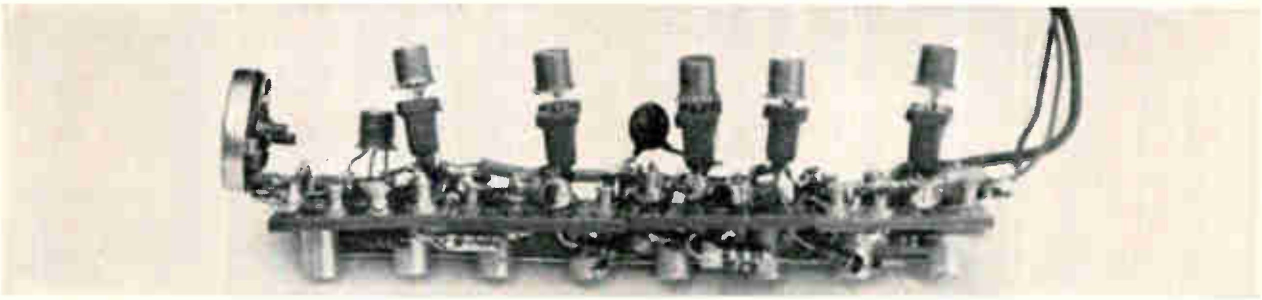
Here's how the meter works. The angular motion of a car causes the infrared radiation from the motor to be chopped by the grid lines in the receiver optics. The modulation pulses produced are stored in C_1 and amplified by Q_1. In the absence of the chopping lines, only a steady change in the infrared carrier level results when a car or other heat source irradiates the detector; no operating pulse is generated.

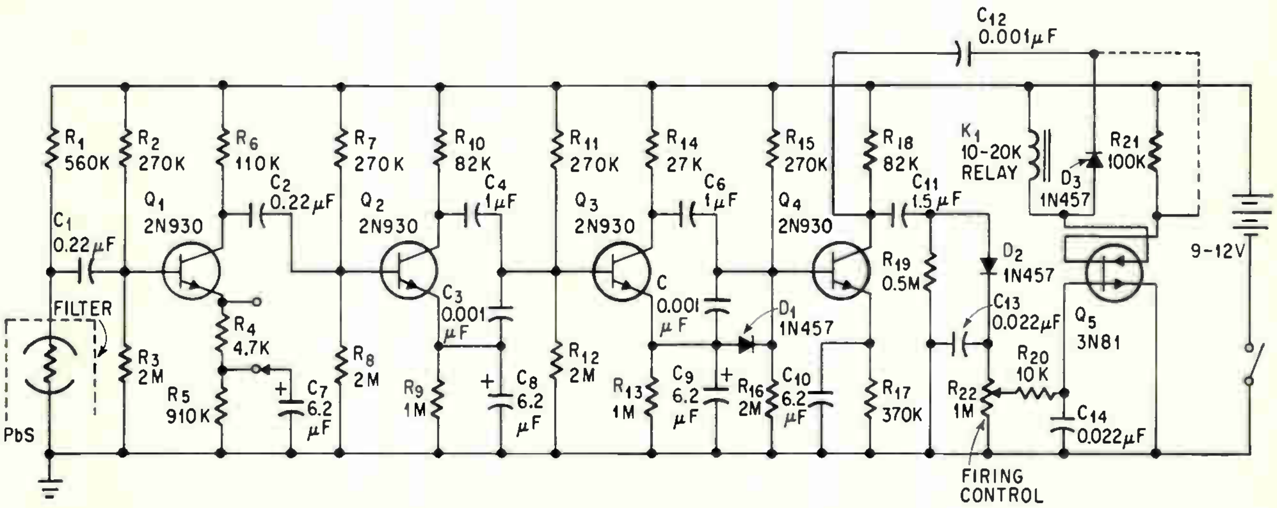
Amplifier design is straightforward, with C_3 and C suppressing any high-frequency oscillations, and D_1 smoothing out fluctuations in voltage. The infrared carrier is demodulated by D_2, leaving only the low-frequency fluctuations caused by car motion. The positive pulses at the output of D_2 are much larger (2.5 v) than the negative ones (1 v) at the junction of D_3 and Q_5. They are applied to the cathode gate of silicon controlled switch Q_5, which turns on and operates relay K_1. This in turn trips the timer of the parking meter.

The silicon switch is turned off by feeding a smaller signal, via C_{12} and D_3, to the anode of the switch. When the car is stopped, the positive pulses cease but the core of K_1 "rings," maintaining the voltage across the coil for a brief period. The negative component of this ring turns off or resets the switch. The parking meter remains zeroed until activated by the next motorist's coin.

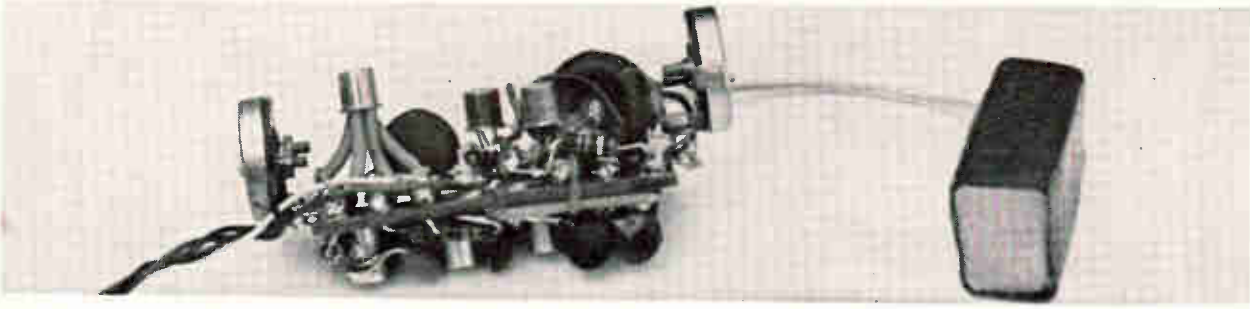
Q_1 is a high-beta, low-current 2N930 transistor. A high input impedance is obtained by suitable resistance and capacitance values. The taps on resistors R_1 and R_5 allow both input impedance and gain to be varied.

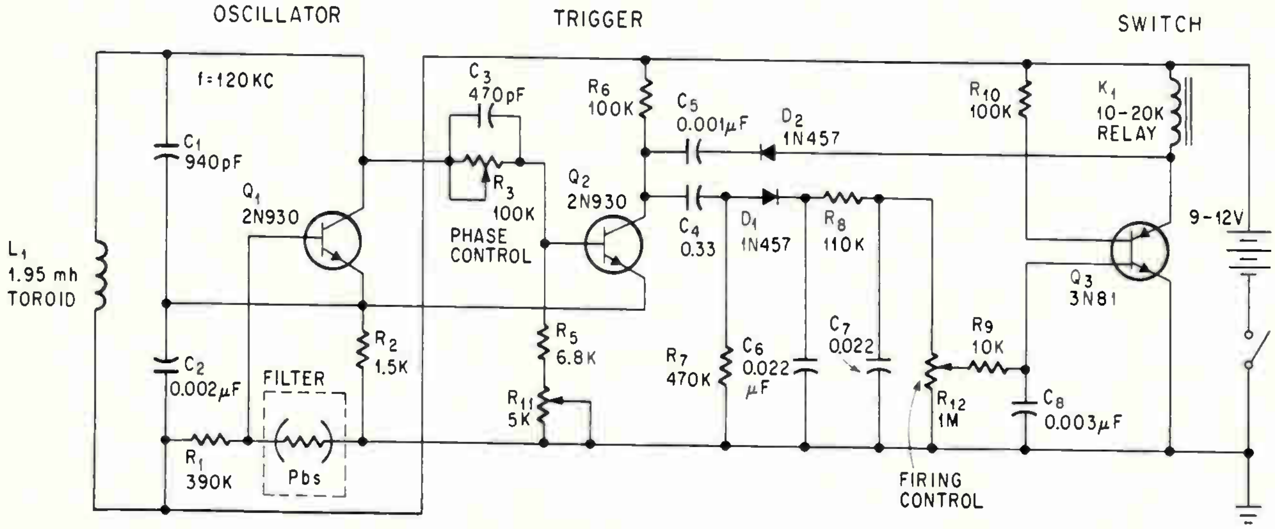
R_{17} may be replaced with a potentiometer as a gain control if C_{10} is connected to the wiper. A unijunction transistor, such as the 2N3004, can be used in place of the silicon controlled switch for higher sensitivity (around 20 microamperes) but, because it has no anode gate lead, rewiring is necessary. Using a 12-volt battery gives a gain of 101





Amplifier follows receiver optics. Silicon npn transistors are used in each stage in straightforward design. Relay resets meter to zero.





Two transistors and a silicon controlled switch are used in another system. Design is a combination Colpitts oscillator and Schmitt trigger.

decibels; maximum gain using a 9-volt battery is 97 decibels; a 12-volt supply is recommended because below 8 volts the gain falls sharply. The amplifier's noise rating is less than two decibels.

Another approach

The alternate sensing circuit shown above uses only two transistors and a silicon controlled switch. It was tested for a week after the amplifier on page 73 had been removed. This circuit is a combination Colpitts oscillator and Schmitt trigger.

In operation, R_{11} is adjusted to a point where the load of Q_2 on Q_1 barely prevents oscillation. Infrared radiation without motion lowers the lead sulfide's resistance and produces oscillation at about 120 kilocycles, although other frequencies may be used. At this point the emitter bias on both stages also drops, and the carrier signal is shunted by the combination of D_1, R_8, and C_6-C_7.

With lateral motion of the heat source, however, the resulting low-frequency modulation introduces two slight changes that together cause Q_2 to oscillate momentarily instead of just to amplify. These changes are a closer phase relationship between the two stages and a small back-up of the Q_2 output signal—controllable by the value of C_4—to cause superregeneration. A burst of modulation pulses then emerges from the RC filter to fire the silicon switch. Turn-off is obtained as before.

The frequency is not critical and a larger inductance, L_1, may be used. The sensitivity without optics is 1 x 10^{-6} watts per square centimeter. Potentiometer R_3 can be a 10,000-ohm resistor for economy.

For one-shot operation in other applications, a positive pulse on the cathode gate of Q_3 turns the silicon switch on and a negative ring in K_1 turns Q_3 off. For continuous circuit operation, C_5 and D_2 should be eliminated and a reset switch inserted in series with the cathode lead, to ground, of Q_3. For more sensitive operation, around 20 microamperes, Q_3 can be a unijunction transistor such as a 2N3004, and R_{10} must then be removed. The load may be in the anode gate circuit of the 3N81 if desired.

A 2N2646 unijunction was originally used ahead of the 3N81 for higher trigger sensitivity; later this was found to be unnecessary.

In a future model, the dry battery will be replaced with a rechargeable 12-volt nickel-cadmium type.

The author

W. E. Osborne's previous article in Electronics on infrared [Aug. 16, 1963, p. 26] formed the basis for an intruder-alarm system now widely used by the military. Osborne holds seven patents in the field of infrared. He is a consultant to several electronics companies.

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Power Rating	2 Watts at 40°C	3 Watts at 40°C
Operating Temperature Range	−55 to +125°C	−55 to +105°C
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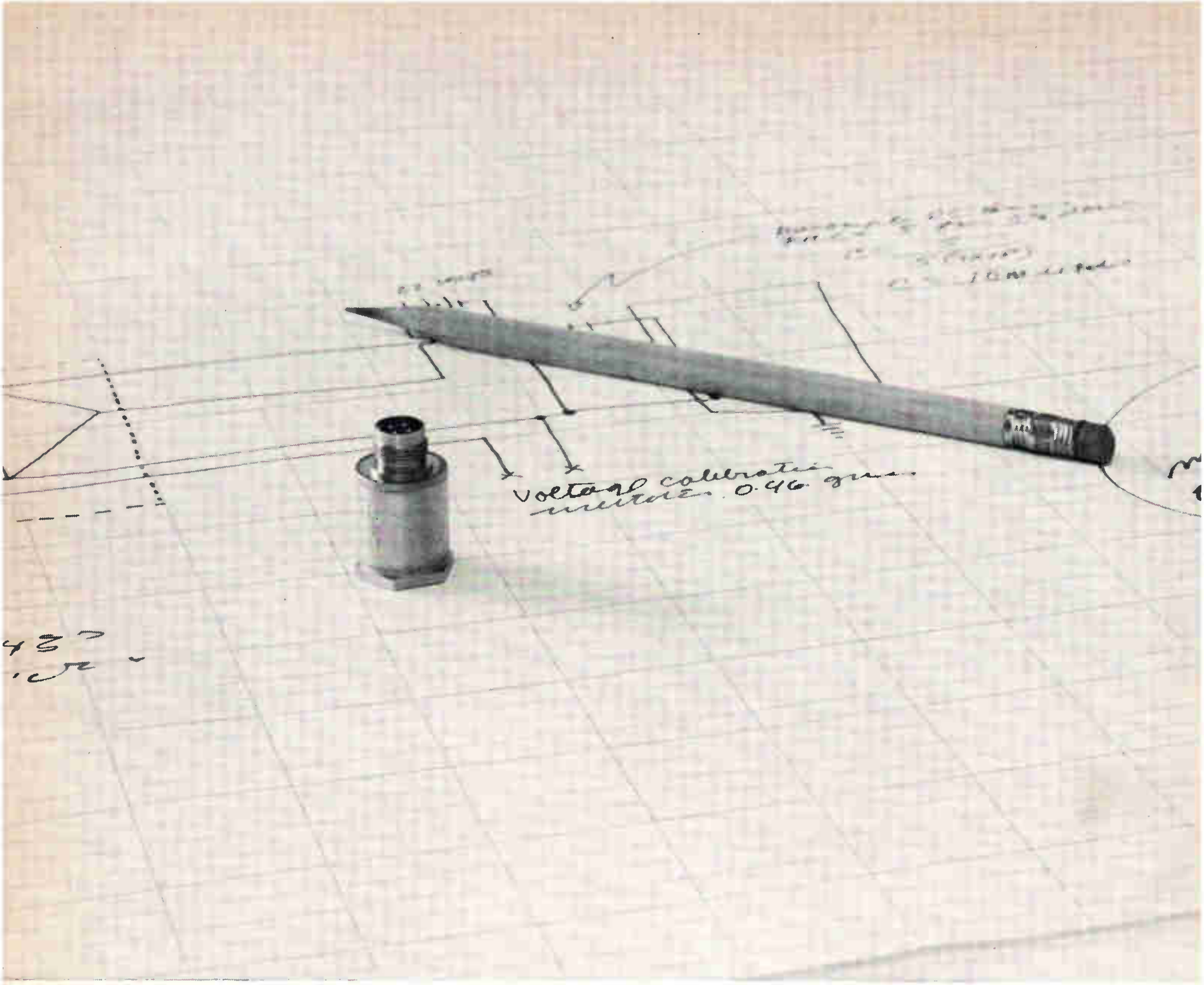

Someday, all piezoelectric accelerometers will imitate this one

It contains its own source follower, is smaller, lighter and more precise than equivalent instrumentation has ever been before.

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Circle 76 on reader service card

Military electronics

The dangerous depths

A serious threat to security is posed by enemy submarines that roam undetected beneath impenetrable thermal layers in the deep sea. Here's what the Navy is doing about it

By Seth Payne
Washington News Bureau

In Washington there is a compelling awareness of the need for effective antisubmarine warfare techniques. Continuing reports of improved Soviet underwater capability have put pressure on the Navy, the Defense Department and Congress to develop successful countermeasures without delay. ASW management has been reorganized, new funds are available for a concentrated push, and the electronics industry is being asked to meet the challenge.

The Soviet threat continues to grow. The Russian nuclear-powered underwater fleet already numbers between 25 and 30 submarines and more are being built. Some carry ballistic missiles. These ships are fast, maneuverable and quiet. They can remain deep below the surface for weeks on end, and travel at speeds of 40 to 50 knots.

