Electronics®

Tunnel diode inverters: page 56
High-temperature safeguard for transistors: page 66
Transmitting high power by microwave: page 86

September 21, 1964
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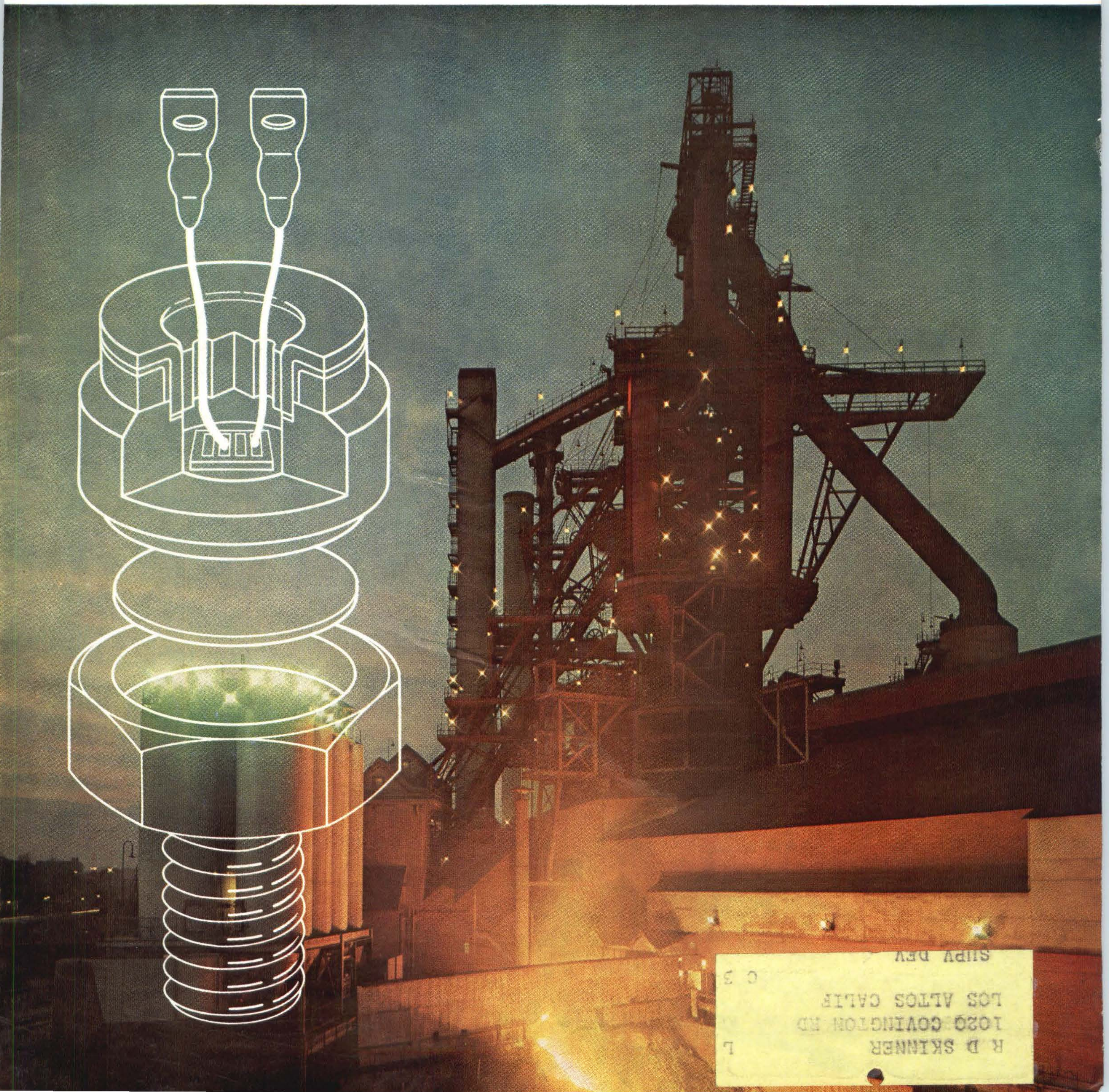
Below: the scr invades the industrial scene, page 78



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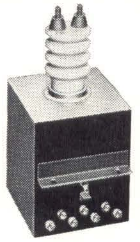
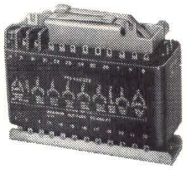
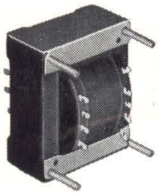


Low capacity current limiting filament transformer. Primary 118 V. 60 cycles to 6.3 V. at 3 A., 8 A. at short circuit. 25 MMFD capacity. 30 KV hipot and 200:1 capacity divider; 5 x 3¾ x 4½", 9 lbs.

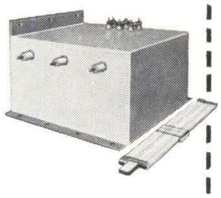
MIL-T-27B ultraminiature Scott connected power transformer, 5/16 Dia. x 13/32" H., 1/10 Oz. Primary 28 V. 400 ∽ with taps @ 50% & 86.6%. Two units provide 28 V two phase from three phase source.



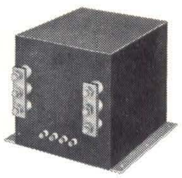
Molded Power Transformer 3 Phase. Input 200V, 380-420 cps. Electrostatic Shield, 8 output windings. 26 terminals. MIL-T-27B, Grade 2 Class S. Max. Alt. 50K Ft. Size 6 x 2½ x 5", 8 lbs.



Commercial type molded power transformer. Primary 115/230 V., 50/420 cycles to 680 VCT.-.015 A., 6.3 VCT.-1.2 A., 6.3 V.-.6A. Size: 2½ x 3 x 2⅞", weight: 1.6 lbs.



Three phase high voltage power transformer. Primary jumper hardware for easy conversion from delta to wye inputs. Made to MIL-T-27B specifications. Primary: 440 V 60 cycles delta or wye 3 phase input. Secondary: 2100 V line to line or 1215 V line to line @ 242 ma.



High current filament transformer. Primary 140/156 V., 47/63 cycles to 1.8 V.-1070 A. Current limiting through separate primary reactor, MIL-T-27B; 10 x 10 x 11½", 150 lbs.

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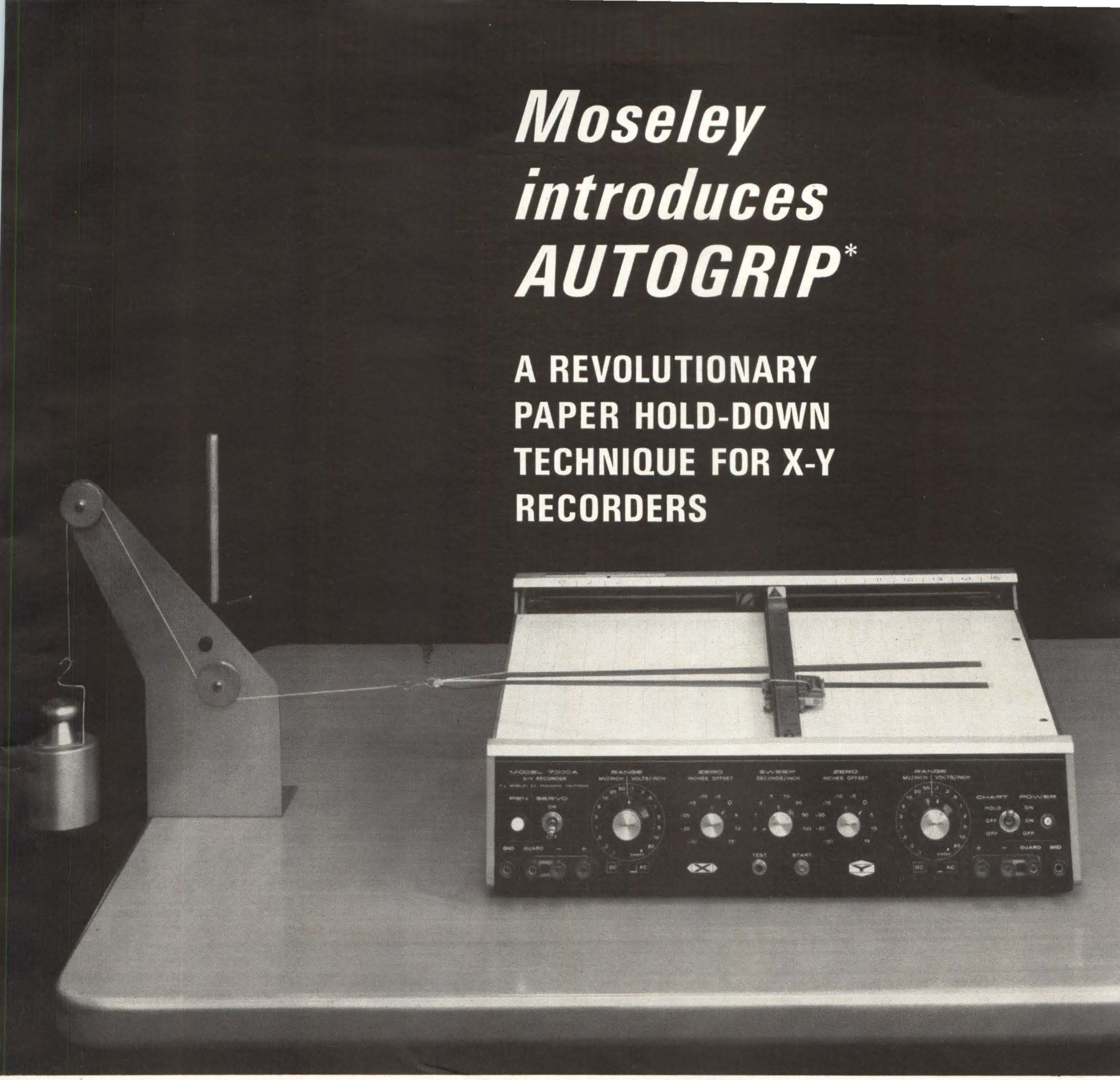
Circle 900 on reader service card



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*Trade Mark Pat. pend.