Soon, however, both Soviet and United States submarines will be capable of operating at even deeper levels, beneath protective thermal layers of the sea. Detection devices now in use will not be able to pierce this thermal cover; submarines operating beneath it will be able to roam the depths unchallenged. To counter this threat, new sensors must be developed.

I. Management shakeup

Top Navy brass will run two major new offices that constitute a first step in the reorganization of ASW management. Last May, Vice Adm. Charles D. Martell was named director of antisubmarine warfare programs. He is the highest ranking officer ever to head the ASW effort, and has been given broad powers. While he is mainly concerned with policy, Martell will also set ASW requirements, establish priorities, and shepherd projects from the development stage into fleet operation. He will be the man who settles the arguments.

The second new office will be run by Rear Adm. C. A. Karaberis, manager of the ASW systems project, in the Office of Naval Materiel. His job is to get the equipment. He can ask for assistance from any branch of the Navy.

Karaberis' authority at the technical and management level is just as broad as Martell's on the policy level.

Both men report to the top—Karaberis to the Secretary of the Navy, Adm. Paul H. Nitze and Martell reports to the Chief of Naval Operations, Adm. David L. McDonald.

Careful review. There are literally hundreds of ASW projects that must be coordinated if the entire program is to be managed effectively. A technical team is now going over every ASW project funded by the Navy with a fine-tooth comb. The group is assessing each project, untangling snarls and assigning priorities.

When the job is finished, in about a month, Karaberis predicts that "Some cutting is going to be done." Word has gone out from Karaberis' office in the Navy Dept. building on Constitution Ave. that projects showing only marginal improvements over existing equipment won't be continued.

Industry can expect the same treatment from policy-maker Martell, across the river in his Pentagon office. "The fiscal 1966 budget will be heavier in research," the admiral said, "but we will be more selective in programs. Once a program has been selected, though, it will be funded heavier than in the past."

Big money. Research for ASW, now about $350 million, is expected to be increased about 10% next year.

Total spending for ASW in fiscal 1965 will be between $2.5 billion and $3 billion. Martell predicts that

Vice-Adm. Charles D. Martell sets policy and settles arguments.

spending in fiscal 1966 will probably climb to $3.5 billion.

II. Criticism

The new Navy management is going to lower the boom if industry doesn't shape up. At a Navy research symposium recently, attended by representatives of many industries, Martell complained of a lack of cooperation from business. He said the Navy "is not getting the kind of support industry is capable of giving and that other high-priority programs receive."

The admiral wouldn't be more specific, but lesser-ranking officers said the criticism was aimed primarily at the electronics industry. In guarded references, they cited the SQS-26 as an example. This is the best sonar equipment in the fleet today but, according to the Navy critics, the equipment went into operation before it was completely ready and the Navy has been plagued with maintenance problems. Future installations are expected to give less trouble.

Karaberis doesn't expect ASW problems to be solved by spectacular breakthroughs. He believes the answers will come through painstaking work along fairly conventional approaches.

While advances have been made in electronics, too few have worked their way into ASW applications, said Capt. Charles Bishop, head of surveillance and control. Microminiaturization is one example. Under the new program, the Navy and industry are trying to determine to what extent, and when, this advance can be used fully in ASW.

While many companies have demonstrated the ability to produce components, they lack experience in systems engineering, he added.

Quality control. There are problems with industry's conventional production capability, too. "One of the major technical problems we are faced with," said a top Naval officer, "is to get industry to produce equipment in conformity with specifications." The Navy wants better quality control from industry. Specifically, it wants equipment that functions well in a wide range of temperatures.

Devices to penetrate the ocean from aircraft are also urgently needed, but right now the Navy has little in the works that shows promise. Project Clinker, using infrared sensors to seek changes in water temperature caused by a moving submarine, has made little progress after years of testing.

III. Chain of command

Reporting directly to project manager Karaberis will be a chief scientist; a plans, programs and financial management director; a technical director; and a systems engineering director. They will get reports from the heads of major programs and from directors of other groups.

Karaberis expects to have his office organized and working within a year. During that time, he will have checked all of the Navy's inhouse laboratories to determine whether they're making the best possible contribution to the ASW program.

Consultant. TRW Space Technology Laboratories will be paid about $10 million a year over the next several years to provide consulting services. Its work will cover systems analysis, integration engineering, test support, technical support and engineering evaluation.

IV. Sub hunters

Because they operate in the same medium and get better results from sound equipment, submarines have the best capability for detecting other subs.

Hunting enemy subs by submarine, however, has its disadvantages. Communication between

Rear Adm. C.A. Karaberis is manager of new ASW systems project.

submarines and their own surface ships or aircraft is limited.

The use of active sonar to search out enemy subs also reveals the hunter ship's location. Passive listening by subs works fairly well, but depends on either pre-positioning or chance.

Surface ships—mainly destroyers —are the backbone of the ASW forces. Their sonars can detect submarines 5 to 10 miles away with a 50% probability factor. Sonar performance, however, is unpredictable. Sending sound through the water depends directly on the amount of power output in sound signals and on the continuously changing characteristics of water.

Navy engineers concede that they have almost reached the limits in the amount of power, or signal strength, that transducers can emit in the water.

Variable-depth sonar, lowered by cable from surface ships, gets below thermal layers. It has been in operation for three or four years. But the cable restricts its operations and the sonar is cumbersome.

Right now, the Navy has no follow-on sonar system under development. But further improvements in components for the SQS-26 and BQQ-1 systems are being made.

Bottom bounce. The SQS-26 that bounces signals off the bottom of the sea is one of the best sub detectors the Navy has on its surface ships. The General Electric Co. has a $38-million contract to build 26 of them for installation in 1967.

The Edo Corp. is building 12 more.

The BQQ-2, the most advanced submarine sonar, is installed on the latest nuclear subs.

Planar array. The most promising prospect in sonar for surface ships is a system known as planar array [Electronics, Dec. 14, p. 18]. This has been under development by TRG, Inc., of New York, since 1960 for the Office of Naval Research. Now the project has been sent to the Bureau of Ships for model testing. The first shipboard test should be made within a year.

Planar array is expected to allow the Navy to increase its sonar signal strength, give better range and bearing data, and give better signal-to-noise performance.

Barriers. While the Navy believes that its main system for hunting enemy submarines will always be based on a fleet of ships, it is experimenting with barrier types of detection. These are devices strung along the ocean bottom that pick up sound signals and alert a central control. Karaberis says that from a technical standpoint, barrier systems are good. Two such systems already in limited operation are called Colossus and Caesar.

Reading sonar signals. At the same time, the Navy is working on better detection sensors. It is also seeking electronic means of reading return signals from sonars. This is now done almost entirely by sonar operators. What the Navy would like is a signal-processing and memory system that can digitize the return signal for electronic analysis.

The service believes that target signals bounced off submarines may be lost in background noise. Electronic analysis could detect these hidden signals where human operators couldn't. Several companies are working on this requirement, including the General Dynamics Corp., Litton Industries, Inc., TRG, Inc., and Columbia University's Hudson Laboratories.

Sub defense. Ability to protect themselves and to evade detection are urgent problems for submarines in the Polaris fleet.

The gravity of the problem results from the enormous role the Defense Department has assigned to the Polaris missile. By 1970, the United States' strategic might will rely almost entirely on the Polaris and Minuteman ballistic missiles. To protect Minuteman, whose site locations are well known, the missiles are buried underground. Polaris missiles are carried deep beneath the surface of the sea in nuclear-powered submarines.

The invulnerability of Minuteman depends on how well it is protected. Will it withstand a direct hit by an enemy missile? Or does the enemy have enough missiles to knock out all the Minuteman sites? Can the powerful electromagnetic pulses from the detonation of a well-placed nuclear device knock out all the electronics in missiles waiting underground?

The invulnerability of Polaris depends on how successfully the submarine carrying it can hide from a searching enemy and how well the Navy's ASW techniques can detect and destroy an attacking fleet.

Major antisubmarine-warfare projects

A-New: A program that continually tests and evaluates new airborne ASW equipment. The goal is to integrate all the devices by a computer and centralized displays.

Clinker: The use of airborne infrared devices to detect the presence of submarines. Success has been limited, but the project will continue.

Variable-depth sonar: A sensor that can be lowered by cable from a ship or helicopter, through thermal layers, to detect submarines operating at deeper levels. The cumbersome gear slows down the craft from which it operates.

SQS-26: The most advanced sonar for surface ships, the "26" was designed to bounce signals off the convergence zone, reaching targets 30 miles away, and receive echoes from the target via the same route. The most reliable performance, however, has resulted from bouncing signals off the bottom of the sea, detecting targets from 5 to 10 miles away. This sonar will be installed in 40 or more ships.

Planar array: A new technique to mount sonar farther back from the ship's bow, to conform with the hull design. Other improvements offer promise of better information on bearing and range. The equipment developed by TRG, Inc. will be tested next year.

BQQ-2 Sonar: The most advanced sonar system used by the latest nuclear-powered submarines consists of three sonars; the BQQ-1 Sonar for long range search; the BQQ-2 for classification; and the BQG-2A for fire control.

Colossus: A barrier-type ocean-surveillance system using cable-monitored hydrophone. The network is in limited operation.

Caesar: A smaller version of the Colossus project. Caesar is in limited operation.

Nutmeg: A joint Canadian-U.S. barrier system similar to Caesar and Colossus. It is being evaluated.

Lolita: A temporary barrier system that is laid from the air. It lasts for about a week. Part of the Nutmeg project, Lolita is under evaluation.

Satellite monitoring: Although not an official program, consideration is being given to use of a satellite to monitor a large number of buoy-anchored, underwater detection devices.

Asweps: ASW environment prediction system. Water characteristics are measured by ships and aircraft, then sent to a central station from which they are broadcast to users. The system is being evaluated.

Seahawk: A high-speed ship to be built to house ASW equipment in the 1970's.

Spade: A program to update SQS-23 sonar.

Padloc: A project to develop passive sonar for surface ships. The project, which uses advanced signal-processing and display techniques, shows promise.

Puffs: An operational passive detection system for submarines.

Forac: Fleet operational readiness accuracy check sites. These are underwater calibration ranges for electronic equipment such as sonar. Two are in operation: Guantanamo Bay, Cuba, and San Clemente Island on the West Coast. Two are under construction; one near Pearl Harbor, the other off Cape Cod, Mass.

Autec: Atlantic underwater test and evaluation center in the Bahamas, near Andros Island. This range will be fully operational by 1966.

Artemis: Continuing experimentation with active sonar techniques.

Trident: A research program for studying detection techniques, using both acoustc and nonacoustic devices.

UTRP: Underwater tactical range in the Pacific Ocean. Similar to the Autec installation, this range will be off Maui Island, Hawaii. It will be ready in 1966.

McNamara's cost-cutting program: industry likes aims, not fine print

Report cards from the Pentagon will tell firms how they're doing in the drive to cut costs but industry has its own views

The Defense Department won't issue the first of its semiannual report cards assessing industry's success in cutting costs until Jan. 30 but grumblings can already be heard from several segments of the industry.

The report cards, based on guidelines established last summer by Defense Secretary Robert S. McNamara, are designed to provide the Pentagon with the first soundly based, uniform measure of industry contributions to cost-cutting. And they also are designed as a guide for the Defense Department in choosing among competing contractors for future jobs.

Although this is but one part of McNamara's vast cost-cutting program, it's expected to be one of the most important.

Profit or loss? For some companies, these report cards may spell the difference between red and black ink in their future financial reports. A company's record in cost-cutting will help determine its chances of being tapped for additional projects. And the report cards also will be used as a guide in determining fee and profit structures in negotiated awards.

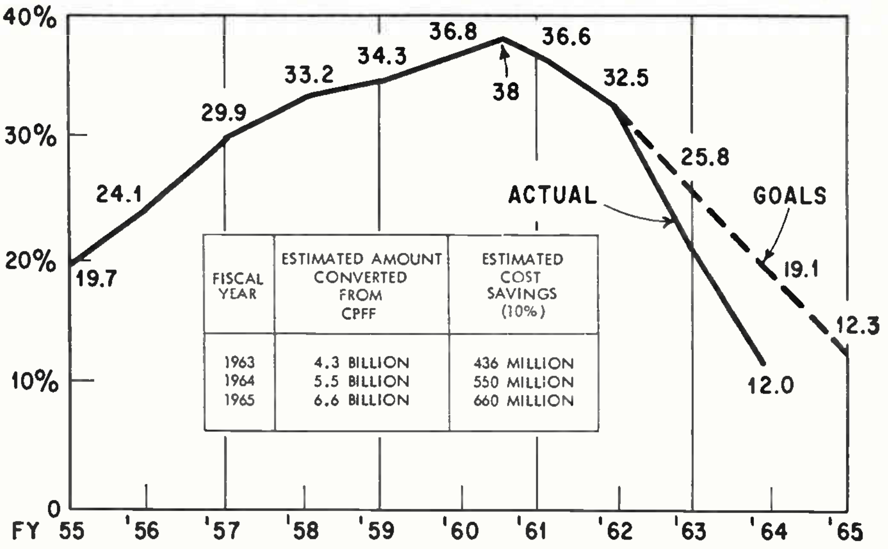
For the government, the program is designed to be a most far-reaching, continuous way of saving the military money; it will reach into all aspects of defense spending.

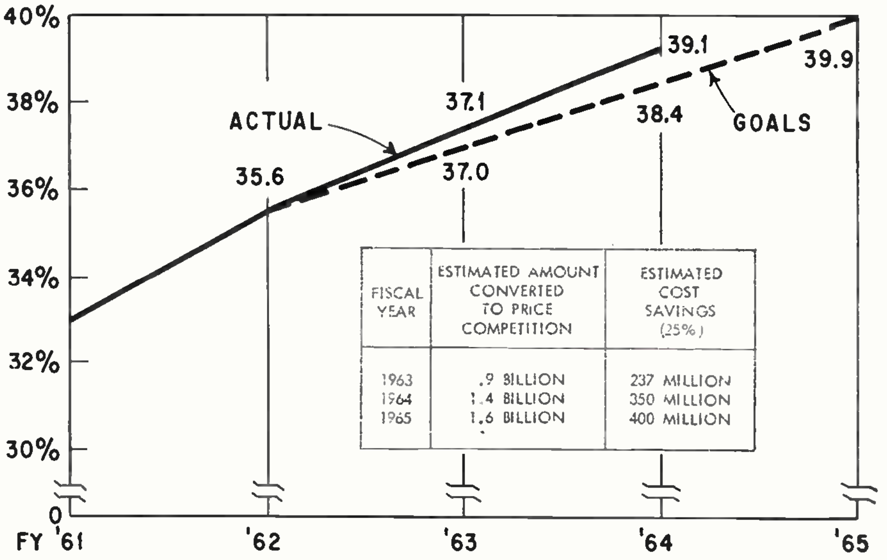
I. Monitoring program

Briefly, the program works like this:

When a contract is awarded, the Pentagon advises—critics say it threatens—a company that it's expected to find new ways to trim

Military contracts: a shift in emphasis





Dollar value of military contracts awarded on a cost-plus-fixed-fee basis, shown in top graph, took a nosedive starting in fiscal 1960, when Robert S. McNamara became Defense Secretary and shifted the emphasis to incentive and fixed-price contracts. Lower graph shows rise in the percentage of awards made on a competitive basis.

Report from
BELL LABORATORIES

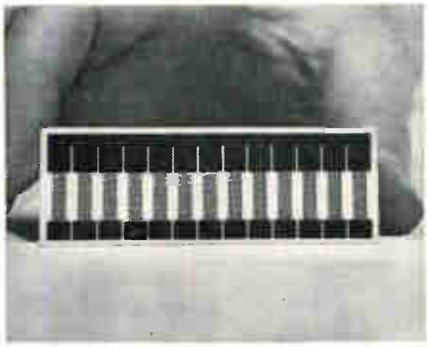
NEW MATERIALS FOR COMMUNICATIONS

At Bell Telephone Laboratories we believe that progress in communications technology depends directly on our ability to understand the fundamental behavior of materials, to synthesize new materials with special properties, to improve existing ones, and to specify their use in Bell System communications equipment. The six examples shown below illustrate research and development of this kind.

Bell Telephone Laboratories
Research and Development Unit of the Bell System

SUPERCONDUCTOR. Experimental 75 kilogauss superconducting solenoid. Wire consisting of compacted niobium and tin in a niobium jacket is wound and later heated to form niobium-tin compound (Nb_3Sn), which has a transition temperature of 18° Kelvin and a critical field greater than 200 kilogauss. Compound and wire-forming technique were developed at Bell Laboratories.

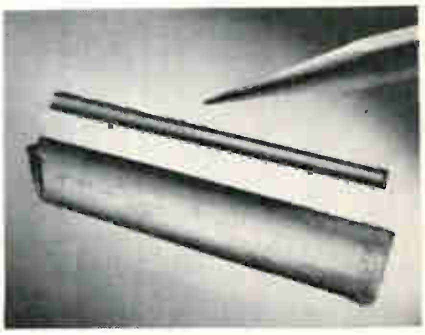
INSULATOR. Electron microscope photograph of polyethylene, 9800 diameters magnification, showing overlapping ribbon-like crystals, a structure characteristic of many polymers. At Bell Laboratories, studies of the formation of such groups of crystals have contributed to an understanding of the electrical and mechanical properties of these materials.



THIN-FILM RESISTORS. Tantalum thin-film resistors (zigzag patterns above) offer new possibilities for reliable, low-cost circuits. Bell Laboratories people discovered how to fabricate films routinely with values precise to one part in five thousand, and with expected aging during a 20-year life of less than one part in a thousand.

MAGNETIC MATERIAL. Remendur, latest member of a large family of high-performance magnetic materials developed at Bell Laboratories, is shown here in sheet form and as element of new telephone switch. A malleable, ductile cobalt-iron-vanadium alloy, Remendur has a remanence of 21,500 gauss.

SEMICONDUCTOR. Beginning in the 1930's Bell Laboratories people carried out extensive studies of semiconductors—studies that led to the invention of the transistor. Photograph shows crystals of zinc oxide, a semiconductor with piezoelectric properties, grown at Bell Laboratories by a hydrothermal method.



LASER MATERIAL. Among many materials developed at Bell Laboratories is nickel-doped magnesium fluoride, shown here as grown from melt and in polished rod form. Laser action in this material generates lattice phonons as well as a beam of coherent infrared photons.

costs. The program applies only if the military contract exceeds $5 million. The Pentagon assigns a monitor—usually a production expert from one of the military services—to evaluate the company's progress twice a year. The monitor determines the validity of each reported cost savings, rejecting, for example, savings that he thinks compromise performance.

While industry in general salutes the objectives of the program, many companies don't like the fine print.

Invasion of rights. One caustic critic, the Western Electronic Manufacturing Association, charges that "many of the implementing regulations . . . (deny) a contractor his reasonable costs and a fair profit." The association also objects to the principle behind the monitoring program. It claims a "serious invasion of the contractor's rights."

"In the past two years," the group notes, "contractors have been subjected to a bewildering and rapid change in the climate of defense procurement policy."

The changes have been rapid, with the Pentagon speeding the shift of military procurement from a noncompetitive to a competitive basis and from cost-plus-fixed-fee contracts to incentive and fixed-price agreements.

II. Challenging the specs

One of the Pentagon's pet projects for cutting costs is value engineering, a procedure that reviews design specifications to determine whether the cost of an item can be lowered or a cheaper substitute found without degrading performance or reliability.

Theoretically, a company that finds a cheaper way to produce a product shares the savings with the Pentagon.

But says Eugene L. Rogers, director of marketing of Microwave Electronics Corp., sometimes it isn't clear how a company shares in the savings. You need a good lawyer to tie down the formula in a contract, he adds.

And, he notes, there is no point in getting into value engineering unless the contractor can be reasonably sure that the effort will lead to large-scale production. The government is trying to sidestep that complaint by including a kind of royalty-payment clause in new contracts. In such a case, the company is assured that it will get part of the future financial benefit from its value-engineering program.

Who gets the cash? But despite these efforts, the association criticizes the government for expecting to take "immediate advantage of the cost reductions achieved" by a company rather than have it "accrue" to the company.

Many companies are looking at the intense cost-cutting program warily.

Too early to tell. Says the marketing head of a New England research-oriented company: "Many companies are taking a wait-and-see attitude. It's too early to tell whether you can do a research and development job for the government on a fixed-price basis without losing your shirt."

He adds that the government has undoubtedly lost some good sources because a number of concerns are reluctant to bid a fixed price on a research and development project. "Incentives are fine," he says, "but it's hard to pinpoint the incentive basis in R&D, especially in the research part."

Eitel-McCullough, Inc., an electron-tube producer, calls the government inflexible. The company, whose profit recently has been slipping despite rising sales, blames the Pentagon's cost-cutting program for causing price erosion in certain product areas. Tubes are a high-risk business, the company says, yet the Pentagon treats them like a low-risk business.

Complaints, complaints. In reply to criticism of the inflexibility of the program, George Fouch, deputy assistant secretary of defense for equipment maintenance and readiness, says that sometimes when a company does a lot of griping, it turns out it hasn't done its homework on a particular project and can't prove its point.

A spokesman for the electronics industry praises the aims of the cost-cutting program but, he explains, sometimes an eager beaver several echelons below McNamara tries to sell his pet program.

So, although some programs are models of efficiency, others cost more to operate than the money they are supposed to save. When all the programs are added up, the spokesman said, there is a question whether the cost of the operation is worth it.

FCC gets report condemning Babel on mobile radios

Study by EIA shows channels are becoming more and more crowded. Results document need for action by the regulatory agency

By Alexander A. McKenzie
Communications Editor

The Electronic Industries Association has spent about a year to document what practically everybody knew all along: land-mobile radio channels are so crowded in some areas that the signals received sound like the Tower of Babel.

But the report does furnish the radio industry and users of mobile radios with more documentation of their contention that the Federal Communications Commission should come up with a solution.

The EIA used the agency's own data on the more than two million users of mobile radios. It paid the FCC to feed the information into a computer and came up with this disheartening conclusion: The problem will get worse if the FCC licenses more mobile radios, and eventually the service will be choked off without attaining its potential of 3.7 million transmitters by 1970, although their uses have "been interwoven into the economic and social fiber of our community."

I. Shuffling channels

If nothing else, the study—detailing the degree of concentration for each channel in the country—may provide the commission with a guide to use in shuffling some existing channels to ease some overcrowding.

What the report does, in effect, is endorse the claim that a fresh approach is needed. Earlier this year, the commission set up a government-industry Advisory Committee for Land Mobile Services to look into possible solutions. One possibility is to see if mobile radio channels can operate on unused television bands. But even if the plan works, such a move would only ease the crowding temporarily.

No tricks. Aside from such sophisticated shuffling, William J. Wiesz, chairman of the land-mobile section of the EIA, said present technology can't pull a rabbit out of a hat; it can't squeeze more channels onto the limited bandwidth.

With the public's ever-increasing demand for more radios—thousands are licensed each year—the agency is faced with two immediate possibilities: continue to shuffle existing channels, or continue to split existing channels.

But channel-splitting leads up a one-way street with a dead end. Each time channels are split—cut to provide additional channels—the radio service becomes somewhat degraded. And in areas where many transmitters are situated on a tall building or a mountain, the concentration contributes to even more interference.

II. A tight squeeze

The report disclosed that over half of all licensed transmitters are concentrated in 8% of the land mass of the United States, and half of the police-radio channels are squeezed into 2% of the land area.

And in cases where users share or propose to share a channel, the FCC must set up stiff engineering standards, as it does with television stations, to avoid interference.

Is there an answer? The EIA report detailed the problems the

Line busy? Overcrowded mobile radio lines hamper communications.

FCC faces in seeking a solution—if there is one—to the overcrowding. The use of some channels is severely restricted by nearby broadcasting of television and f-m and a-m radio stations by harmonics from one mobile channel to another, and by noise.

Beyond this, weather often plays havoc with mobile radios. Sunspot activity and ionization in the ionosphere also cause interference.

Temperature inversion—in which a layer of cool air is boxed in by warmer air above it—can cause extraordinary propagation of radio waves. These conditions have been known to cause mobile radio transmitters in San Diego to interfere with others in Los Angeles, 110 miles away, although mobile radios are designed to operate in a 10- to 20-mile radius. Similar problems have been reported between stations in Washington, D. C., and western Massachusetts.

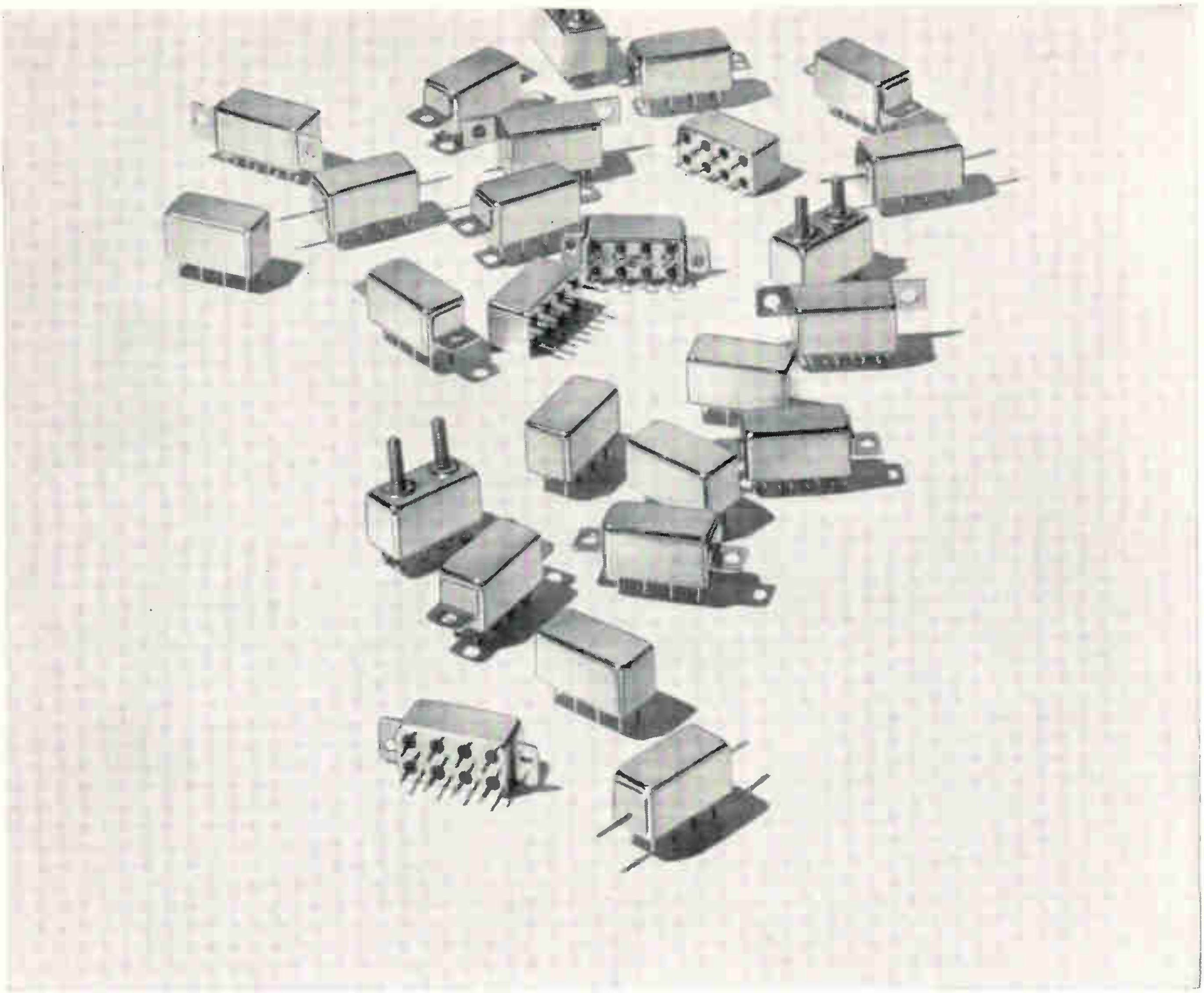
III. Feeding the computer

Because FCC authorizations for transmitters show sets' latitude and longitude, the computer had little difficulty plotting maps of the U.S. illustrating how heavily each channel is loaded. Excluding 916,000 common-carrier units, such as trucks and buses, there were 133,600 base stations and 1,949,723 mobile units licensed at June, 1963, a total of 2,083,323 transmitters when the data for the study was assembled. The analysis didn't include nearly 300,000 transmitters for which FCC lacked geographical data—nearly 14% of total.

Maps for each channel were prepared from this data, and the sum of all the maps for all the services show channel activity.

Use of maps. To see how this study might be used in determining channel shuffling, consider this situation:

In the Chicago area, the police have 11 fixed transmitters on the air full-time. These transmitters operate at 450 megacycles. But there are 2,000 mobile units working part-time, sending signals at 150 megacycles. A quick look at the figures indicates that the 450-megacycle band is little used while the 150-megacycle band is heavily used. But evaluation of the computer's data shows that the 11 transmitters are being used as intensely as the 2,000 transmitters.



The all-new, all-welded Series E relay sets a new standard of reliability

Significant improvements in reliability have been achieved in the Series E through the use of advanced electron beam welding, the elimination of organic insulating material and simplified design features.

Welding of the contacts and motor assembly directly on the header eliminates internal wiring and the associated problems. Actual fusion of metal by welding gives a stronger joint between the header and can than is possible with soldering, providing maximum stability under shock and vibration. And, complete elimination of solder flux residue insures reliability of performance in dry circuit or minimum current applications.

But, the Series E offers even more! Bifurcated contacts, for instance, provide positive contact throughout the vibration frequency spectrum. Contact bounce and resistance are drastically reduced through increased contact pressure.

And there's more! For complete details write for the Series E technical bulletin.

BASIC SPECIFICATIONS

Contact Ratings: Dry circuit, low level, 2 amp.

Shock: 100 g's, 11 $\pm$ 1 ms

Vibration: 30 g's, 10 to 3,000 cps

Temperature: $-65°C$ to $+125°C$

Weight: 0.28 oz.

Meets or exceeds Mil-R-5757

LEACH CORPORATION
RELAY DIVISION

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Solid-state receiver with modular design

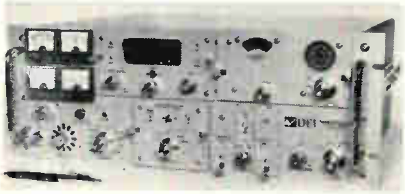
Virtually free of spurious responses, it offers an order of magnitude improvement in handling strong signals

The TR-711 solid-state telemetry receiver offers a wide choice of previously unavailable plug-in modules. Any combination of plug-in modules can be used, providing unlimited receiving combinations adaptable to any telemetry system. Tuning range is 100 to 2,300 megacycles, determined by a plug-in tuning unit.

An optional plug-in oscilloscope for monitoring video waveforms can be installed instead of the standard spectrum-display module. Modular plug-in predetection up-and-down converters are also available. A unique mixer design virtually eliminates spurious responses. These features are not available in present solid-state receivers, according to the manufacturer.

A rear-apron 30-Mc i-f input connector allows the TR-711 to be used as a 30-Mc receiver. The unit has been designed for rapid interchangeability of modules with a finger-activated release mechanism that eliminates the need for conventional thumb screws.

Full-scale deviation ranges are determined by plug-in f-m demodulators. The deviation meter is calibrated directly in kilocycles rather than as a percentage of i-f bandwidth. This eliminates the confusing mathematical computations required in receivers using percentage i-f bandwidth meter calibration to determine carrier deviation. Additionally, the deviation range switch provides high accuracy when low deviations are used in a wide i-f bandwidth, allowing the measurement or setup of individual f-m/fm subcarriers in a multiplexed fm/fm signal. The deviation meter also provides direct indication of phase modulation in degrees when a phase-demodulator module is used instead of standard f-m demodulators.