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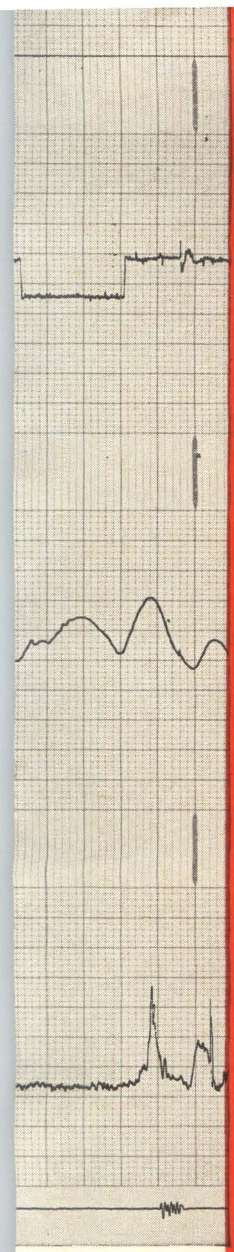
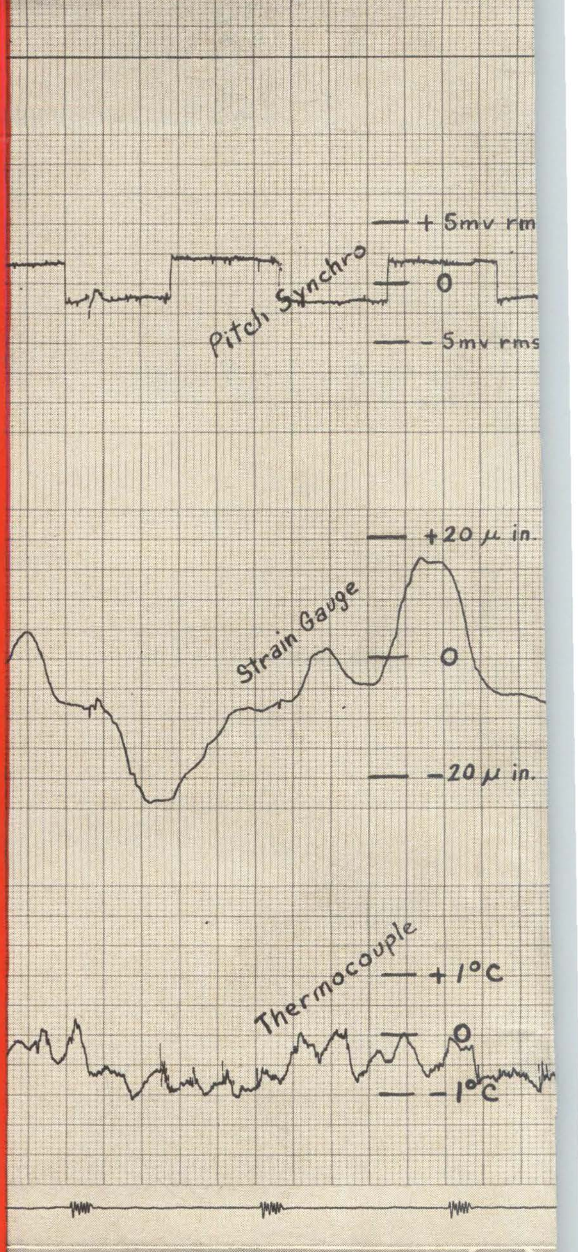


ticklish signals?



PUT THEM ON PAPER WITH EASE WITH THIS NEW SOLID STATE OSCILLOGRAPH

Now you can precisely measure and record a greater variety of AC and DC variables — over wider dynamic ranges and with more signal-conditioning capabilities at your command — with this new Sanborn 7700 Series 6- and 8-channel oscillograph. A choice of highly developed plug-in preamplifiers (eight in 7″ x 19″ of panel space) gives you recording capabilities such as: 1 μv/div. to 250 volts full scale in a single preamp, which also has multi-range, calibrated zero suppression built in . . . phase-sensitive demodulation of in-phase or 180° out-of-phase floating signals, 60 cps to 40 KC, with calibrated or uncalibrated adjustable phase shifting . . . carrier signal recording from 10 μv/div. and with calibrated zero suppression and cal. factor.

The all-solid-state circuits in this new system also mean cooler operation with less power than tube circuits . . . easy servicing of modular circuits on accessible plug-in cards . . . simpler, smaller power supplies with integral AC excitation . . . and generally improved drift, gain stability, noise and linearity characteristics. Combine these advantages with the proven and widely-used Sanborn *heated stylus*-Permapaper® recording method: true rectangular coordinate writing with *higher* resolution at slow chart speeds, *no* spills or smears, *greater* environmental immunity, *no* priming or constant attention needed. Call your HP field engineering office for complete specs — or write Sanborn Company, Industrial Division, Waltham, Mass. 02154

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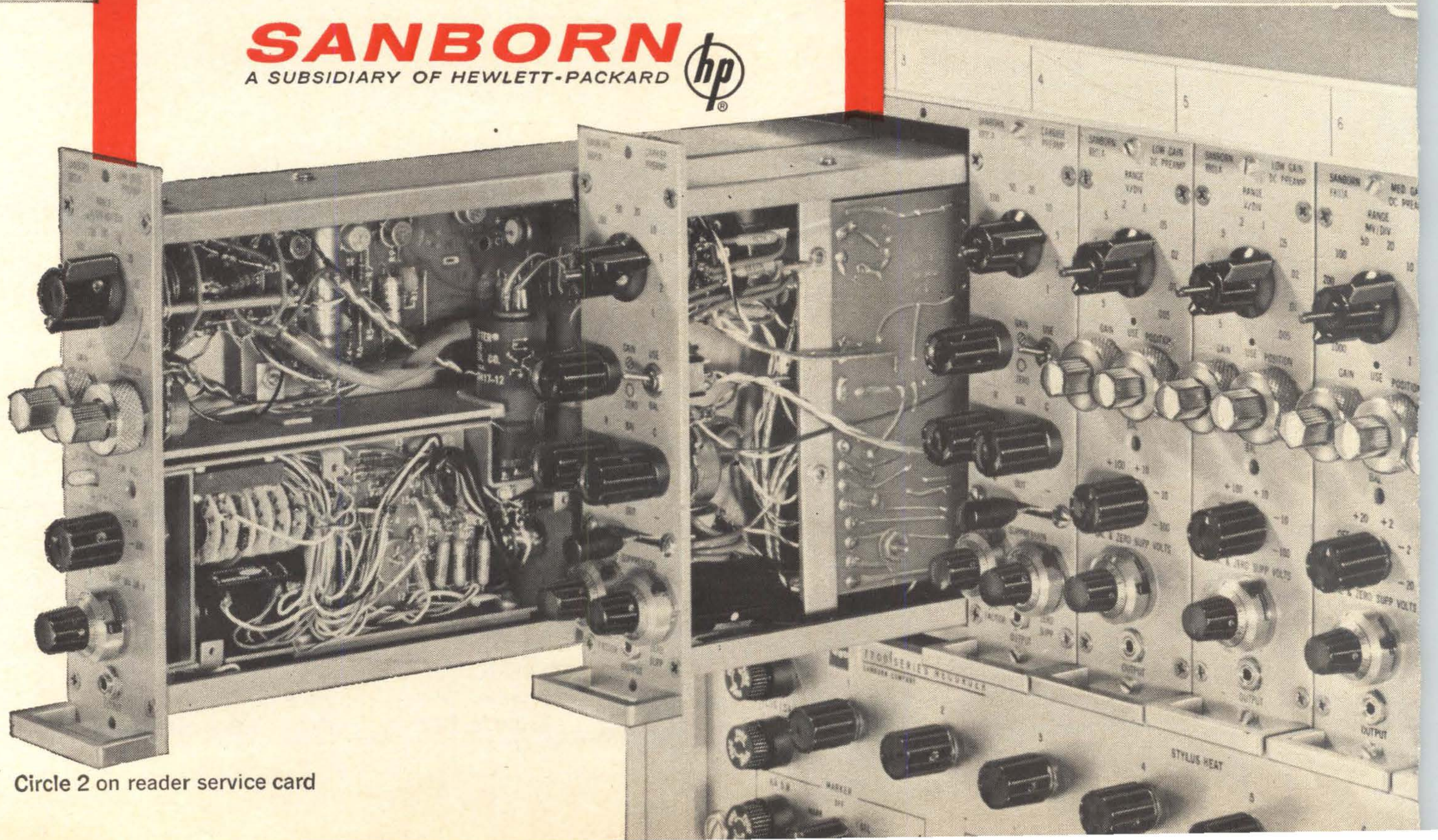

Circle 2 on reader service card

September 21, 1964
Volume 37, Number 25

Electronics

In this issue

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Probing the news

Technical articles

I. Design

II. Application

Electronics

Electronics: September 21, 1964, Vol. 37, No. 25

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Readers Comment

Thinking machines

The views you express in "Machines that think" [July 13, p. 90] disregard the general view ably expressed in Michael A. Arbib's book "Brains, Machines and Mathematics." Computers and automation have a future that, both from a materialistic and spiritual point of view, is limited only by the number of available communication channels.

If the term "cybernetics" is used to describe the theory of making computers that perform in relation to the working of the brain, as a shadow is related to a person, then cybernetics will prove useful. But statements like the one you ascribe to [W. Ross] Ashby that "we know definitely that a computer can do anything a human brain can do—or more" are misleading and utterly remote from reality.

Forty years ago there might have been justification for this sort of talk; but today, when our knowledge of physics is being atomized and is becoming more and more incomprehensible; when we know that even animals (migrating birds, shells, etc.) are working with detectors beyond our comprehension; when we know from experiments carried out at London University that an extra-sensory capability exists that has all but demolished the law of causality; today we must accept the fact that even the best heuristic programing is not going to help beyond a certain improvement of our calculating machines.

It is time that our cyberneticians accept what all leading physicists have recognized for years: that there is an unbridgeable gulf between models and reality in spite of the fact that models can, for special applications, and with the help of our brain, develop reality.

F. Steghart
Gerrards Cross, Bucks
England

▪ Ashby means that the computer can perform any one particular function of the human brain, providing we can specify that function;

not that we can remove a human being's brain and replace it with a computer. Ashby's work concerns finding the mathematical limits for possible machines, which of course is very different from knowing how to build them.

Superpower tubes

Some of the information by one of us (L. F. Eastman) in "Superpower tubes: their capabilities and limitations" [July 13, p. 48] may be misleading due to lack of completeness.

First, curves D and E on normalized cathode current (versus beam voltage) are actually J_cR/K for the solid beam and $J_cR\delta/K$ for the hollow beam, where J_c is the cathode current density, K is the gun perveance, R is the cathode-to-beam area ratio and δ is the hollow beam thickness-to-radius ratio. It should be noted, as stated in the article, that all R ratios are not possible at all beam voltages. Hollow-beam R ratios are at present small; that is, less than 20.

Next, even though curve C gives the potential depression between the anode cylinder and the electron beam (a parameter important for estimating the necessary control of the outer beam diameter), it does not indicate the total potential depression to the beam center (inner edge of the hollow beam). This total potential depression is less for a hollow beam and thus allows much higher gun perveance in a hollow beam than in a solid beam for the same total potential depression. A curve of representative total potential depression versus perveance for solid and hollow beams (below) helps to explain in this idea.

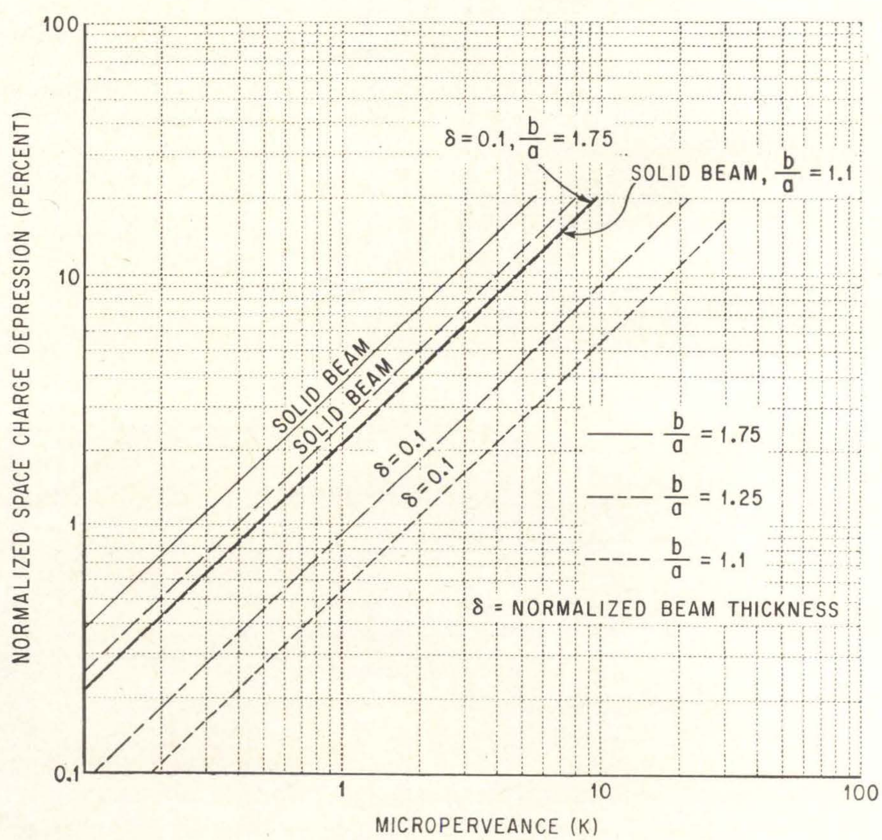
(Miss) R. Biss
Cornell Aeronautical Laboratory
Buffalo, N.Y.