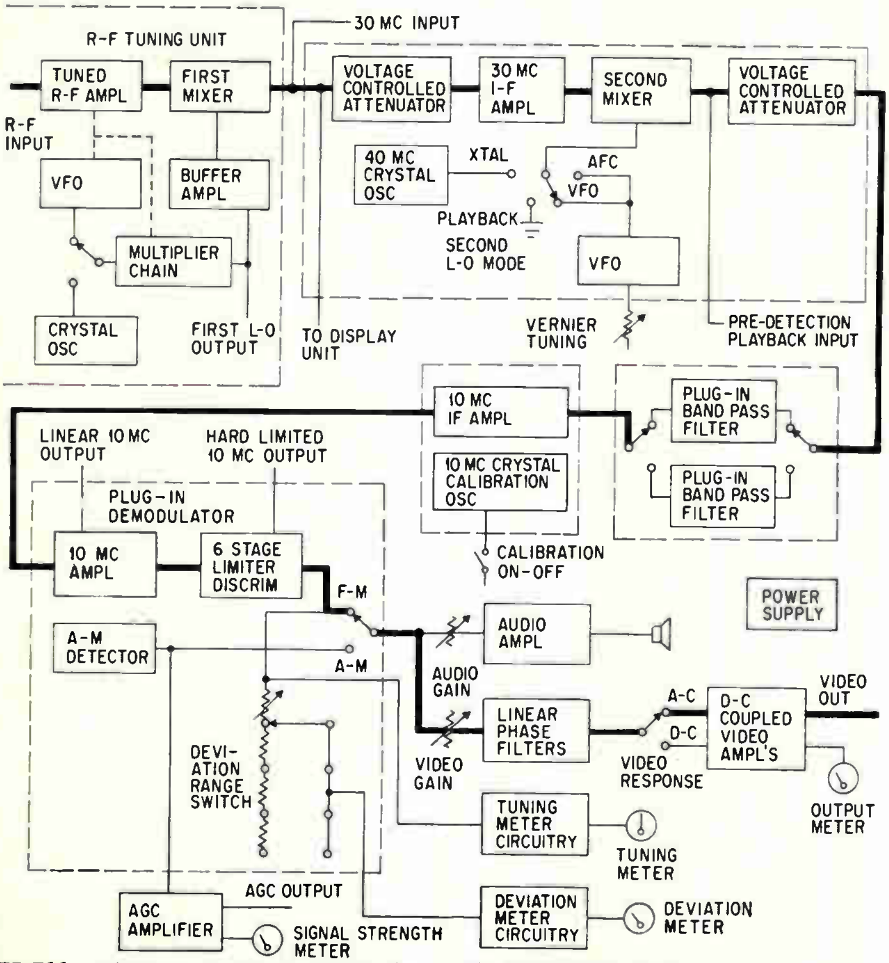


The a-m detector, used in all demodulators, is a high-level detector providing low distortion and linear operation with signals employing percentages of modulation. An a-m/f-m selector switch is provided which distributes the output of either the f-m detector or the a-m detector to the main video amplifier channel, thereby providing full video filter capabilities and aural monitoring for a-m and f-m signals.

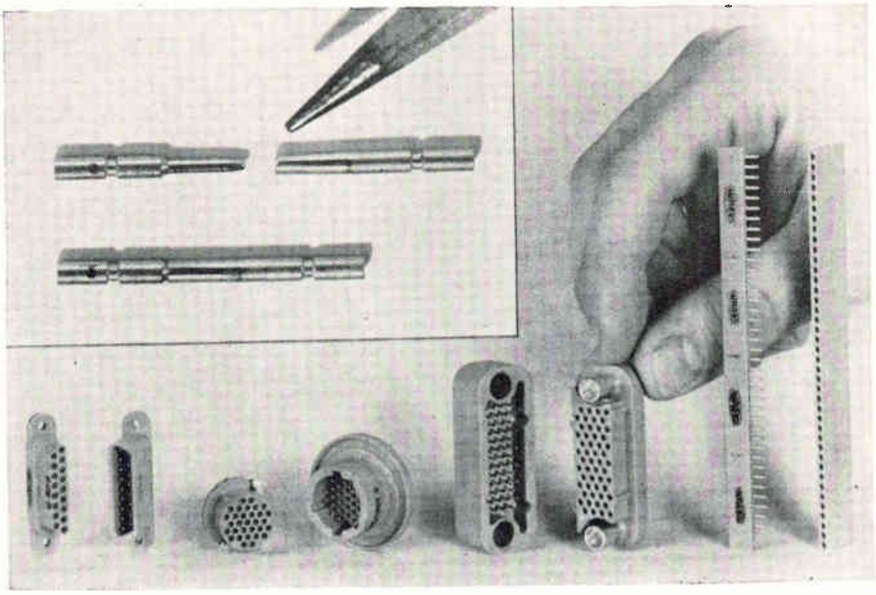
Front-panel plug-in filters are also available with 3-db bandwidth of 10, 30, 50, 100, 300, 500 and 750 kc, also 1.0, 1.5 and 3.3 Mc. Any two filters can be plugged in simultaneously, and an i-f selector switch allows for instantaneous selection of either filter.

Power transformers and reactors in the receiver are hermetically sealed, and all components are substantially derated for maximum life and reliability. The TR-711 is said to be ideally suited for aircraft, mobile van, and shipboard use.

Defense Electronics, Inc., Rockville, Md.
Circle 350 reader service card



TR-711, with heavy line representing signal going through receiver



High-retention connector contact

A high-retention contact has been developed for use with an entire line of miniature electrical connectors including strip, circular and rack-and-panel dielectric configurations. Called Relia-Tac, the contact assembly utilizes a solid pin which mates with a slotted-tube socket contact. The slotted portion of the socket contact is compressed into a tapered shape for maximum retention of the male pin. This assures low contact resistance. Relia-Tac contact assemblies are interchangeable with the manufacturer's Wire-Form contacts. They can be removed individually with a simple tool. Contacts are available with nickel-alloy sleeves for welded terminations and eyelet-type female contacts for specialized interboard connection and potted component use. They are available for welded, solder and wrap terminations.

Amphenol Microelectronics, 2837 S. 25th Ave., Broadview, Ill. [351]

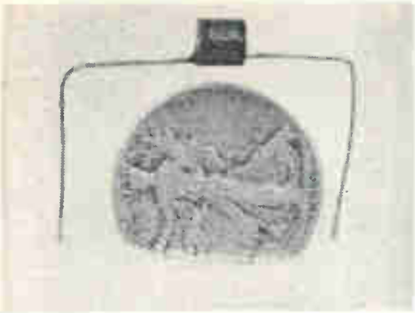
Wide-band transformers meet MIL-T-27B

Compact, wide-band transformers are being manufactured and guaranteed to MIL-T-27B. They afford 10,000 hr life expectancy operating to a temperature of 105°C. Frequency range is 300 cps to 400 kc; primary impedance, 600 ohms balanced center tapped; secondary impedance, 2400 ohms balanced center tapped; insertion loss, 1 db max; distortion, 1% max; operating level, 2 mw. This molded epoxy transformer measures 1.13 in. sq. max base by 0.75 in. max height including moisture-lock standoffs. Weight is 1.5 oz. Pin terminals are 0.040 in. diameter by 0.25 in. minimum length.

United Transformer Corp., 150 Varick St., New York 10013. [352]

Nanosecond resistors aid computer design

This ultrahigh-speed (nanosecond), wirewound resistive element features new multifilar winding and construction techniques. The manufacturer claims these Nanistors are capable of attaining speeds that were previously impossible, except with film or composition compo-



nents. Major applications are in the computer design field. Digital-to-analog conversion in computers is obtainable at clock frequencies up to 10 Mc, while maintaining the accuracy and stability previously limited to slower speed wirewound components. Nanistors are also useful where high-frequency circuitry is required. Features include shunt capacitance of approximately 0.2 pf, ambient temperature range of —55° C to 145° C, and high-reliability design. Nanistors have a mean-time-before-failure of over 10 million hours (when used within specified operating conditions), and comply with all military specifications applicable to common types of wirewound components.
General Resistance, Inc., 430 Southern Blvd., New York, N.Y., 10455. [353]

Mercury thermostat controls an oven

A mercury thermostat controls an oven of solid-state design that holds an MC-13 (HC-13/U) crystal or electronic component to within ±1°C at constant ambient. Operating differentials are much smaller than conventional mechanical and bimetal thermostat ovens. Model 572 oven measures 2.5 by 1.3 by 0.62 in. with a 1.5 by 0.75 by 0.43 in. cavity. Operating temperature range is 0 to 60°C with a wide range of oven set temperatures available. The oven will withstand 15 g vibration, meet MIL-I-6181 rfi requirements, MIL-E-5272 environment and can be used for airborne applications.
Monitor Products Co., Inc., 815 Fremont Ave., S. Pasadena, Calif. [354]

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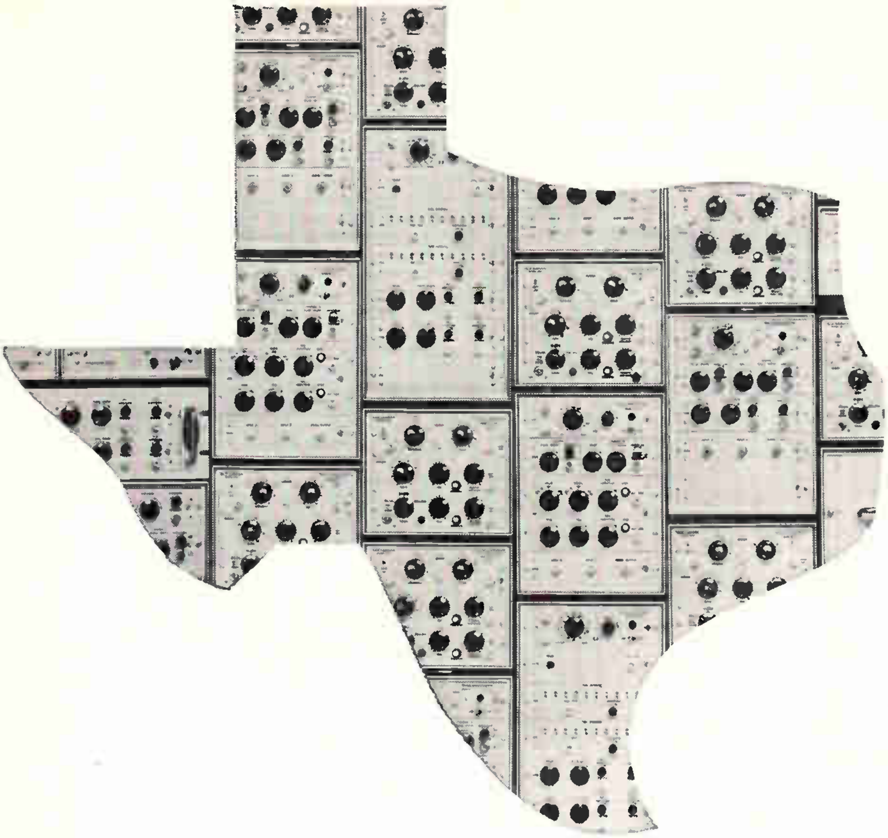
Multiapplication delay generator

A precision laboratory delay time generator, model 610, furnishes extremely short delay times. The input to output time of a pulse can be varied from 10 μsec to 1 nsec in 1-nsec increments. Provision is made for additional delay up to 0.1 sec. The unit has a wide variety of applications—trigger control of wideband oscilloscopes for nanosecond pulse measurements; for instrument calibration of delay time and sweep time, and gating speed in counters; for sync pulse control in laser and maser research; as a variable gating source in breadboarding digital circuits; and wherever extremely accurate nanosecond delays are needed. Accuracy of time delay is within ±0.5 nsec of the dial setting; jitter of output pulse when sequentially repeated is less than ±0.05 nsec. Additionally, the output pulse is variable in amplitude from 0 to 5 v and width from 20 to 200 nsec. Model 610 has all solid-state circuitry for light weight, compactness and portability. Price of the unit is $3,950.

Eldorado Electronics, 601 Chalomar Road, Concord, Calif. [381]

Instrument converts resistance to current

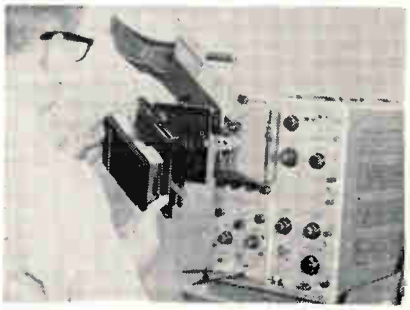
The 900 series resistance-to-current converter is a precision instrument that delivers a d-c signal proportionally controlled by an external



New Instruments

resistive element such as a three-lead potentiometer slidewire element. Three models are offered with basic output ranges of 5 and 20 ma d-c. Over-all accuracy is better than 0.5%. Zero and span trimmers are provided on this all-solid-state instrument. Back, panel, or surface mounted units are offered. Output current is unaffected by loop resistance change, making this instrument suitable for telemetry, analog recorder retransmitters, and similar applications.

InstruLab, Inc., 1205 Lamar St., Dayton, Ohio 45404. [382]



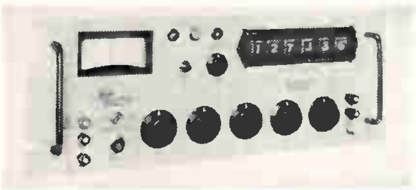
General-purpose oscilloscope camera

Type C-27 combines general-purpose utility and performance in a design compact enough for multiple stacking on 7 in. rack-mount oscilloscopes. Convenient lift-on mounting provides quick camera set-up, and swing-away hinging gives unrestricted crt viewing for normal oscilloscope operations. All controls are easily accessible. Adjustments are made without removing the camera from the oscilloscope. For efficient use of film, the back rotates for vertical or hori-

zontal positioning and also slides into any of nine detent positions for multiple-exposure photography. The f/1.9, 1:0.85 lens supplied with the standard C-27 camera offers an ideal compromise of writing rate and image size. Convenient loading and picture development outside the camera is provided by a pack-film back. Variations of the standard C-27 are possible through 7 interchangeable lenses and 4 film-backs—which permit custom designing for specific needs. Price of the standard C-27 camera is $420.
Tektronix, Inc., P.O. Box 500, Beaverton, Ore., 97005. [383]

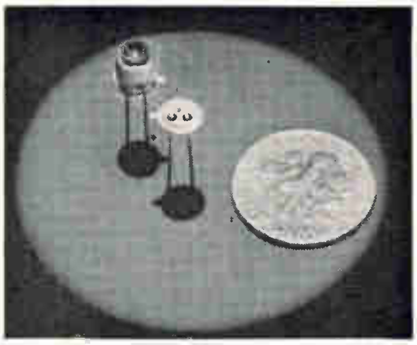
System error bridge with 6-digit readout

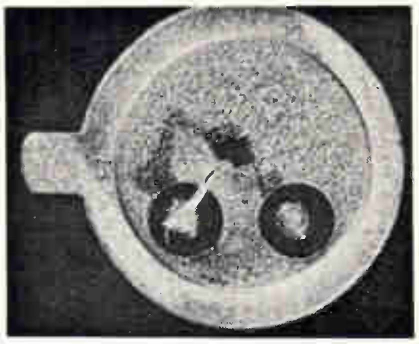
The new system error bridge, model SEB-2A, makes possible the conversion of synchro/resolver outputs to an in-line six-digit readout. Readability of 0.001° is featured over a full 360° range. The equivalent angle of synchros and resolvers is displayed without in any way loading the system under test. Widely used to measure inertial systems and precise servo systems, the instrument will also test individual synchros and resolvers in accordance with MIL-S-20708C. Measuring only 7 in. high by 19



in. wide, the system error bridge uses pure resistive elements to avoid the loading effects of conventional inductive components. It is said to be the only synchro/resolver bridge whose accuracy remains unaffected by the source impedance of the system under test. A solid-state, phase-angle voltmeter is integrated into the panel. Phase reference is not needed due to an automatic phase selector circuit. Absolute accuracy is 20 sec-of-arc regardless of system source impedance; frequency, 400 cps; price, $2,000.
Theta Instrument Corp., Saddle Brook, N.J., 07663. [384]

New Semiconductors





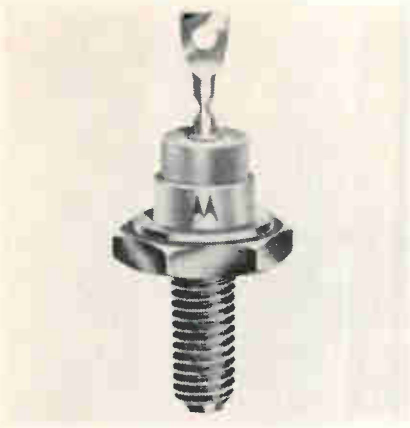
High-output GaAs light-emitting diodes

Three new gallium arsenide light-emitting diodes (LED's) have been developed with infrared output an order of magnitude higher than other commercially available IR LED's at room temperature, according to the manufacturer. This breakthrough in power is said to greatly increase the application scope for LED's. For example, in computer card readers the new diodes are well matched to present day silicon detectors and may well permit the reading of cards by reflective means. Other pulsed and c-w applications for the LED's are in security photoelectric systems, high-speed IR photography, thickness monitoring of semitransparent material, optical-coupled computer elements where it is desirable to transmit information quickly without cables, and in conjunction with a light-activated switch to give high-voltage isolation. One of the new types, the LED-10, has a minimum continuous output at room temperature of 100 μw, with a 300-μw typical output. This output is achieved with an input of 100 ma at a wave length of 9,000 angstroms and a spectral bandwidth of 210 angstroms. Pulsed output at —77°K (liquid nitrogen) is as high as 3 w (wave length of 8,450 angstroms, spectral width of 170 angstroms). Another major advantage of the new LED's is their high-frequency modulation—well above 10 Mc. This feature is particularly useful in data and communications systems where large amounts of information are to be put on light beams. The tiny LED package consists of a TO-46 header with a 20-18 style cap with lens. Height is 0.225 in.; diameter, 0.230 in. The LED-11 is essentially the same as the LED-10 except for a removable lens cap that permits designers to supply their own optics. The LED-9 is a lower output version of the LED-10. Prices for the LED-10 and -11 are $45 for 1 to 99 and $30 for 100 and up. The LED-9 is $12 for 1 to 99 and $8 for 100 and up.

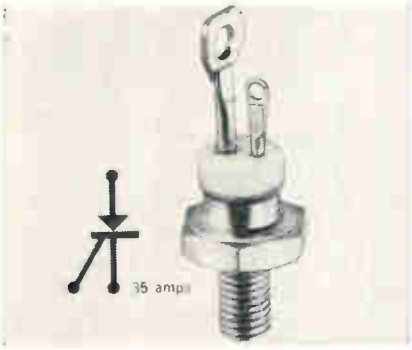
General Electric Co., Semiconductor Products Dept., Syracuse, N.Y. [371]

High-frequency power varactor

A new silicon varactor, the 1N4388, has been designed for high-frequency (to 1,200 Mc), high-power (to 25 w) harmonic generation applications. The device will double a 20-w, 500-Mc input signal with a typical efficiency of 60%. According to the manufacturer, this varactor diode has a unique graded impurity profile junction structure as compared to the conventional abrupt junction type of device. A significant characteristic of this type of structure is an enhancement of nonlinearity accomplished by the fast recovery of minority carriers stored during forward voltage surge. This action results in better



efficiency retention at high-power levels, and less distortion of amplitude-modulated signals. The 1N-4388 is available in the stud-mount DO-4 package. Prices are: \$42 (1-9), \$35 (10-99), \$28 (100 and up).
Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix, Ariz., 85001. [372]



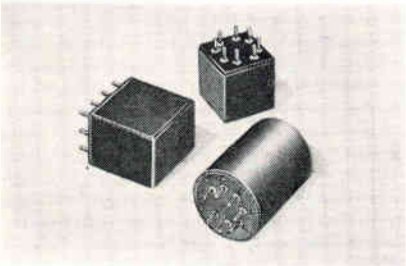
Scr's provide high surge ratings

A new series of 35 amperes rms, 22 amperes average, silicon controlled rectifiers provide surge current ratings up to 150 amps. The 2N681 series also offers 12 transient peak reverse voltage ratings from 35 to 960 v, peak forward gate current of 1.2 amps, peak reverse gate voltage of 5 v, peak forward gate voltage of 10 v, peak gate power of 5 w and average gate power of 0.5 w for all units in the series. Temperature ratings on the devices range from −65°C to 150°C. The scr's have all-welded TD148 case construction with glass-to-metal hermetic seals, and all their internal joints are hard soldered for maximum resistance to internal stress.
Tung Sol Electric Inc., One Summer Ave., Newark 4, N.J.[373]

Commutators designed with FET's

New low-level, field-effect commutators and multicoders are announced. Capable of sampling differential signals down to a 5 mv full-scale range, the type 360 units have been developed so that the current fed back to the signal sources is virtually eliminated. In the −25°C to +85°C temperature range, for example, backcurrents will not exceed 0.01 μa during signal "off" time, and ±0.10μ during signal "on" time—many times lower than was possible before, according to the manufacturer. Offset voltages of type 360 units are said to be inherently lower than conventional transistor counterparts. Silicon semiconductor design provides high accuracies, long service-free life, and extreme environmental capability with respect to shock, vibration, acceleration and temperature (−55°C to +110°C). Variations in the 360 type of unit provide for straight commutation, IRIG, PAM and PDM output formats, and a PDM record output for direct entry into a tape recording head. Standard units may be specified to have 30, 45, 60 or 90 channels, and a pulse repetition rate of either 112½ or 900 pps, stable to within 1%. Standard features include the ability to withstand high signal overvoltages to 35 v, low noise, minimum crosstalk, and small drain on the 28 v d-c power source. Approximate size is 35 cu in., and weight, fully encapsulated, is about 36 oz for a 30-channel PAM commutator.

Dynaplex Corp., P.O. Box 341, Princeton, N.J. 08540. [401]



Epoxy-encapsulated resistor network

A miniature, prepackaged resistor network is announced for use in analog computer circuits, voltage dividers, summing networks, resistance-capacitance networks, and similar applications. The Dav Pak is said to be the smallest standard resistance network available, with matching tolerances as low as 0.002% and molded-in pins for increased strength during assembly. As a result of placing the entire resistor network into one epoxy encapsulated unit, each module can be assembled faster than any one single axial-lead component. This greatly reduces the chance of assembly damage to critical components. The Dav Pak also eliminates completely the problem of matching resistors, since all prematched components are placed permanently into one encapsulated unit. And since there are fewer components to store and inspect, there is a considerable saving in assembly and inventory time and cost. Dav Paks are available with resistance tolerance to ±0.005 ohm: resistance ratio match to ±0.002%; temperature coefficient of ±2 ppm/0° to 60°C; temperature coefficient match of ±1 ppm/0° to 60°C; stability of ±0.002%; and rise time of less than 0.1 μsec. Dav Paks operate at temperatures from −65°C to +145°C. All units exceed the requirements of MIL-R-93 for short time overload, humidity, moisture, salt-water immersion, temperature cycling, dielectric strength, shock, vibration and low-temperature operation.

Daven Division of McGraw Edison Co., Livingston, N.J. [402]

Magnetoresistance analog multiplier

The new series 3051 magnetoresistance multiplier uses feedback methods in conjunction with two accurately matched magnetoresistance bridge circuits to achieve 0.1% accuracy over a wide dynamic range of input signals. Multiplier output is 2 v peak to peak without amplification and the operating temperature range is $-55°C$ to $+85°C$. Three analog input signals can be handled simultaneously by this unit in accordance with the relationship: output $= A \times B \div C$, where A, B and C are the three independent inputs. One single multiplier can therefore multiply and divide simultaneously. Developed for process control applications, analog computation, data manipulation and high accuracy wattmeters, the multiplier provides an order-of-magnitude better accuracy than comparable nonfeedback versions. External operational amplifiers are used to close the feedback loops. Series 3051 develops 2 v p-p output for 24 v applied to the output bridge and 20 ma through the magnetic coil. Frequency range for the magnetic circuit is d-c to 1 Mc using standard coils, higher with special coils and ferrite core. Resonance principles used to neutralize coil inductance permit frequencies to 100 kc. The bridge circuit, using 1,000 ohm magnetoresistors, works from d-c to 1 Mc. Packaged in a can 1$\frac{1}{16}$ in. high by 1$\frac{5}{8}$ in. square, the multiplier weighs 6 oz. It is priced at $185 each.

American Aerospace Controls, Inc., 123 Milbar Blvd., Farmingdale, N.Y. [403]

Compact, C-band radar transponder

This crystal video radar transponder has been designed for use in missiles and target drones. It weighs 3 lb and measures 2⅝ in. square by 7⅛ in. long. It is built to withstand the rough environmental conditions inherent in missile applications. The transponder's receiver is tunable from 5,400 to 5,600 Mc with a sensitivity of —45 dbm over the entire range. The transmitter can be tuned from 5,500 to 5,750 Mc and has an output of 50 w minimum. Removable access plugs permit both receiver and transmitter to be tuned externally. The standard unit employs a double pulse interrogation signal, but decoders for 1 or 3 pulse signals are available. Entirely transistorized except for the transmitter tube, a ceramic triode, the model AN/DPN-65 features a solid state modulator with a recovery time of less than 20 μsec. A four-part circulator is provided for duplexing and for transmitter protection. Power input for the standard model is 7.5 v d-c but the unit can be obtained for use with a 28 v d-c input. Power drain is 15 w max. The regulated power supply is designed to operate at temperatures between —40°C and +70°C. It can withstand vibrations of 25 to 2,000 cps at 12 g, accelerations up to 80 g, and an impact of 100 g in all directions. Quantity prices for the model AN/DPN-65 begin as low as $1,975.

Aero Geo Astro Corp., Edsall and Lincolnia Roads, Alexandria, Va., 22314. [421]

Co-ax power divider covers broad band

A three-port resistive coaxial power divider is offered for applications over the frequency range from d-c to 10 Gc. Model 1506 uses a newly developed resistive film that has a low temperature coefficient, the ability to withstand pulse power, long term stability and physical ruggedness. Well matched on all three ports, it has a maximum vswr of 1.25 up to 10 Gc. Insertion loss between input and one output arm is 6 db nominal, —0.2 db + 1.2 db maximum at 10 Gc. Phase difference is 0° nominal between output arms with maximum asymmetry of power division 0.2 db to 4 Gc, and 0.35 db to 10 Gc using type N male connector as input and type N female connectors as outputs. Calibrations are supplied on a permanently attached nameplate at d-c, 3, 6 and 10 Gc. Price is $135 each.

Weinschel Engineering, Gaithersburg, Md. [422]

Coaxial isolators in small packages

Two new, high-ratio coaxial isolators are available. Both units feature extremely high isolation and low insertion loss in minimum size packages. Model LS10JI covers the frequency range of 1.7 to 2.4 Gc with 60.0 db minimum isolation, 1.0 db maximum insertion loss and

a maximum vswr of 1.20. Size is 7¼ in. long, 4 in. wide and 1⅛ in. high. Weight is 3¼ lb. Model C35JI, for the 5.4 to 5.9 Gc range, has 60-db minimum isolation, 0.8 db maximum insertion loss and vswr of 1.20 maximum. Dimensions are 3¼ in. long, 2 in. wide and ⅞ in. high. Weight is ½ lb.

E&M Laboratories, 7419 Greenbush Ave., N. Hollywood, Calif. [423]

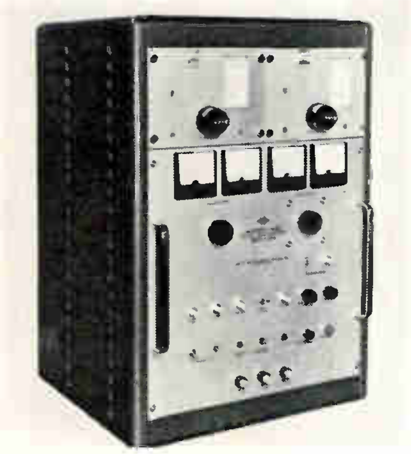
Precision attenuators for 26.5 to 140 Gc

These new precision attenuators are designed to provide accurate, frequency-insensitive millimeter attenuation measurements. The units permit the accurate measurement of isolation, coupling, insertion loss, and gain. Other applications include the calibration of radiation pattern recorders and bolometer amplifiers, and the setting of signal source power levels. The series 510 instruments are compact, self-supporting test devices, designed in six waveguide sizes for laboratory operation over the 26.5 to 140 Gc range. Variable attenuation is accomplished by rotation of a resistive vane mounted in a section of circular waveguide. Attenuation is insensitive to frequency, and depends solely on the angle of rotation. This rotary vane operation provides highly accurate attenuation values across the full waveguide bandwidth, and permits the

use of a direct-reading calibrated drum readout. The vane consists of a formed mica card, coated with a film of resistive material. The card is secured in grooves in the interior waveguide surface, and the entire section is rotated about its longitudinal axis by a precision, anti-backlash gear drive. Ball bearing mounting ensures smooth rotation with minimum friction. The readout mechanism is coupled directly to the drive shaft to minimize errors between attenuation setting and indication. The drum is calibrated in decibels by means of a photoetching process. Tapered input and output rectangular-to-circular transitions provide a highly efficient energy transfer with negligible reflections and loss. These transitions are terminated in standard waveguide flanges.
TRG Inc., 400 Border St., East Boston, 28, Mass. [424]

Microwave triode is pulse signal source

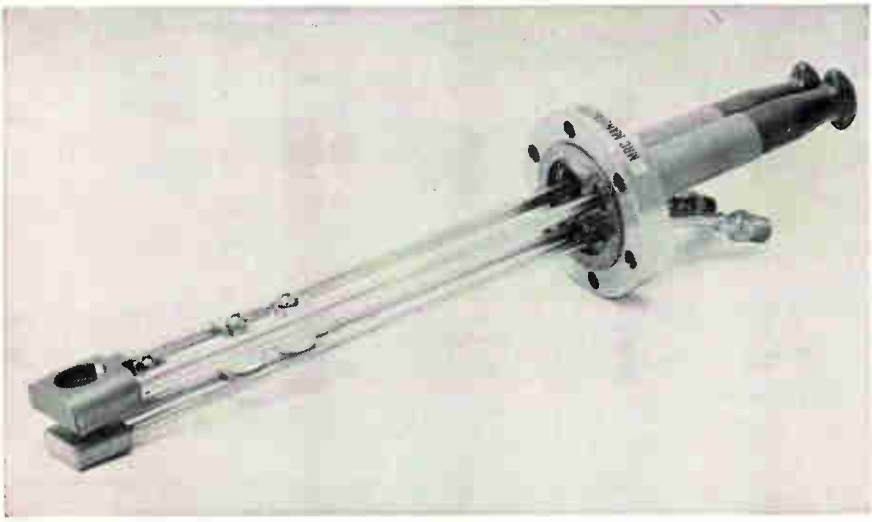
A new pulse signal source is said to supply the highest pulse power currently available from triodes in a standard instrument. Typical power is 15 kw in L band, 10 kw in S band and 2 kw in C band.