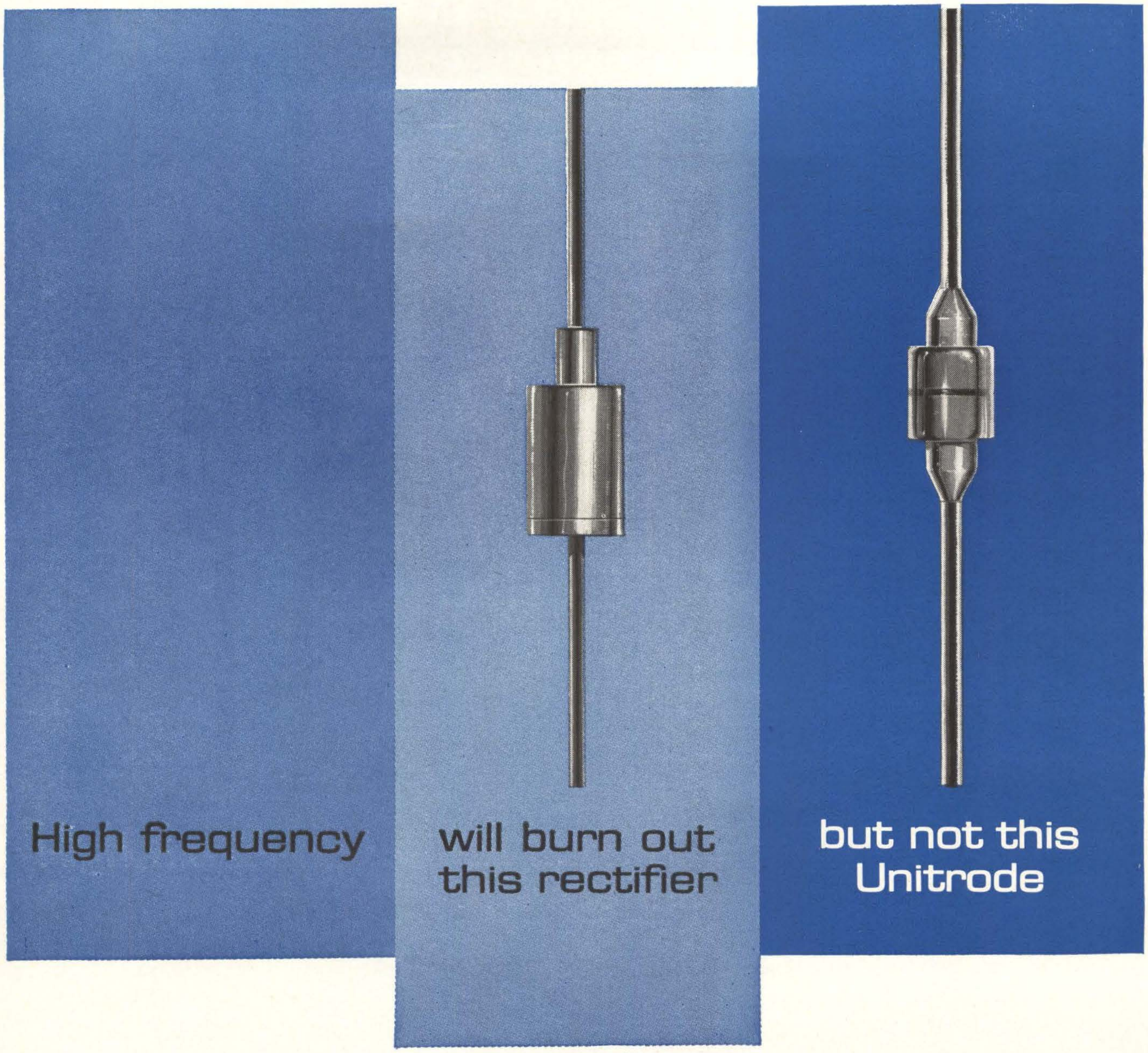
L.F. Eastman
Cornell University
Ithaca, N.Y.

Magnetoresistance

Concerning my article "Magnetoresistance: better than Hall-effect multipliers" [Apr. 6, p. 66], may I ask you to print an additional remark that part of this work was developed during the author's sojourn in Switzerland, with the Institut für höhere Elektrotechnik, Federal Technical Institute, Zurich, and Landis & Gyr AG, Zug.

S.F. Sun
Institut für Höchstfrequenztechnik
Stuttgart, Germany





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Unitrode makes this possible by a novel silicon diffusion process that nearly eliminates the reverse current spike during turn-off — and considerably shortens turn-off time. Further, the new fast-switching series has the unique one-piece Unitrode construction that survives long term overloads without damage and is immune to aging effects.

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Individually inspected, 100% tested, Unitrode fast-recovery rectifiers have to cost more than ordinary rectifiers. But if performance is more important to you than pennies, compare all the remarkable devices based on the Unitrode principle: 3-amp silicon diodes, 3-watt zeners, high-voltage stacks and bridge assemblies. They're stocked by Unitrode representatives nation-wide.

For information, product demonstration and samples, contact UNITRODE CORPORATION, 580 Pleasant Street, Watertown, Massachusetts 02172. Tel: (617) 926-0404, TWX: (617) 924-5857.

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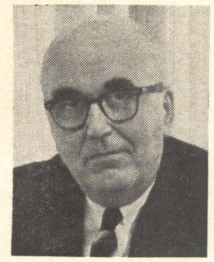
People

Russel A. Schlegel, 50 years old, is leading the Rockwell Manufacturing Co. into the new and hotly competitive market of medium-sized systems for process control. One of Rockwell's major rivals will be the Honeywell Corp., Schlegel's employer for 19 years.



Rockwell hired Schlegel about seven years ago to head its newly acquired Republic Flow Meters Co. About a year ago, he was named a vice president in charge of the new Measurement and Control division that had absorbed Republic.

The division will make its big splash next month when it introduces 14 products for process control. Schlegel conceived most of them.

What does he do when he isn't planning new products? "I try to sell them," Schlegel answers. He holds an amateur pilot license, but the 100,000 miles he logged last year between plants in California, Georgia and Chicago were in commercial aircraft. A self-styled "frustrated architect," Schlegel had a hand in remodeling Rockwell's 50-year-old building in Chicago.

The Raytheon Co. has named **Joseph A. Ricca** general manager of the commercial computer business it bought from the Packard-Bell Electronics Corp. Ricca, 42 years old, directed memory-system business operations at the Aeronutronics division of the Philco Corp. His professional background is in engineering and marketing. He's also an excellent chef. Ricca has developed several microprograming techniques. Raytheon expects to use his skills to expand its line of microprogramed computers.

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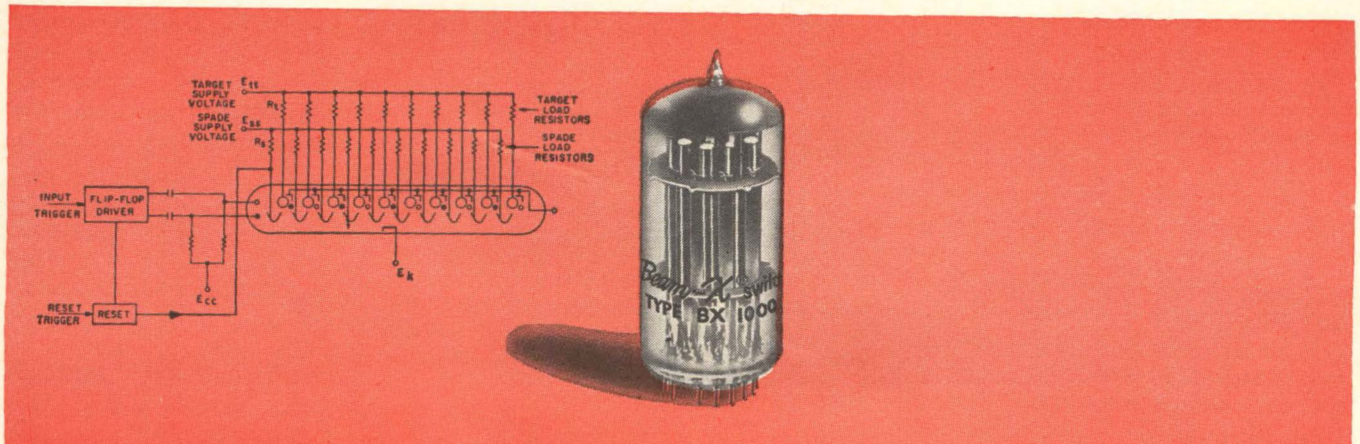

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Meetings

AIAA Military Aircraft Systems and Technology Meeting, (Secret), AIAA, USAF, BuWeps; NASA;-Langley Research Center, Va., **Sept. 21-23.**

AE-4 Electromagnetic Compatibility Conference, SAE; McDonnell Aircraft Corp., St. Louis, Mo., **Sept. 22-23.**

Profession Technical Group on Antennas and Propagation International Symposium, PTGAP/IEEE; International Hotel, John F. Kennedy International Airport, New York, **Sept. 22-24.**

Broadcasting Annual Symposium, PTGB/IEEE; Willard Hotel, Washington, **Sept. 24-26.**

Annual Communications Conference, Cedar Rapids Section of IEEE; Hotel Roosevedt, Cedar Rapids, Iowa, **Sept. 25-26.**

Canadian IEEE Communications Symposium, Canadian Region IEEE; Queen Elizabeth Hotel, Montreal, **Sept. 25-26.**

National Power Conference, IEEE, Inc., ASME; Mayo Hotel, Tulsa, Okla., **Sept. 27-Oct. 1**

Society of Motion Picture and Television Engineers Technical Conference, SMPTE, Inc.: Commodore Hotel, New York, **Sept. 27-Oct. 2.**

Allerton Conference on Circuit and System Theory, University of Illinois, CTG/IEEE; Allerton House, Conference Center of the University of Illinois, Monticello, Ill., **Sept. 28-30.**

Tube Techniques National Conference, Advisory Group on Electron Devices; Western Union Telegraph Co. Auditorium, New York, **Sept. 28-30.**

Society for Applied Spectroscopy National Meeting, SAS; Sheraton-Cleveland Hotel, Cleveland, **Sept. 28-Oct. 2.**

Physics of Failure in Electronics Annual Symposium, Rome Air Development Center, IIT Research Institute; IIT Research Institute, Chicago, **Sept. 29-Oct. 1.**

Society for Information Display National Symposium, SID; Shoreham Hotel, Washington, **Oct. 1-2.**

Current Trends in Optical Physics Semiannual Symposium, American Physical Society; State University of New York College at Cortland, Cortland, N.Y., **Oct. 2-3.**

American Documentation Institute Annual Meeting, ADI; Sheraton Hotel, Philadelphia. **Oct. 4-8.**

Air Traffic Control Association National Meeting, ATCA; Chalfonte-Haddon Hall, Atlantic City, N.J., **Oct. 5-7.**

National Communications Symposium, PTGCT/IEEE; Utica, N.Y., **Oct. 5-7.**

Industrial and Commercial Power Systems Annual Conference, ICPSC/IEEE, Philadelphia Section IEEE; Marriott Motor Hotel, Philadelphia, **Oct. 6-8.**

Electronic Information Handling Conference, University of Pittsburgh, Goodyear Aerospace Corp., and Western Michigan University, Webster Hall Hotel, Pittsburgh, **Oct. 7-9.**

Fall URSI Meeting, PTG/IEEE; University of Illinois, Urbana, Ill., **Oct. 11-14.**

Electrochemical Society Meeting, Electrochemical Society; Sheraton-Park Hotel and Motor Inn, Washington, **Oct. 11-15.**

Energy Conversion and Storage Conference, Oklahoma State University, Stillwater, Okla., **Oct. 12-13.**

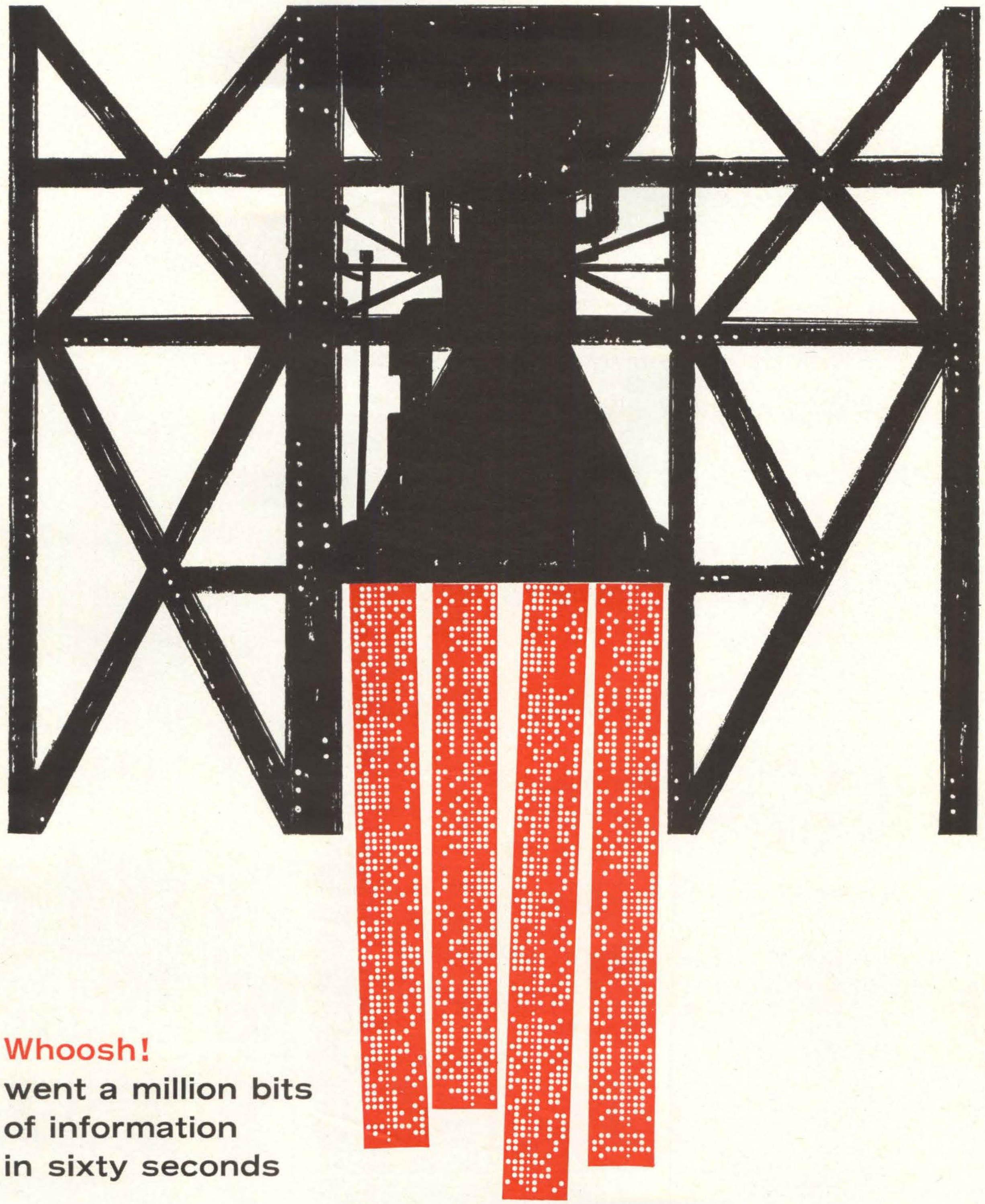
ISA Instrument-Automation Annual Conference and Exhibit, ISA, Park-Sheraton and New Yorker Hotels and Coliseum, New York, **Oct. 12-15.**

The Road to Commercial Electronics: A Conference on Converting Military Capabilities to Civilian Markets, Electronics Magazine, IIT Research Institute; Grover M. Hermann Hall, Chicago, **Dec. 1-2.**

Call for papers

Joint Automatic Control Conference, ASME, IEEE, ISA, AIAA, AICE; Rensselaer Polytechnic Institute, Troy, N.Y., June 22-25. **Nov. 15** is deadline for submitting papers to J.L. Shearer, Mechanical Engineering Dept., Pennsylvania State University, University Park, Pa. Topics include control theory, applications, components and control reliability.

Microwave Theory and Techniques Symposium, G-MTT/IEEE; Jack Tar Harrison Hotel, Clearwater, Fla., May 5-7. **Nov. 15** is deadline for submitting 10 copies of a summary (not to exceed four pages) to John E. Pippin, Chairman, Technical Program Committee, 1965 G-MTT Symposium, Sperry Microwave Electronics Co., P. O. Box 1828, Clearwater, Fla.



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Circle 11 on reader service card

The scanner-classifier console of the MTDS system. Microelectronic shift register cards using TI integrated circuits improved the reliability of the tracking computer used in the system.

How Litton achieved "cost effectiveness" with TI integrated circuits*

Each Marine Corps Tactical Data System is more reliable because 9100 SOLID CIRCUIT® semiconductor networks are used in vital shift registers of the system's tracking computer. Here is how engineers of the Data Systems Division of Litton Industries saved time and reduced costs on this improvement.

Litton engineers wanted to use Texas Instruments integrated circuits in a tracking computer in the Marine Corps Tactical Data System (AN/TYQ-2). They had already achieved a reliability improvement in the AN/ASA-27 (ATDS) computer indicator used in the Grumman E2A Aircraft by replacing discrete-component shift registers with microelectronic units made by TI. The question at hand was "how to gain the benefits of integrated circuits quickly and at the lowest possible cost."

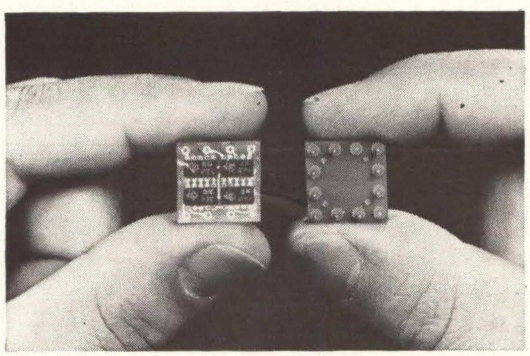
Litton's investigation revealed that modules already developed and proved in the ATDS System could be used without modification. These modules are assembled on printed circuit boards to form shift registers that are directly interchangeable — on a card-for-card basis — with the original discrete-component circuits.

Many benefits were realized. Litton costs for the modification were low. Delays in production were avoided. Evaluation procedures were simplified. Existing production facilities were used without modification. Production economies realized as a result of multiple system procurement were passed on to the end system users.

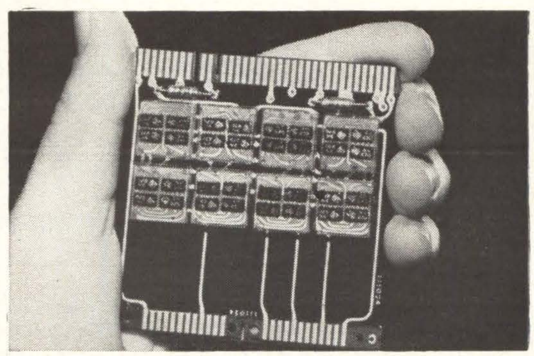
To summarize, the effectiveness of the Litton MTDS was achieved without delaying the project or adding to development costs appreciably . . . thanks to the versatility of Series 51 semiconductor networks and "Master Slice" variations supplied by TI.

Ask your local TI sales engineer or distributor for more information on the several linear and digital lines of SOLID CIRCUIT semiconductor networks and on the economies of using Master Slice variations. A telephone call will bring the information you need.

*Patented by TI



Here is the basic module supplied Litton by TI. Four semiconductor networks are assembled on a miniature circuit board with pin spacings adapted to Litton production requirements.



Several basic modules are then assembled to form a shift register card as shown. These cards are interchangeable with the discrete-component cards they replace.

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Accuracy and repeatability. The family includes nine instruments—ranging from the Model 50 Transistor Beta Tester to the Series 4000M Integrated Circuit Multiparameter Tester with Magnetic Disc Programming. Each is built to insure unparalleled accuracy—resolution as fine as ± 1 millivolt and ± 1 picoamp. Fairchild also employs advanced digital and low current pulse testing techniques to insure repeatability: when tests are repeated, conditions are identical and users can be confident that changes in results reflect changes in the device itself and not the equipment.

Low maintenance requirements. Highly reliable silicon Planar transistors and diodes are used exclusively in all Fairchild instruments. In addition, most models also feature self-protective circuitry, such as automatic short prevention. Users average less than 5% down-time. For prompt help with any maintenance problem, sales offices are staffed with thoroughly trained engineers and technicians.

Relatively low capital investment. Prices for these instruments are far below the research and development expenditure any company would incur attempting to build its own equipment with similar capabilities. Because of the modular design approach used, each instrument is readily expandable to avoid obsolescence. This feature also allows Fairchild a great deal of flexibility in assembling custom testing systems.

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844 CHARLESTON RD., PALO ALTO, CALIFORNIA, 962-2451 ■ TWX: 415-492-9414 ■ FAIRCHILD SEMICONDUCTOR, A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORP.

Editorial

Rx for a 'can't-do' headache

Not everybody agrees that suppliers of military electronics should diversify into commercial markets. More and more often you hear that companies just can't make the transition, they don't have the know-how.

Early this month we received a thoughtful letter from a reader who spelled out this view clearly. In part, he wrote: "In view of the sustained levels of military spending, your continued pleas for diversification seem to this reader rather like over-reacting. The basic inflexibility of some companies looks like the major stumbling block because such companies are product- and technique-oriented instead of problem- and solution-oriented. They do not seem able to envisage ways in which their engineering and product capabilities can meet the shift even from strategic systems into tactical weapons."