Plug-in heads permit frequency coverage from 100 to 6,000 Mc with excellent resolution. Pulse widths are available from 0.1 to 25 μsec. The completely self-contained instrument includes many metering, monitoring and safety features.
Applied Microwave Laboratory, Inc., 106 Albion St., Wakefield, Mass. [425]

Circle 99 on reader service card

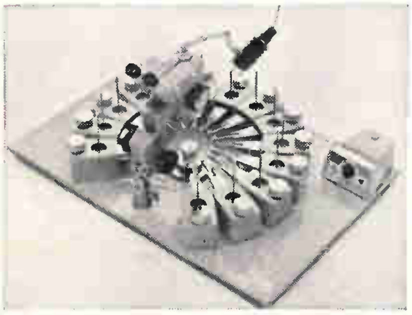
New Production Equipment



Electron-beam gun for vapor deposition

A new, work-accelerated electron-beam gun is said to represent the latest development in vapor deposition. The V4-200, designed to produce thin metallic and nonmetallic films in high vacuum, is able to achieve temperatures in excess of 3,600°C for controlled evaporating of such refractory materials as tungsten, tantalum, carbon and metallic oxides. Under the work-acceleration principle, a beam of electrons flows from an emitter (filament) to an anode (material). Upon striking the material to be deposited, the electrons release their kinetic energy, causing heating. The material holder is a water-cooled pedestal. Both pedestal and electron-beam filaments are replaceable and can be supplied in various materials. The manufacturer claims that operations with the V4-200 are simpler than with the self-accelerated guns, and costs are lower. The V4-200 is available for use in 12 in., 18 in., and larger bell jar systems. The gun is mounted on a vacuum flange with Viton "O" rings, or a copper gasketed seal for ultrahigh-vacuum systems. The unit can be used with the company's standard vacuum collars, which will accept up to 50 different types of feed-throughs. The company also provides a new electron beam power supply, model V4-3000, for use with the gun. The power supply is a high reactance type unit with a specially developed electron beam transformer package which is short-circuit proof (and carries an unlimited three year warranty). One power supply can operate several guns simultaneously. The guns cost approximately $400, and the power supply, $1,700.

Materials Research Corp., Orangeburg, N.Y. 10962. [451]



Test station for microcircuits

A new series of test stations is announced for testing diodes, transistors, integrated and thin-film circuits in slice and dice form. Model D-1400 test station incorporates 14 micropositioners, operated by a single joystick handle. Each DR-100 micropositioner can establish an almost instant probe contact to areas as small as 0.0005 in. in diameter, reducing testing time to a bare minimum. Stations can be equipped with any number of micropositioners. Also, individual micropositioners are available. Stations are recommended for testing on laboratory, as well as production scale.

The Dumas Instrument Co., 2950 Baker St., Costa Mesa, Calif. [452]

Controlled-environment work stations

A complete line of complementary units provide high-caliber clean room atmospheres for every step in the processing of microcomponents. The Sterilscope units are available for every phase of production requiring a controlled environment for high reliability and quality. Different Sterilscope units are designed for washing, drying, machining, assembly, testing, inspection and packaging. Used together, they compromise a harmonious and efficient assembly line operation. Special units can be made for specific functions. Used singly or in small numbers, Sterilscope units are in effect localized, small-space clean rooms. They can be combined in larger numbers to perform all the functions of expensive clean rooms at considerable savings. Sterilscope units meet the highest standards of cleanliness, including both Federal Standard Specification No. 209 and USAF T.O. 00-25-203.

Metalab Equipment Co., 270 Duffy Ave., Hicksville, N.Y. [453]

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New Materials

Oil-resistant filament tape

An oil-resistant, filament tape has been developed for Class 105°C continuous temperature operations. Known as Scotch brand electrical tape No. X-1146, it is designed as a tough holding and insulating tape for use in oil filled transformers and other components immersed in or exposed to hydrocarbon based oils. X-1146 has a backing of acetate film, reinforced with glass filaments. It is coated with a special thermosetting, pressure-sensitive adhesive, developed specifically for maximum resistance to hydrocarbon oils. A temperature of 266°F for 30 minutes is all that is required to completely thermoset this tape. Thermoset samples of this tape applied to polyester film have been immersed for 100 hours in No. 10 transformer oil at 100°C, after which adhesion to the film averaged 30 oz per in. width, per ASTM D1000 test procedures. Repeating the identical test on steel, the adhesion was 48 oz per in. width. X-1146 has an electric strength of 5,500 v. The tape is 8 mils thick and has a tensile strength of 250 lb per in. width and adhesion to steel is 40 oz per in. width, as measured by ASTM D1000.

3 M Co., 2501 Hudson Road, St. Paul, Minn. 55119. [441]

Polyurethane resin features toughness

The combination of exceptional toughness and room-temperature cure, said to be unprecedented, is offered by Stycast CPC-16. This two-part solid urethane casting rubber has been extensively tested against epoxies and other urethanes for both physical and electrical characteristics. In encapsulation applications, it induces minimum stress on embedded components when subjected to —40°C. The product is available in a clear amber or in various opaque colors. After mixing it gels at room temperature in 4 hours and cures in 16 hours. Its working viscosity is sufficiently low to permit vacuum impregnation of coils, or the encapsulation of intricate modules. The cured material shows excellent adhesion to a variety of materials. Among its properties are: hardness of 75 Shore A; tensile strength, 3800 psi; elongation, 160%; and brittle point, —80°F. Stycast CPC-16 is available in the 2-lb experimental kit, in 1 gallon or 5 gallon containers. In quantity it is priced in the $2-per-lb range.

Emerson & Cuming, Inc., Canton, Mass. [442]

New Books

Superconductivity

Theory of Superconductivity
John M. Blatt
Adademic Press, Inc.,
1964, 486 pp., $12.50.

This is one of several books on superconductivity that have appeared in the last couple of years. Such is the natural result of, first, a major breakthrough in the theoretical understanding of superconductivity and, second, technological advances that give superconductivity a potential for important industrial applications. The present book is concerned mainly with the former aspect of the subject, although it also touches on a number of points directly related to the applications.

Prof. Blatt has a lively style of writing, and his reputation for clarity in explaining difficult concepts will certainly not be diminished by this book. Inasmuch as he was one of the leading figures in the development of the "Australian school" of superconductivity theory, with its stress on the Bose-Einstein condensation, it is not surprising that the derivation and discussion of the microscopic theory is from this point of view. Since this is not the orthodox approach to the subject, his book is unique among the several that have recently appeared. Since this variation of approach is concerned only with the foundations of the theory and not with results or applications, this should not frighten away those who are interested only in the mainstream.

The first chapter is a review of the basic experimental facts concerning superconductivity. In the preface it is stated that the book "presupposes a first course in quantum mechanics." Although this is true for most of the treatment, the first chapter can be read with profit by anyone seeking a clear, concise introduction to superconductivity.

The next four chapters on "The Bose-Einstein Gas Model," "The Quasi-Chemical Equilibrium Theory," "Self-Consistent Treatment of the Ground State" and "The BCS (Bardeen - Cooper - Schrieffer) and Bogoliubov Theories at Zero Temperature" deal with the foundations of the microscopic theory.

The next four chapters are concerned with the extension to nonzero temperature and application of the theory to a study of thermodynamic quantities, the Meissner effect, and persistent currents. The final chapter, entitled "Further Problems," deals with aspects of superconductivity closely related to industrial applications. These are hard superconductors (the common term "type II superconductor" is never used here), superconducting compounds and thin films.

The applications that draw on these aspects are, of course, superconducting magnets and superconducting switches. The author incorrectly credits M.J. Buckingham with making the original suggestion of using thin-film superconductors as computer elements in 1958. Actually there were three independent publications of the idea in 1957 by M.J. Buckingham, J.W. Crowe and J.C. Garwin, and F.W. Schmidlin and E.C. Crittenden. There is even a report that Von Neumann suggested the idea as far back as 1950.

The work closes with two appendices on statistical mechanics and the quasi-chemical equilibrium theory, a rather extensive bibliography through 1963, and a fairly complete subject index (it even has an entry on white dwarf stars).

J.C. Swihart
Thomas J. Watson Research Laboratory International Business Machines Corp., Yorktown Heights, N.Y.

Electronic Maintenance

Project FIST: Fault Isolation by Semi-Automatic Techniques
G. Shapiro, O.B. Lang, G.J. Rogers, and P.M. Fulcomer Jr.
National Bureau of Standards, Monograph 83, 1964, 72 pp, 55¢.

An interesting and valuable description of Project FIST, developed by the National Bureau of Standards jointly with the Navy, aimed at the problem of maintaining new noncomputer electronic equipment. The monograph contains descriptions of the test equipment and procedures, and suggestions for the design of the equipment.

Technical Abstracts

Stable microcircuits

Temperature-controlled microcircuits.
B. Weir and T. Prosser, Amelco Semiconductor, Mountain View, Calif.

In designing solid-state instruments, considerable attention is given to reducing circuit sensitivity to environmental temperature. Normally a rise in temperature increases the transistor current gain, increases the collector cut-off current and decreases the base-to-emitter voltage. In voltage-regulator diodes with breakdown voltages above six volts, greater voltage drops occur with increased temperatures.

Common methods for nullifying temperature-induced changes in amplifiers include stabilizing the gain by employing negative feedback, using differential stages so that changes in identical components will cancel, and combining devices with negative and positive temperature coefficients, and placing the circuit in a temperature-stabilized enclosure. But another approach is possible.

It is possible to control the temperature of the microcircuit and the heat sink on which the microcircuit is mounted, even though the package's outer surface is exposed to an uncontrolled ambient temperature. This may be accomplished by using a single chip of silicon containing a sensing bridge, an error amplifier and a heater. When power is supplied, the microcircuit becomes automatically heated to a selected temperature. This temperature is above the uncontrolled temperature of the header's exposed surface. As a result the microcircuit, which is mounted to a small heat sink inside of the header, is unaffected by normal variations in the temperature.

When the heat-sink temperature is regulated, other microcircuit chips may be attached to it and their temperatures will also be regulated. A wheatstone bridge is formed on the microcircuit surface by alternate layers of p-type silicon having positive and negative temperature coefficients of resistance. The bridge is designed so that it is balanced only at the expected operating temperature of the microcircuit. At temperatures above or below this temperature, an error signal is introduced to a two-stage differential amplifier.

The differential amplifier is formed by diffusing four transistors in a single chip and depositing several tantalum-film resistors on the oxide surface of the chip. The output from the differential amplifier drives an output stage that consists of a Darlington transistor pair and the diffused-silicon heater resistor (also contained within the single chip). Although the Darlington pair is not a part of the internal configuration at this time, progress is being made toward building a microcircut control system completely enclosed within the header.

Presented at the 1964 Western Electronic Show and Convention, (Wescon), Los Angeles, Aug. 25-28.

Medical transducers

Transducers for producing Biological energy. G.H. Myers
Bell Telephone Laboratories, Inc.
J.F. Belford, Hoffrel Instruments, Inc.
V. Parsonnet and I.R. Zucker,
Newark Beth Israel Hospital

Some characteristics of piezoelectric transducers may extend their usefulness in medical electronics. Transducers are now used mostly as cardiac pacemakers but they are of interest in higher power applications that require intermittent duty only and use the energy developed by the expansion and contraction of the aorta as the heart beats.

The present device, consisting of flat plate transducers mounted in cantilever fashion with molded pieces at the ends, is placed in the body so that it encircles a portion of the aorta. With earlier transducers the aorta had to be severed and resewn. The new transducer can accommodate various sized blood vessels by using a fixed hinge with adjustable inserts at the end of the flat plates. This eliminates screwdriver adjustments during the fitting procedure, permits the hinge to be encapsulated, and simplifies operating room manipulations.

Prime consideration during the design process should be given to the transducer material's dielectric constant rather than the piezoelectric constant. The most formidable problem in power-producing applications is the prevention of loss during the matching phase. By obtaining the lowest possible source impedance rather than trying to achieve high voltage-level outputs the problem is minimized. The Clevite Corp., which produces the PZT piezoelectric ceramic from which comes the material for this type of transducer, has developed a material with a high dielectric constant.

Fatigue in transducer material over a long period of use is another problem. It is believed that material fatigue in the new transducers will be minimal since the rate of aorta flexure is very low.

Presented at the 17th Annual Conference on Engineering in Medicine and Biology. Nov. 16-18, Cleveland.

Microwave delay lines

Voltage-variable delay line
K. Evans and O. Zommers.
Microwave Associates, Inc.
Burlington, Mass.

A microwave delay line, based on a variation of the crossed-field approach, has been designed, built and tested. It is said to overcome some limitations of other delay lines, notably that of bandwidth.

The new line uses a cylindrical electron beam that is made to interact with a helical slow-wave structure, on which is impressed a pulsed radio-frequency signal. The delay can be varied by varying the accelerating drift potential. The signal is extracted, after a transformation from the radial-position mode to the slow-wave mode, by a short helix coupler as in a conventional traveling-wave tube.

In theory, the new scheme produces a delay that can be adjusted instantaneously up to several microseconds: it also has broad-bandwidth possibilities.

An experimental model was built by adapting a C-band traveling-wave tube. Operating with a continuous-wave signal at 5.5 gigacycles, the device was used to demonstrate that such a delay line is feasible and to confirm its theoretical analysis.

Presented at the 1964 Electron Devices Meeting, Oct. 31, Washington.

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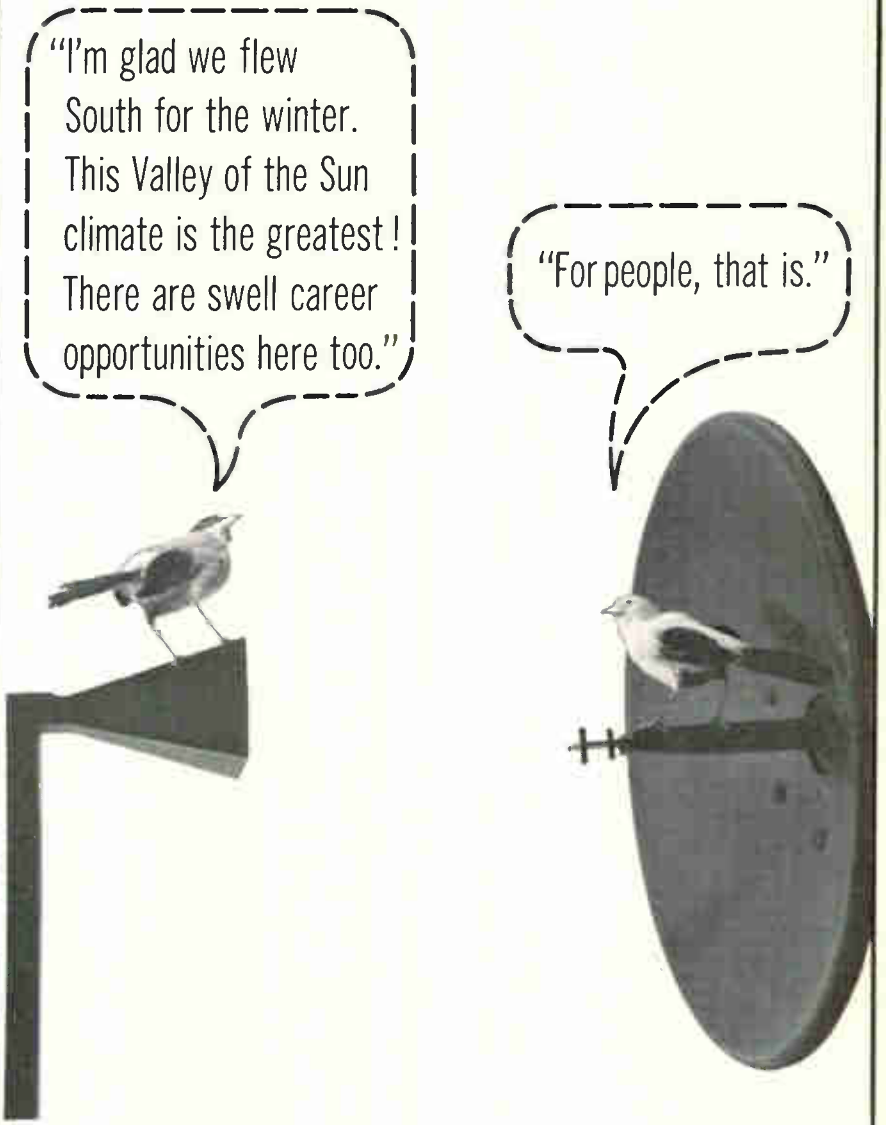

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New Literature

Engineering reliability. Lenhurt Electric Co., Inc., SanCarlos, Calif. Volume 13, No. 9 of the Demodulator contains an article that discusses some of the fundamental aspects of reliability, including such related subjects as quality control and human engineering.
Circle **462** Reader Service Card

Fixed resistors. Ohmite Mfg. Co., 3630 Howard St., Skokie, Ill., 60076. Bulletin 109 describes low temperature coefficient, high-stability, power resistors with precision tolerances. **[463]**

Power transistors. Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz., 85001. Explanation of the latest developments in power transistors, reliability data, device selection and replacement cross reference charts, are all included in a 16-page brochure, No. T4258. **[464]**

Thermistors. Palmer Electronics Inc., 71 Monroe St., Garfield, N.J., has published two product data bulletins on bead- and disk-type thermistors. **[465]**

Switching transistors. Bendix Semiconductor Division, Holmdel, N.J., 07733, has available an applications note describing the SOAR (Safe Operating Area) method of specifying the exact transistor to use in switching or d-c applications. **[466]**

Silicon controlled rectifiers. Sarkes Tarzian Inc., Semiconductor Division, 415 N. College Ave., Bloomington, Ind., has available catalog 64SCR9, a silicon controlled rectifier brochure. **[467]**

Composition resistors. Speer Carbon Co., Bradford, Pa., 16701. A 16-page handbook describing the manufacturing and quality control of the fixed carbon resistor is available to engineers writing for it on their letterheads, with full titles.