This argument is partly true; however, it doesn't negate the basic need for companies to diversify if they are to share in the coming boom in electronics. We believe that a management that is willing to diversify can acquire the essential knowledge.

One giant step in the learning process can take place Dec. 1 and 2 at the conference on "The Commercial Road to Electronics" cosponsored by Electronics magazine and the Illinois Institute of Technology Research Institute.

On this program, industrial leaders who have succeeded in commercial electronics will describe how they did it, spelling out the necessary changes in philosophy and pointing out some pitfalls. Dr. L. T. Rader, vice president of the General Electric Co.'s Industrial Electronics division, will keynote the conference, discussing "The management view of commercial operations."

Here is the program:

Session I. Product Planning

1. Comparing commercial and military product planning
2. What is a good product idea?
3. Panel: How we do product planning in:
   - Consumer electronics
   - Medical electronics
   - Industrial electronics

Session II. Engineering

1. Engineering organization and philosophy for commercial products
2. Cost consciousness in design
3. Profile of the engineer needed for commercial work

Session III. Manufacturing

1. Slanting production to commercial markets
2. The engineering aspects of commercial manufacturing

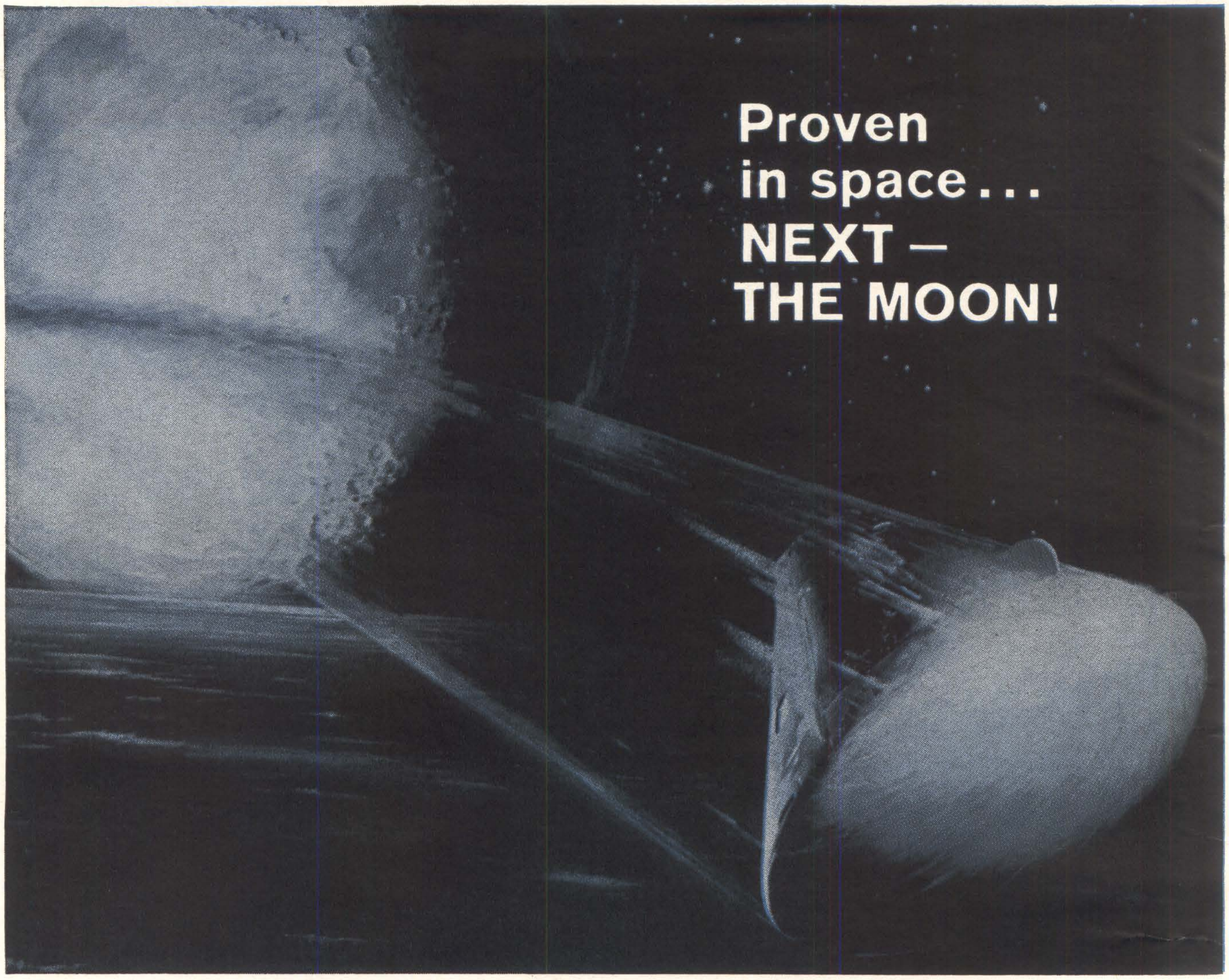
Session IV. Marketing

1. The basis for commercial marketing
2. Marketing opportunities
3. Marketing panel
   - Consumer electronics
   - Industrial electronics
   - Medical electronics
   - The retailer's view
   - The distributor's view

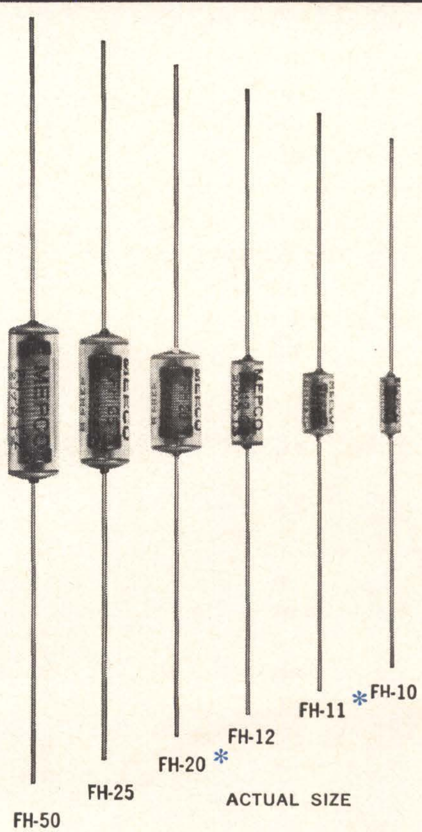
Most students of electronics markets agree that a boom is coming, but that it will be in the industrial and consumer fields. Industry is about to see a flood of new electronic controls. Microelectronic instruments are only a hairbreadth away. And integrated circuits in entertainment products and household appliances are already in the breadboard phase.

Companies outside the electronics industry see this. That's why chemical companies, builders of mechanical products and manufacturers of electrical products are diversifying into electronics.

We believe the die is cast. Many companies that fail to diversify will simply fail altogether in the next decade.



***These are the MINUTEMAN sizes of FH Series Resistors... and APOLLO designs are now utilizing ALL SIX models.**



Now, MEPCO FH Series Hermetically Sealed Glass Enclosed Metal Film Resistors are part of the lunar project! The FH Series features a true hermetically sealed enclosure that protects the highly stable resistance element against the most adverse environmental and use conditions. FH Series Resistors conform to High Reliability Specifications MIL-R-55182. They are constructed to MIL sizes RNR55, RNR57, RNR60, RNR63, RNR65 and RNR70 and meet Characteristics C and E of the specification. Available in ratings from $^1/_{10}$ watt to $^1/_2$ watt. Advanced manufacturing methods, rigid in-process quality control and individual unit testing techniques insure uniform quality, long life and stable performance. Write or call today for complete information and technical data.

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MEPCO

MANUFACTURERS OF **PRECISION ELECTRONIC DEVICES**

Electronics Newsletter

September 21, 1964

Wants circuits to have a ball

Scientific Data Systems, Inc., which recently announced the largest order of integrated circuits to date for industrial use, isn't happy with the packaging. Scientific Data is using both flatpacks and TO-5 can types in its 92 process computer system but finds the circuits, especially the flatpacks are "hard to handle, hard to test and hard to insert on printed circuit boards." The leads, 14 of them, are too close together and bend too easily.

The company suggests the flatpack be embedded in a plastic ball with self-supporting leads. "With this type of package, we could really reduce manufacturing, handling and testing costs," says a company official.

Fashion note for astronauts

One of the world's most unusual workshops has just been completed at Wright-Patterson Air Force Base, Ohio. **It is a space-maintenance facility in which astronauts will practice spaceship repairs while wearing electronically controlled space suits.** First in-orbit use of the suits will be in 1966, as part of the Gemini flight program.

An astronaut will be strapped into a mechanism that floats on films of air, nearly duplicating weightlessness. **It can spin him like a top if he makes any unbalanced movement. To avoid this, he'll use torqueless tools.** Other equipment to be tested includes electron-beam and ultrasonic welders being developed for space use.

The astronaut will also wear a maneuvering unit smaller than the one he'll use in space. The backpack contains a gyro-controlled automatic stabilization system that prevents tumbling by firing tiny gas jets. At his waist, he wears a control unit that lets him turn on the jets to move in any direction. The backpacks, made by Ling-Temco-Vought, Inc., have been tested for more than a year in cargo planes. But the planes must fly in ballistic trajectories which provide weightless conditions for only 20 seconds at a time. Operational units of the spacesuits will include a telemetry system to transmit biomedical and performance data, and two-way radio.

A companion simulator, for tests of a radio-controlled version of the backpack, is also in use at the base. With it and a closed-circuit television system, the astronauts will practice repairs with a remote-controlled system. **The astronauts will remain in the spacecraft while remotely-controlled tools get to work on the outside.**

Lasers tackle microcircuit job

The growing market for microcircuit-interconnection equipment is the target of a very low power laser being developed at the Speedway, Ind., laboratories of the Linde Co., a division of the Union Carbide Corp.

The welder will be able to make welds as small as a fraction of a mil in diameter. Beam outputs will range from 1 joule down to a few hundredths of a joule (1,000 joules equal one British thermal unit). **The welder will compete with precision electrical welders and may even compete with the thermocompression bonders that are a staple tool for attaching hairlike lead wires to microcircuits.** For example, an optical mask might be used to divide the beam so six or eight welds could be made simultaneously.

Linde says a beam output somewhere between 0.02 and 0.5 joule will be needed for delicate microcircuit work. When leads were welded to thin-film circuits at 0.5 joules—the lowest output with the present lab model—the welds looked like doughnuts—a bare spot on the substrate surrounded by a ring-shaped weld. The new welder will be ready in January and cost about $10,000.

Color-tv tests for Netherlands

Selected viewers in a 60-square-mile area near Eindhoven, the Netherlands, will get a look at the United States color-television system on Oct. 14. They'll submit technical reports on the transmission to Philips Gloeilampfabriken, N.V.

Philips has already experimented with the United States system and, because it is the most advanced, favors it over the French and German systems. But the method European color television will adopt still depends on the long-awaited decision of the International Radio Consultative Committee [Electronics, March 6, p. 17].

Lightning strikes space program

There will be no manned Gemini flight this year. Bad weather has forced postponement of the first launch until early next year. Lightning struck the Gemini launch pad at Cape Kennedy and the resultant damage necessitated repairs in the pad's electrical wiring. Valuable checkout time was lost when the Gemini launch vehicle had to be taken off the pad because of threats from hurricanes Cleo and Dora.

Klystron amplifier loses weight

A klystron amplifier weighing only 32-ounces paves the way for lighter weight, more compact and more efficient space communication systems. The new klystron developed by Litton Industries Electron Tube division is electrostatically focused. Earlier versions, introduced two years ago, weighed five pounds. [Electronics, Dec. 28, 1962, p. 26.]

The all-metal ceramic microwave tube has a nominal power output of 20 watts, continuous wave, at 2287.5 megacycles, but can be varied from 5 to 50 watts by varying the beam voltage. At the 20-watt power level, the beam voltage is 1,650 volts, the nominal efficiency is 30% (without a depressed collector), the gain is 20 decibels, the bandwidth is 5.5 megacycles, and the noise figure is 28 decibels.

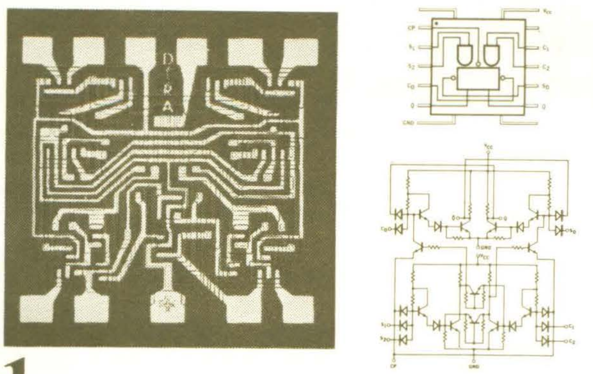
Values do not vary substantially over the entire power range. Since the focusing is electrostatic instead of magnetic, there are no external magnetic fields and only one power supply voltage in addition to the cathode heater supply is needed.

Lasers to measure Explorer's range

The search for laser applications continues. Now, for the first time, lasers will be used by the National Aeronautics and Space Administration to determine the range of a satellite.

After the Ionosphere Beacon Explorer is launched—during the next two weeks—an air-cooled ruby laser situated near NASA's Wallops Station, Va., will direct a beam of light, with one joule of power at one pulse per second, toward glass reflectors on the satellite as it passes. When the laser beam strikes the reflectors, it will be returned to the source, permitting precise measurements to be taken of the satellite's position in space. **A water-cooled laser at Goddard Space Flight Center will perform identical experiments.**

Circle 19 on reader service card →



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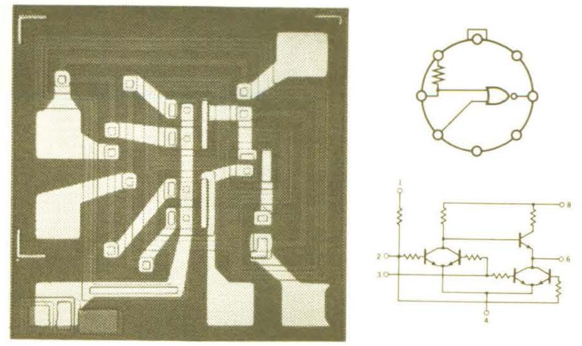

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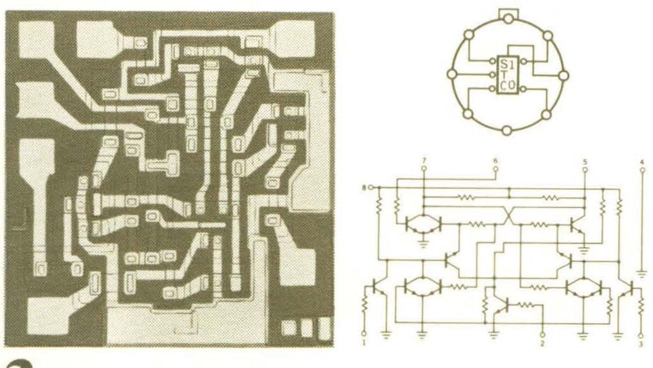

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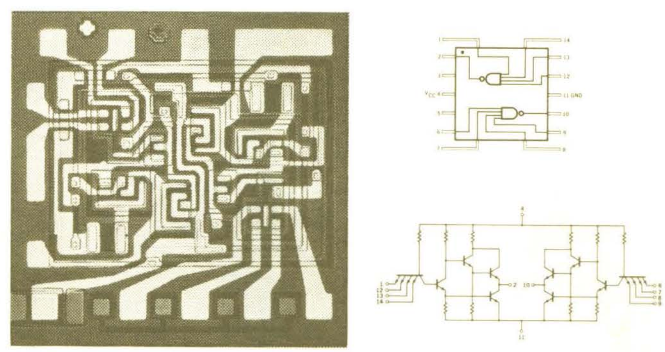

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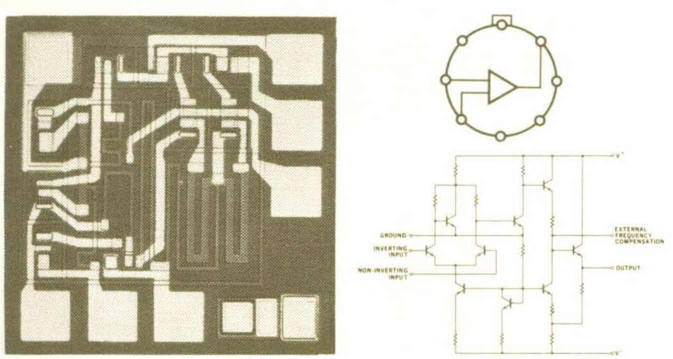

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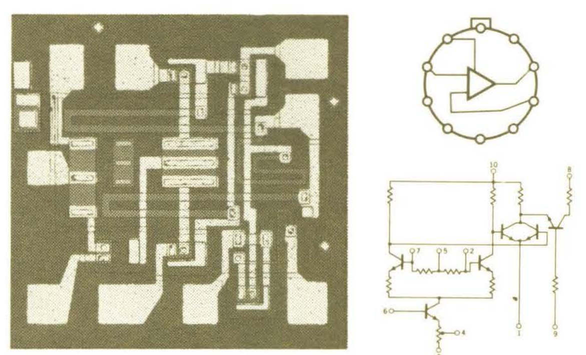


6._______________

Can you identify these integrated circuit types?

Match the correct letter below with number above:

(a) J-K flip-flop, a complete general purpose storage unit by Fairchild

(b) Dual gate using transistor-transistor logic by Fairchild

(c) Diode-transistor logic clock-gated flip-flop by Fairchild

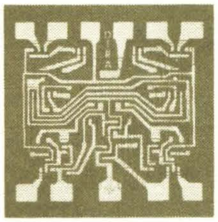
(d) Low power inverting driver circuit by Fairchild

(e) Sense amplifier custom-manufactured by Fairchild

(f) Operational amplifier by Fairchild

Find the answers inside—
along with more information on the industry's widest integrated circuit line...

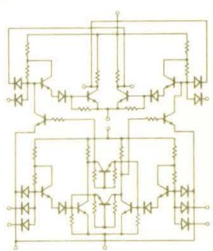
Total Capability—Fairchild Microcircuits



1(c) Diode-Transistor Micrologic (DTμL)

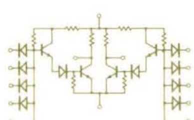
DTμL Flip-Flop 931

Clock Gated flip-flop
Propagation Delay (Typ):
50 nsec
Power Diss (Typ) 25°C: 20mW
Fan Out: 9



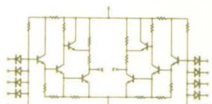
DTμL Dual Gate 930

Dual 4-Input Gate
Propagation Delay (Typ):
25 nsec
Power Diss (Typ) 25°C: 5mW
Fan Out: 7



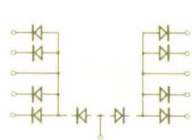
DTμL Buffer 932

Dual 4-Input
Propagation Delay (Typ):
25 nsec
Power Diss (Typ) 25°C: 15mW
Fan Out: 20



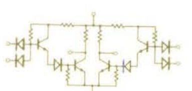
DTμL Input Extender 933

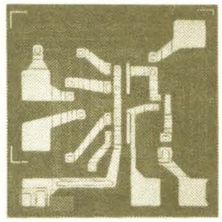
Dual input 4 high speed diode anode array to be used when increased fan-in is required



DTμL Quad Gate 946

Quad 2-input gate. Noise immunity 1 volt @ 25°C
Propagation Delay (Typ):
25 nsec
Power Diss (Typ) 25°C: 5mW
Fan Out: 8
Available September, 1964

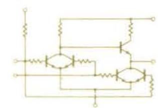




2(d) Milliwatt Micrologic (MWμL)

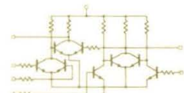
Gated Buffer 909

A low impedance inverting driver circuit. Used typically as a line driver, in multi-vibrators, or for pulse differentiation
Propagation Delay (Typ):
80 nsec
Power Diss (Typ) 25°C: 10mW
Fan Out: 30



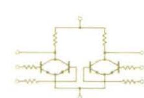
Modulo 2 Adder 908

Generates the Mod. 2 addition or exclusive OR function
Propagation Delay (Typ):
90 nsec
Power Diss (Typ) 25°C: 10mW
Fan Out: 4



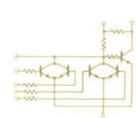
Dual Gate 910

Used as a pair of NOR gates R-S flip-flop, pair of inverters, or double inverter
Propagation Delay (Typ):
45 nsec
Power Diss (Typ) 25°C: 4mW
Fan Out: 4



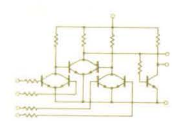
4-Input Gate 911

Used as an OR gate by applying true inputs
Propagation Delay (Typ):
80 nsec
Power Diss (Typ) 25°C: 4mW
Fan Out: 4



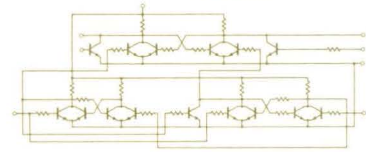
Half-Adder 912

A multipurpose combination of three basic RTL circuits for a complete half-adder or an exclusive OR gate
Propagation Delay (Typ):
90 nsec
Power Diss (Typ) 25°C: 8mW
Fan Out: 4



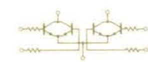
Type D Flip-Flop 913

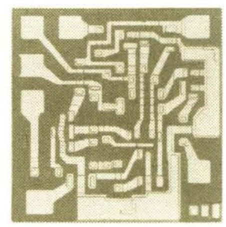
This element is a gate flip-flop for use as a binary in registers and counters
Propagation Delay (Typ):
100 nsec
Power Diss (Typ) 25°C: 15mW
Fan Out: 3



Gate Expander 921

A Dual 2-input gate without node resistors, to be used when increased fan-in is required
Propagation Delay (Typ):
40 nsec

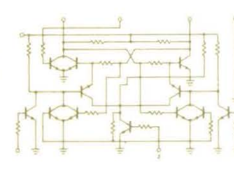




3(a) High Speed Micrologic (μL)

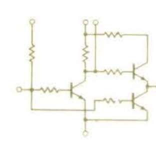
J-K Flip-Flop 916

A complete, general purpose, storage element suitable for use in shift registers, counters, or any type of control function
Propagation Delay (Typ):
10 mc
Power Diss (Typ) 25°C: 52mW
Fan Out: 3



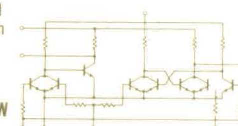
Buffer 900

A low impedance inverting driver circuit
Propagation Delay (Typ):
16 nsec
Power Diss (Typ) 25°C: 30mW
Fan Out: 25



Counter Adapter 901

Provides gated, non-inverted complementary outputs from a single-valued input
Propagation Delay (Typ):
24 nsec
Power Diss (Typ) 25°C: 55mW
Fan Out: 5

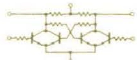


F/1-9564

Off-the-shelf silicon Planar digital and analog circuits plus a complete custom capability. Devices for full military temperature range: −55°C. to +125°C.