Solid-state choppers. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif., offers a comparative data profile for 20 different models of its line of microminiature solid state electronic choppers. **[468]**

Button mica capacitors. Sangamo Electric Co., Box 359, Springfield, Ill., 62705, has released bulletin 2312 on a complete line of type MHW welded-seal button mica capacitors. **[469]**

Rod memory computer. The National Cash Register Co., Dayton, Ohio, 45409. A commercial data processor with a main memory made entirely of thin-film storage elements is described in brochure SP-1578. **[470]**

Microwave instruments. Weinschel Engineering, P.O. Box 577, Gaithersburg, Md. Data sheets are available on the model 1506 coaxial power divider (d-c to 10 Gc), model 904 series broadband thermistor mounts (8.2 to 12.4 Gc), and model 569/624 high power termination (d-c to 3 Gc). **[471]**

Environmental test equipment. American Research Corp., New Britain Ave., Farmington, Conn., has published a 12-page catalog describing its line of environmental test equipment **[472]**

Electrostatic charge amplifier. Kistler Instrument Corp., 8989 Sheridan Drive, Clarence, N.Y., 14031. A transistorized electrostatic charge amplifier with wide frequency response is described in bulletin 210964. **[473]**

Sound-level meter. General Radio Co., West Concord, Mass. Volume 38, No. 10 and 11 of the Experimenter illustrates and describes type 1565-A, a compact, inexpensive sound-level meter. **[474]**

Analog and digital data processing. Pastoriza Electronics, Inc., 385 Elliot St., Newton Upper Falls, Mass., 02164, offers a catalog of analog/digital systems, modules, and training aids. **[475]**

Rotary selector switches. Daven Division of McGraw-Edison Co., Livingston, N.J. Short form catalog S-84 (8 pages) illustrates and describes a line of rotary selector switches. **[476]**

Voltage-variable capacitors. Eastron Corp., 25 Locust St., Haverhill, Mass., offers a bulletin on voltage variable capacitors designed for low-and medium-frequency applications requiring large values of capacitance and high Q. **[477]**

Silicon controlled rectifiers. Tung-Sol Electric Inc., One Summer Ave., Newark 4, N.J., has released a bulletin describing a series of scr's having a forward current of 35 amps and a peak one-cycle surge current of 150 amps. **[478]**

Voltage sensor. Voltron Products Inc., 1020 S. Arroyo Parkway, Pasadena, Calif. Data sheet 6032 contains application information, diagram drawings and specifications on d-c Voltrips with normal-impedance input. **[479]**

D-c relay. Acromag, Inc., 15360 Telegraph Road, Detroit, Mich., 48239, has available six bulletins covering the specifications, theory and application of the model 370, a 50-pv d-c relay. **[480]**

Core memory unit. Ampex Corp., Computer Products Division, 9937 W. Jefferson Blvd., Culver City, Calif., 90230. A six-page folder illustrates and describes the RS core memory unit with 1.0 μsec cycle time. **[481]**

Pressure transducers. Data Sensors, Inc., 13112 Crenshaw Blvd., Gardena, Calif., 90249, announces a four-page bulletin on its complete line of bonded strain-gage pressure transducers for aerospace and industrial applications. **[482]**

Wire, cable, tubing. Daburn Electronics & Cable Corp., 96 Prince St., New York, N.Y., 10012, offers a 32-page catalog describing more than 50 types of wire, cable, tubing and electronic hardware carried in stock. **[483]**

Crystal-controlled oscillators. General Micro-electronics Inc., 2920 San Ysidro Way, Santa Clara, Calif., 95051. A technical data sheet describes a line of crystal-controlled oscillators that utilize specially designed semiconductor integrated circuits. **[484]**

December 28, 1964

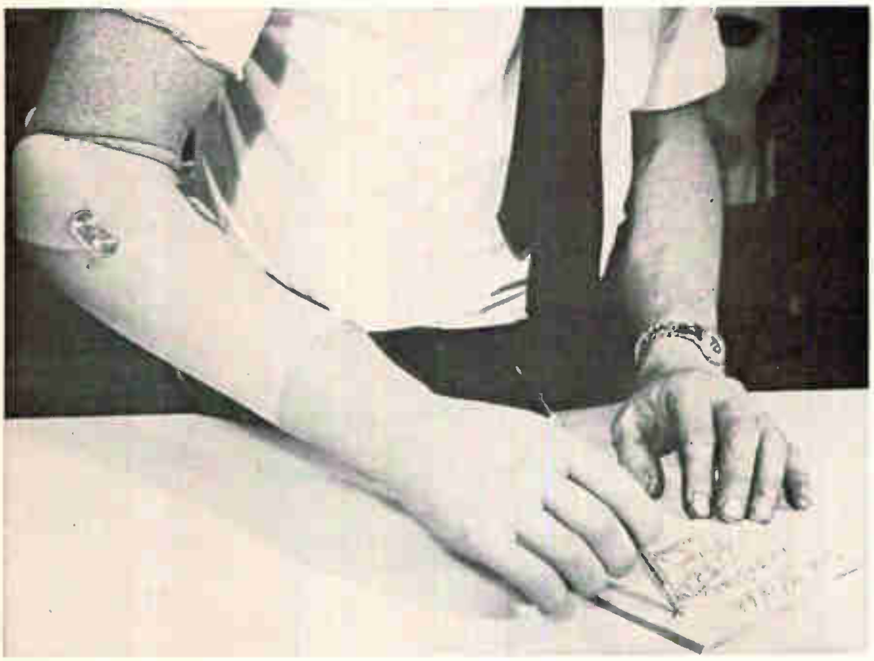
Electronics Abroad

Volume 37
Number 32

Soviet Union

Electronic arm

Sergei Zubkov got out from behind the wheel of his car, lifted the hood and began fussing with a screwdriver and wrench. When he had the engine running smoothly again, he went back into the car, lighted a cigarette, and resumed his trip.



Electronic arm writes legibly after the user has had two hours' instruction and practice.

This incident wouldn't be worth reporting—if Sergei's right arm hadn't been amputated just below the elbow during World War II.

One of 200. Sergei is one of about 200 Russians who have been fitted with electronic arms, which use muscle currents to control movements of the fingers. Now the device is being used in Britain, by an organization called the Lady Hoare Thalidomide Appeal, which paid the Russians $30,000 for rights to the device for eight years. The British organization was formed to help limbless babies. Lady Hoare has granted a license to J.E. Hanger & Co. of London to manufacture the prothetic sleeve.

In Moscow, Yakov Yakobson described what's new about the arm he helped to develop. Grasping an article with most artificial limbs involves muscles relatively distant from the forearm, he explained. But with the electronic arm, the fingers are moved electrically and they are guided by electric currents in the upper part of the forearm.

Muscle contraction is caused by biological currents sent along nerve fibers. These currents are picked up by electrodes, mounted to the skin and attached to the prothetic sleeve that fits over the arm. The currents are then amplified and used to trigger a tiny three-watt d-c motor built into the artificial limb. The motor makes the artificial fingers bend and straighten.

The muscle signals vary from 50 to 200 cycles per second and from 25 to 200 microvolts.

Flip of the wrist. Next year the Russians hope to add a wrist-turning capability to the electronic arm; at present the arm only bends up and down. And in 18 months they hope to be able to control an entire arm instead of just a forearm.

A British engineer who studied the electric drive-motor figures it must be a byproduct of Soviet missile work. It's a low-inertia, instant-reversal device with high—but undisclosed—power-to-weight ratio. The 12-volt motor is considered the key part of the electronic arm.

The rechargeable battery is said to be able to operate the arm for two days. The entire arm weighs 2 pounds, 11 ounces; of this, the battery comprises 11½ ounces.

Lifting an egg. One British amputee, who lost his right hand in North Africa works at a factory that makes conventional artificial arms. It took him only two hours to learn to use the electronic arm well enough to pick up an egg, lift a glass to his mouth, and write his name.

Another patient, after a longer practice period, says he's able to hold onto straps on buses, buy tickets and handle the change—things he couldn't do with metal hooks.

About 20 electronic arms are in use in Britain.

Great Britain

Computer teamwork

Britain's steel industry continues its massive modernization program. Associated Electrical Industries, Ltd., has a contract to install the first on-line, closed-loop computer control to operate a plate mill in Britain. The $700,000 installation, scheduled late next year, will make the Lackenby plant of Dorman Long Steel, Ltd., one of the most modern in the world.

AEI is manufacturing a GE/PAC 4000 computer under license from the General Electric Co. in the United States. The British electronics concern also will be in charge of the mill's systems engineering, programing and commissioning.

Day's job in a second. Computer controls will take just fractions of a second to perform mill-setting calculations that would require several days if done with a calculator. In real time, the computer will determine optimum mill settings for each slab, using a continuous stream of data from the mill instrumentation. Then it will set up the mill automatically. Present methods require a predetermined pattern of control, using data on punched cards.

The computer will start with four main tasks: on-line control of the universal plate mill, control of the furnace that reheats the slab, display of slab-plate tracking data for a big stretch of the process line, and logging of data. Later it may be given more duties.

Bookkeeping, too. Another approach in British steelmaking involves several computers. In 1962 Richard Thomas & Baldwin's Spencer works opened a steel mill designed for eventual operation "on a multicomputer basis." The company says its hot-strip mill is being run successfully by four computers—three Elliott 803s and one ITE 412.

Another company, the Park Gate Iron & Steel Co., employs three computers not only for making steel but for accepting customers' orders and balancing the accounts. Park Gate, a subsidiary of Tube Investments, Ltd., uses the computers at its Rotherham works.

Japan

Bridgehead in the U. S.

Japanese television makers are broadening their already-substantial bridgehead in the United States market. Exports to the U.S. are up 24.6% from 1963.

To Christmas shoppers and to some retailers, however, the gain hasn't been evident. They see about as many receivers with Japanese names—Sony, Hitachi and others—as last year.

That's because of a new trend in Japanese marketing in the U.S.: The manufacturers are swinging to American brand names.

Sony also has awarded a production license to a Mexican company. It's Sony's first license to a Latin American concern.

A matter of geography. At least 14 Japanese companies export tv sets to the U.S. But only four of them — Sony Corp., Matsushita Electric Industrial Co., Hayakawa Electric Co. and Hitachi, Ltd.—use Japanese brand names. Two of these, Matsushita and Hayakawa, also export private-brand sets.

The biggest obstacle to Japanese companies is geography—the sheer size of the United States. In addition, competition is fierce, both from American companies and from other Japanese concerns.

Even Sony, the leading Japanese invader of U.S. markets, concedes that it cannot cover the country adequately in sales and service.

Local labels. Receivers made by Toshiba, the Tokyo Shibaura Electric Co., are sold in the U.S. with the following labels: Sears, J. C. Penney and Bradford. Sanyo Electric Co. sets are sold under the labels of Master, Sears, Golden Shield, Muntz and Magnavox.

The Yaou Electric Co. sells receivers in the U.S. with Philco and Airline labels.

The Mitsubishi Electric Corp. uses the following names: Westinghouse, Singer, Bradford and Penn Crest.

Victor Co. of Japan, Delmonico; Nippon Columbia Co., Olympic and Fair Crest; Nippon Electric Co., Magnavox; Aiwa Co., Bradford; Osaka Onkyo Co., Commodore and Muntz; Realtone Electronics, Inc., Realtone.

U.S. makers' view. U.S. manufacturers often buy Japanese sets to fill gaps in product lines. When a U.S. company buys from several Japanese manufacturers, however, this makes for complex business relationships.

Industry observers expect a pattern of exclusive tie-ins between individual U.S. companies and individual Japanese concerns.

The coming of color. At least one Japanese company plans to reverse the trend and sell under its own name. Yaou says it will start selling nine-inch portable color tv sets in the U.S. next spring under its own name.

Japan began exporting color tv to the U.S. in July. About 6,000 standard-size units have been shipped so far.

Large black-and-white. The Japanese also seem almost ready to sell large-size transistor tv sets in the U.S. Sony recently introduced a 12-inch transistor set in Japan that sells for $137.50. That's only slightly above the $114-to-$122 price of comparable tube sets. Sony declines to discuss its export plans.

The company says its goal is to bring the price of transistor tv sets 10% below those of tube sets by April, 1966.

Sony's 12-inch operates off 24-volt a-c or d-c power. This voltage, rather than the earlier 12-volt designs, permits the higher horizontal sweep power required by the larger picture tubes.

In Mexico. Sony has also granted its first license in Latin America. The recipient is Industrias Riojas S.A., a Mexico City maker of electronic products for the home.

By the end of the year, the Mexican concern expects to be producing 2,500 Sony transistor tv receivers a year, all with 5-inch or 4-inch screens. Next year, Industrias Riojas also plans to make Sony f-m radios and tape recorders.

The Mexican manufacturer says it won't export to the U.S. but has contracts to sell in Brazil and Colombia.

At first Industrias Riojas will import all of its tv parts from Japan, according to Jose Riojas, Jr. the company president. Within two years, he said, 35% of the parts used will be made in Mexico.

Middle East

Tv in Lebanon

Tiny Lebanon, whose principal products are oil, fruits and sandstorms, now has a television assembly plant.

The George Hawi Middle East Co. opened last month and is already turning out tv sets at a 100-a-month clip.

George Hawi, who owns the company, is a 43-year-old engineering graduate of Cairo University. He has worked, among other places, in Britain and at the Chrysler Corp. plant in Detroit.

Commercial system. Lebanon, with 100,000 set-owners, has the Middle East's only tv broadcasting system that's entirely privately owned. Other systems in the United Arab Republic, Iran and Syria are government-run. The Iraq Petroleum Co. also operates a tv station at Shatt al-Arab, and the Arabian-American Oil Co. has a transmitter in Dhahran, Saudi Arabia.

Jordan and Saudi Arabia plan to begin operating state-owned stations during 1965.

Hawi estimates tv sales in the Middle East at 100,000 a year, and predicts a 25% annual increase.

Cost $200. A 23-inch set retails for about $200 in Beirut, Lebanon. That's approximately 30% less than comparable sets made in the United States.