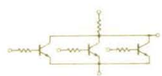
Flip-Flop 902

A bistable flip-flop storage unit
Propagation Delay (Typ): 14 nsec
Power Diss (Typ) 25°C: 22mW
Fan Out: 4



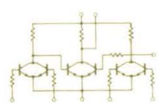
Three-Input Gate 903

A three-input NAND/NOR circuit
Propagation Delay (Typ): 12 nsec
Power Diss (Typ) 25°C: 12mW
Fan Out: 5



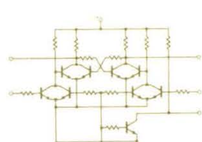
Half-Adder 904

A two-level AND/OR gate suited for use as a complete half-adder, an exclusive OR gate or any similar logic function
Propagation Delay (Typ): 16 nsec
Power Diss (Typ) 25°C: 34mW
Fan Out: 5



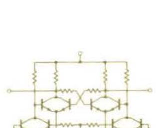
Half-Shift Register 905

A gated input storage element with inverter
Propagation Delay (Typ): 18 nsec
Power Diss (Typ) 25°C: 53mW
Fan Out: 4



Half-Shift Register 906

A gated input storage element without inverter (reduces power dissipation)
Propagation Delay (Typ): 22 nsec
Power Diss (Typ) 25°C: 36mW
Fan Out: 4

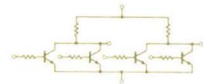


Four-Input Gate 907

A four-input NAND/NOR circuit
Propagation Delay (Typ): 12 nsec
Power Diss (Typ) 25°C: 12mW
Fan Out: 5

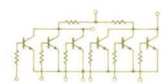
Dual Two-Input Gate 914

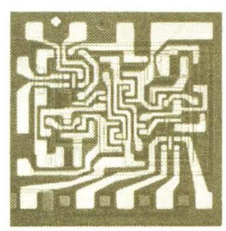
Dual NAND/NOR gates capable of forming a flip-flop, non-inverting gate, or gate plus inverter
Propagation Delay (Typ): 12 nsec
Power Diss (Typ) 25°C: 24mW
Fan Out: 5



Dual Three-Input Gate 915

A dual combination of three-input circuits, one of three similar basic NAND/NOR gates
Propagation Delay (Typ): 12 nsec
Power Diss (Typ) 25°C: 24mW
Fan Out: 5



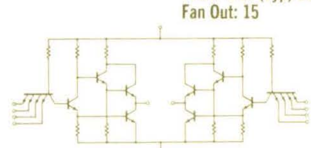


4(b)

Transistor-Transistor Micrologic (TTμL)

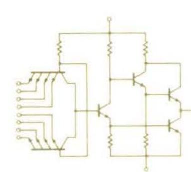
TTμL Dual 4-Input Gate 103

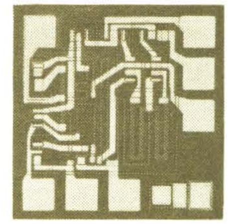
Micrologic Dual 4-Input Gate
Propagation Delay (Typ): 25 nsec
Power Diss (Typ) 25°C: 22mW
Fan Out: 15



TTμL 8-Input Gate 104

Micrologic 8-Input Gate
Propagation Delay (Typ): 30 nsec
Power Diss (Typ) 25°C: 22mW
Fan Out: 15



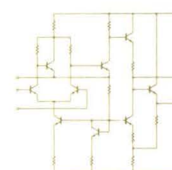


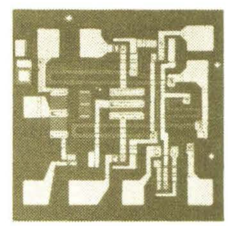
5(f)

Analog

μA702

Operational Amplifier
Gain (Typ): 64 db
Bandwidth (Typ): 1.1 MC
Input Resistance Ohms (Typ): 5 K
Output Resistance Ohms (Typ): 300
Power Diss (Typ) 25°C: 100mW



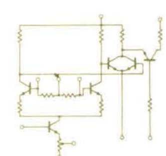


6(e)

Custom

μC113

Sense Amplifier
Gain (Typ): 200
Bandwidth (Typ): 2 MC
Input Resistance Ohms (Typ): 3 K
Power Diss (Typ) 25°C: 40mW

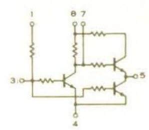


This is just one example of countless digital and linear microcircuits Fairchild can manufacture *to your specifications.* You design and breadboard it, we integrate it. Write for Fairchild's Custom Microcircuit Design Handbook.

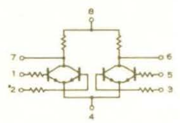
For more answers to your integrated circuit requirements, see the next page.

Total Capability...
Low Price Microcircuits

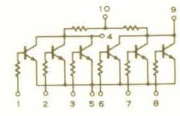
COMPATIBLE SILICON PLANAR EPITAXIAL DIGITAL ELEMENTS GUARANTEED OVER 15°C TO 55°C TEMPERATURE RANGE



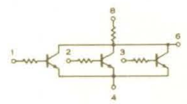
FμL 90029
BUFFER



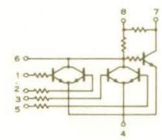
FμL 91029
DUAL
2-INPUT GATE



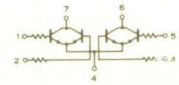
FμL 91529
DUAL
3-INPUT GATE



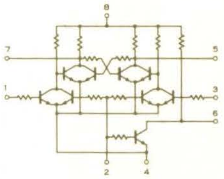
FμL 90329
3-INPUT GATE



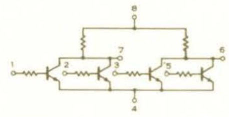
FμL 91129
4-INPUT GATE



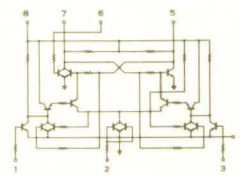
FμL 92129
EXPANDER



FμL 90529
HALF SHIFT
REGISTER



FμL 91429
DUAL
2-INPUT GATE



FμL 92329
J-K FLIP-FLOP

These integrated circuits are specially priced for non-military applications such as commercial computers, industrial control equipment, instrumentation and test equipment. Functional equivalents of Fairchild's Micrologic and Milliwatt Micrologic elements, they are guaranteed from 15°C. to 55°C. They are available in volume quantities, packaged in low silhouette TO-5 type headers with eight or ten leads.

Proven quality. The Fairchild commercial microcircuit line has grown from the industry's oldest and largest integrated circuit capability. Since 1960, Fairchild has produced more than 1,000,000 Micrologic units, primarily for space and defense. Commercial units are manufactured by the same Planar Epitaxial techniques and benefit equally from Fairchild's long experience and rigid production control.

PRICE LIST

	1-24	25-99	MIX 100	NON MIX 100
FμL 92329 J-K FLIP-FLOP	9.50	7.60	6.65	6.35
FμL 90529 HALF SHIFT REGISTER	6.50	5.30	4.55	4.35
FμL 90029 BUFFER	3.75	3.00	2.65	2.55
FμL 90329 3-INPUT GATE	3.75	3.00	2.65	2.55
FμL 91529 DUAL 3-INPUT GATE	4.75	3.80	3.35	3.20
FμL 91129 4-INPUT GATE	4.00	3.20	2.80	2.65
FμL 91029 DUAL 2-INPUT GATE	4.00	3.20	2.80	2.65
FμL 92129 EXPANDER	4.00	3.20	2.80	2.65
FμL 91429 DUAL 2-INPUT GATE	4.00	3.20	2.80	2.65

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A leak rate reliability more than 100,000 times better than the requirement of MIL-Spec 3098 is provided by Reeves-Hoffman cold-welded crystal holders. The miniaturized crystal-controlled dual filter shown above contains two crystals in cold-welded holders.

When NASA's Ranger VII blasted off, cold-welded crystal units supplied by Reeves-Hoffman went with it. These units, which are now spread across the moonscape, functioned perfectly in Ranger VII's central controller and sequencer. They were selected by engineers at the Jet Propulsion Laboratory because they provided the needed reliability in the smallest possible package. It is because of this reliability and miniaturization that cold-welded units are not only on the moon, but also in use in submarine cables and in many other applications where maintenance is impossible or extremely difficult.

Reeves-Hoffman's new cold-welding process eliminates solder, and attendant flux and heat, removes undesirable damping and corrosion, solves problems of thermal isolation. The results: substantial increases in the reliability and stability of crystal units, oscillators and filters; further opportunity for miniaturization; faster delivery; lower cost.

For space, undersea or "down-to-earth" applications, get complete information on Reeves-Hoffman cold-welded units.

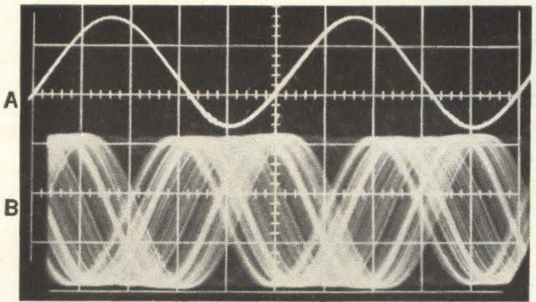
REEVES-HOFFMAN
DIVISION OF DCA

400 WEST NORTH STREET, CARLISLE, PENNSYLVANIA

TIME BASE CORRECTION

A

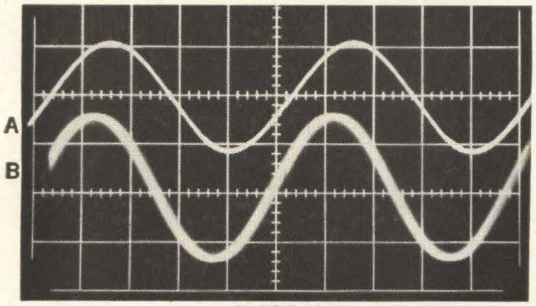
B



CONVENTIONAL

A

B



TICOR II

TRACE A: 100-kc oscillator reference signal
TRACE B: 100-kc line driver output, track 13
One-inch tape, speed 60 ips. Sweep rate: 2.0 μsec/cm.
Photo exposure: 1/25 sec.

EXCLUSIVE STORY ON MINCOM'S NEW 1.5-mc TICOR II

On playback, lock in your tape reference track to TICOR II's reference oscillator signal—the traces above demonstrate a time-base correlation between events holding well within $\pm 0.5\ \mu$sec, continuously anywhere on the tape. This unique and exclusive Mincom 1.5-mc recorder/reproducer immediately updates any existing data reduction center. It opens new doors to data analysis in radar recording, single sideband, serial PCM and other systems dependent on precise time-base stability. Flutter components below 200 cps are essentially removed. Rapidly convertible from ½-inch to 1-inch tape, all solid state, one equipment rack, RFI-shielded. Write for specifications.