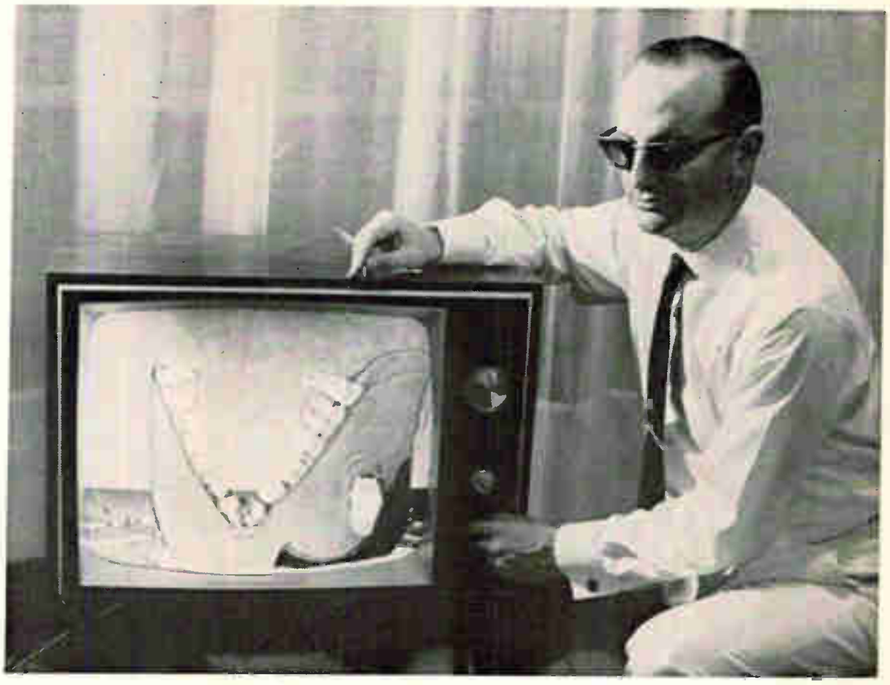
The Hawi sets employ a simple wired circuit containing 10 diodes and transistors and 13 vacuum tubes.

Domestic industry. While the Middle Eastern tv market expands, Hawi expects foreign companies' share of that market to shrink. He cites exclusive contracts between government-run plants and foreign suppliers of parts. He also says many big foreign producers won't bother making specialized sets for relatively small markets such as Lebanon.

"I tried to obtain components from Westinghouse (Electric Co.) based on simplified circuitry," he says, "but the interest just wasn't there."

American companies are overshadowed in Lebanon by Philips Gloeilampenfabrieken, N. V., of the Netherlands, and Grundig GmbH of West Germany. These two companies sell about one-half of Lebanon's tv components.

Labor aids. For his unskilled work force, Hawi prepares schematic diagrams, exploded views of the assembly, detailed full-color photographs, and sets in various stages of completion.



Hawi and one of his first tv sets. Horizontal and vertical controls are automatic.

For alignment procedure, each technician is given a picture of the image he should see on the oscilloscope at each stage of the procedure. He also receives detailed instructions for making adjustments.

The technicians attend a three-month course in assembly. Alignment control is covered in an optional two-week course.

Tv in Syria. In Damascus, Adel el-Saadi, Syria's former industrial minister, announced before his resignation that Telefunken AG would build a television assembly plant in Syria early next year. In Berlin, Telefunken added that components would be supplied from West Germany.

The Syrian official said the plant would be able to produce 25,000 tv sets the first year and 50,000 sets by 1968. Plant equipment will cost $141,250, he added.

France

Mixed-manned radar

When the NATO foreign ministers ended their semiannual meeting on Dec. 17, most of the public disputes had centered on the proposed allied nuclear fleet. But one of the most vexing problems was tackled almost entirely in private. This problem, an important one to the electronics industry is called Nadge—an acronym for NATO air-defense ground environment.

To the North Atlantic Treaty Organization, Nadge represents a communication network linking early-warning radar stations into a single system with a central command-and-control headquarters.

To electronics manufacturers, Nadge represents a $308 million project. Proposals for competitive bids were sent out a few weeks before the NATO meeting.

Decentralized. Some bureaucrats compare Nadge with Sage, the seven-year-old warning system in North America, whose formal name is semi-automatic ground environment. But cynics compare Nadge with the proposed mixed-manned fleet. Nadge will have 15 command-and-control headquarters, one for each NATO member.

Still, Nadge will completely replace the human element with automatic computer control. And if it does not completely unify the radar sets stretching from northern Europe to Turkey, at least it will close gaps in the network.

The bid proposals for the first

time require each company to take into account its country's balance-of-payments problem. Companies are asked to submit plans under which private industry in each NATO country would receive Nadge subcontracts totaling approximately what each country pays for its share of the Nadge system.

This way, no country should suffer any outflow of gold—an important safeguard for the United States, which will put up $100 million, or 30.85% of the cost.

International bidding. NATO is reported to have provided few guidelines in its proposals. Definitions are left up to the companies and their governments.

A consortium must win the bid, and it is understood that Litton Industries, Inc., the Hughes Aircraft Co. and Westinghouse Electric Corp. are forming groups to enter bids. But such arrangements become complex when companies within the consortium are international in scope. Does a wholly or partially owned American subsidiary in a European country count for that country or for the U. S.?

Sweden

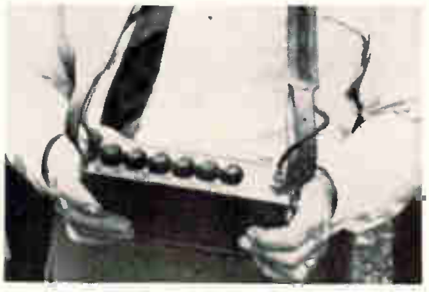
Remote control for trains

Two portable control devices are being tested on Swedish railroads. One is an autopilot for the Stockholm subway. The other is a radio control for engines at switchyards.

In a three-month tryout on a six-mile stretch of subway, the autopilot is said to have passed every test. Now the designers want to improve the braking. On dry rails, the autopilot stops a train within seven feet of a selected point; in contrast, a system being designed for San Francisco's rapid-transit system is expected to be accurate to within one foot. The Swedish engineers hope icy rails won't make their braking system even less precise than at present.

Full use by '68. By the end of 1965, subway officials expect to have autopilots on all trains of one 11-mile line. By 1968 all 650 cars on the full 40-mile length of the Stockholm subway should be controlled by autopilot. The officials expect no opposition from unions.

The autopilot system was developed by Allmanna Svenska Elektriska AB (ASEA) and the Stockholm Subway Authority. The subway's engineers say the autopilot increases train efficiency by eliminating human error, cuts power consumption about $100,000 a year, and requires only one attendant on a train instead of two.



Command box weighs only 5½ pounds, yet controls a 100-ton train engine. New model will have control buttons on front instead of top.

Portable control. The autopilot control box is a portable unit weighing about five pounds. Some relays and actuators in the system, however, are permanently fixed in the subway cars.

The control box is a selector switch for controlling different numbers of cars that make up a train, and a switch for full manual control of a train. Driverless trains aren't contemplated soon.

After a guard closes the door and pushes the "go" button, the autopilot starts the train. Speed is controlled by a cab-signal system. Stopping signals are received 350 yards from the station by a device that consists of an inductive coil between the rails. The coil emits an audio tone at 5,000 cycles per second. By counting a wheel's revolutions, a programed reference-braking curve in the autopilot control box compares the train's speed with the desired speed, and adjusts braking pressure. Closed-circuit television, to give a motorman-guard a better view of the platform, is being tested by the Swedish State Railways and the privately owned Grangesberg Railroad. The test model, manufactured by the Storno Communications Co. of Copenhagen, is being redesigned into a more convenient pack.

Push-button switching. Engines are switched by a portable radio control. The push-button device, with a range of one kilometer, weighs only 5½ pounds and measures 7 by 8 by 2 inches. A flexible antenna fits along the operator's shoulder strap.

The push-button control is linked to a servo system in the train cab. Railroad officials say technicians can learn to operate the device in five minutes.

Three or four men now work at one engine in a yard. These are the driver plus a ground crew that couples and throws switches. With the remote-control device, the driver can get out of the train and do his own coupling and switching.

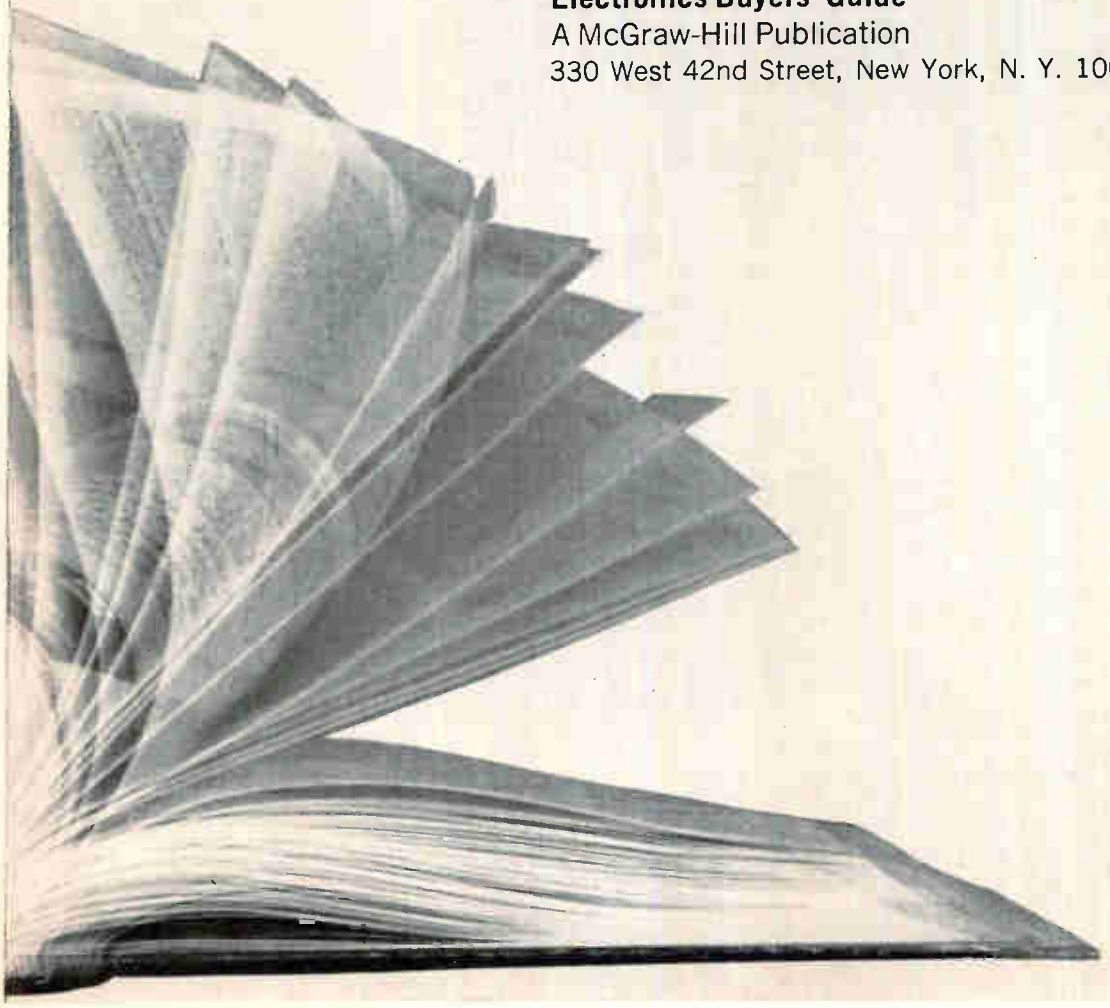
The fully transistorized transmitter in the control unit is said to be the first of its size that is made for civilian use in Europe and that operates at 450 megacycles per second. This frequency was chosen to avoid interference from other transmitters and from electrical wiring in switchyards. The transmitter occupies only one-fourth of the control-unit pack.

Servo Unit. The servo system, designed by the State Railways, is linked to a push-button system in the cab. This allows push-button control either from the remote radio or directly from the cab.

The receiver, a conventional Stornophone V for 450 megacycles, is equipped with relays and tone controls. It is powered by the locomotive's 24-volt battery. Since different tone signals are used, it's possible to have any number of remote-control units in the same switchyard without fear that they'll interfere with one another.

The system—transmitter, remote control unit, receiver and servo system—costs about $4,000. Five such systems are planned.

The Swedish State Railways cooperated with a privately owned railroad, Trafik AB Grangesbergs-Oxelosunds Jarnvagar, in developing the system.



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December 28, 1964

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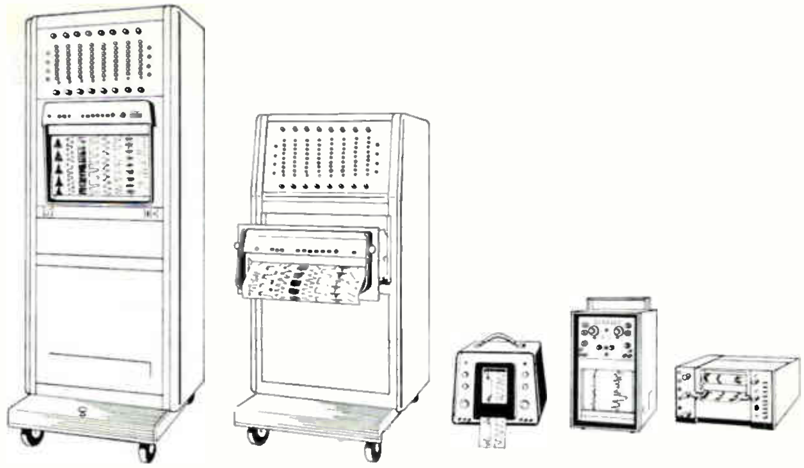

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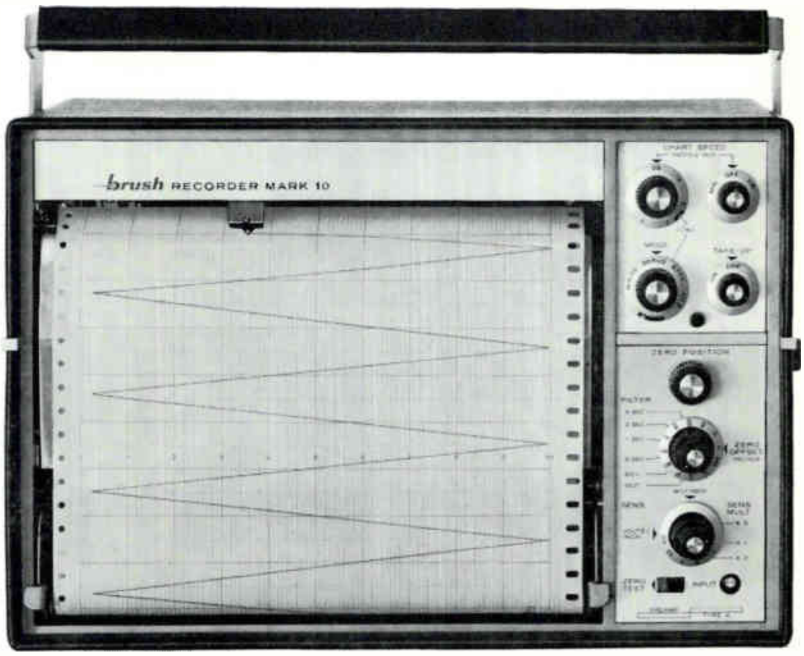

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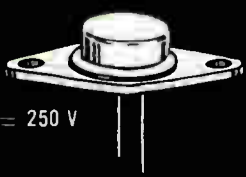

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V_{CEO}(sus) min = 350 V
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$I_{S/b}$	@ V_{CE} = 100 V	250 ma min	250 ma min	250 ma min
V_{CEO}(sus)	@ I_C = 200 ma	175 V min	250 V min	300 V min
V_{CE}(sat)	@ I_B = 125 ma, I_C = 1A		0.75 V max	0.75 V max
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