Mincom Division 3M COMPANY

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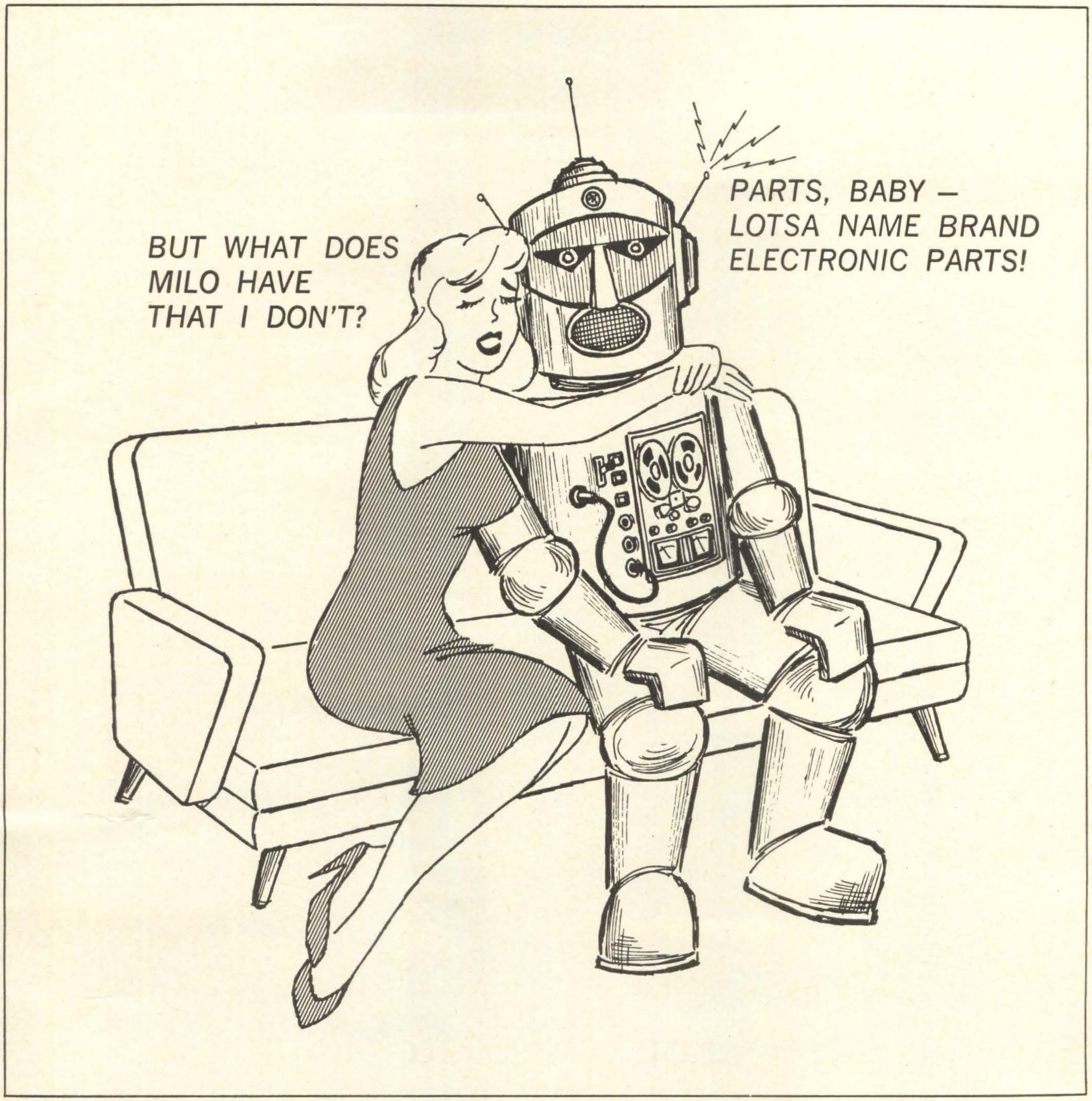

MILO'S "EX" APPEAL is what counts most with those who specify and purchase industrial electronic components: Extremely extensive off-the-shelf stock – we're extravagantly stacked with thousands of different products, over a hundred top name brands; Express delivery of exactly what you order; Expert technical assistance; Exacting followup and expediting of exigent orders; Exemplary experience acquired over twenty years of exclusively industrial distribution. So whenever your desires are explicity electronic, exploit Milo's dependability – because we really care about your needs, and take extra care to meet them.

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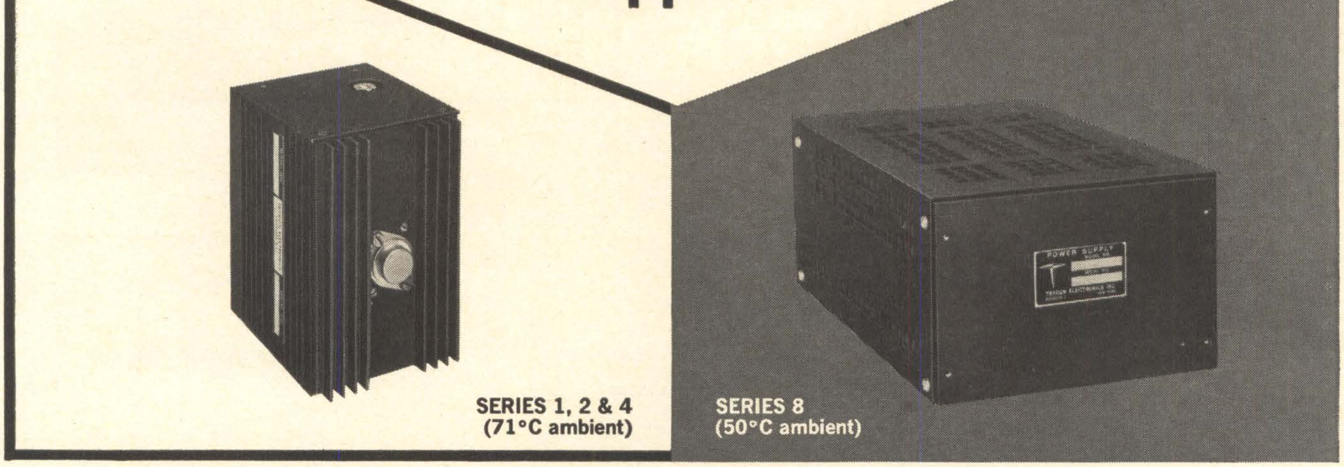

Plug them in anywhere . . . then forget them!

Whether you need Trygon modules for your own use or to incorporate into systems you are producing, you can rely on Trygon dependability. You merely select the proper Trygon module, mount it—horizontally or vertically—and forget it!

Here's why: High-efficiency circuits result in less internal heat build-up and longer life. Series 1, 2 and 4 feature all silicon semiconductors, designed to operate in ambients up to 71°C WITHOUT ANY DERATING! All series have generous built-in heat sinks—no additional heat sinking or forced air cooling is required. Current-limited short circuit protection automatically resets when the fault is removed—so again, you don't have to worry about where you place a Trygon module in a system.

Remote sensing and programming provisions are also built-in. And premium components plus derated circuits yield MTBF figures in excess of 30,000 hours. All components are readily accessible. For additional flexibility, input/output connections are available with either terminal strips, solder lugs or octal sockets.

Overvoltage protection is available on all units as an optional extra. Series 1 is provided with Fixed Overvoltage Protection (FOV) while all other modules (Series 2, 4 and 8) are available with Trygon's standard Automatic Overvoltage Protection (OV).

See the chart for standard models, then contact your Trygon rep. Or, write for complete catalog to Dept. E-24.

ELECTRICAL SPECIFICATIONS

Model	Reg: Load	Reg: Line	Ripple mv RMS	Recovery Time	Ambient Oper. Temp.
Series 1, 2 & 4	0.02%	0.01%	Less than 0.5	Less than 50μ sec	−20°C to +71°C
Series 8	0.01%	0.01%			−20°C to +50°C

Complete line of module rack adapters available for assembly of complex power supply systems to meet your specific needs.

MODELS

Series	Model	OUTPUT Volts	Amps	PRICE† 1-14	Overvoltage Protection
1*	PS20-400	0-20	0-0.4	$140	For Fixed Overvoltage Protection (FOV) add $75 per unit.
	PS32-250	0-32	0-0.25	140	
	PS50-150	0-50	0-0.15	155	
	PS3-1.5F	2.5-3.5	0-1.5	130	
	PS6-1F	4-8	0-1	120	
	PS12-900F	10-14	0-0.9	115	
	PS15-800F	13-17	0-0.8	120	
	PS18-800F	16-20	0-0.8	120	
	PS24-700F	22-26	0-0.7	120	
	PS28-600F	26-30	0-0.6	120	
	PS48-400F	46-50	0-0.4	130	
2	PS10-2	0-10	0-2	160	Note A
	PS20-1.5	0-20	0-1.5	160	
	PS32-1.25	0-32	0-1.25	165	
	PS50-750	0-50	0-0.75	180	
4	PS10-4	0-10	0-4	195	Note B
	PS20-3	0-20	0-3	195	
	PS32-2.5	0-32	0-2.5	200	
	PS50-1.5	0-50	0-1.5	215	
8	PHR20-5	0-20	0-5	250	Note C
	PHR20-10	0-20	0-10	325	
	PHR40-2.5	0-40	0-2.5	250	
	PHR40-5	0-40	0-5	295	
	PHR60-2.5	0-60	0-2.5	325	
	PHR60-5	0-60	0-5	395	

*Lower current models also available, at lower prices

†Write for discount prices on larger quantities

A. For Automatic Overvoltage Protection (OV) add $90 per unit.

B. For Automatic Overvoltage Protection (OV) add $95 per unit.

C. For Automatic Overvoltage Protection (OV) add $95 per unit, except for Model PHR60-5, $125.

TRYGON ELECTRONICS INC.

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Electronics Review

Volume 37
Number 25

Consumer electronics

Music with a bounce

Stereophonic music is a delight to the ear but often an offense to the eye. The large speakers that have to be separated physically to produce the enveloping effect of stereo are connected by wires to the record player. This frequently results in a hazardous, unsightly tangle of wiring in the living room or den.

Now the CBS Laboratories, a division of the Columbia Broadcasting System, have developed a single-unit phonograph that produces high-quality stereo sound without large speakers or outside cables. The Columbia Stereo 360 creates stereo sound by playing the sound out both sides of the phonograph and then reflecting it off the walls of the room.

To produce high quality sound, CBS has turned the record-playing compartment into an acoustic chamber, and coupled it to the bass speakers. Since volume of a speaker is an important factor in tone quality, CBS adds the volume of the chamber to that of its six-inch bass speakers. It even put a false bottom on the instrument to increase the volume further and improve tone quality still more.

This novel approach is the brainstorm mainly of Peter Goldmark, director of CBS Laboratories. It was Goldmark who developed the long-playing record in 1948.

The new phonograph is only 22 inches wide, about 30 inches long, and 6 inches high. Six speakers, three on each side, are squeezed into its functional shape. Two are bass, two are medium and two are high-frequency speakers.

Bouncing sound. While listening to music at concerts and studying its path to the audience, Goldmark discovered that nearly three-quarters of the sound was produced by reverberations coming from every direction. He thought he might be able to build a stereo set based on the same principle.

Placement of the phonograph can affect, to some extent, the fidelity of the sound reproduction. CBS recommends it be positioned diagonally in the corner of a room so that sound from each side of the instrument bounces off a wall and back into the room.

Transistorized amplifier. To fit the electronics into the flat front edge of the unit so they would not intrude into the acoustical record-player chamber, Goldmark built two solid-state amplifiers that draw little power, only 15 watts apiece. Each amplifier is designed as a push-pull transistorized circuit so neither needs transformers. This reduces the total number of components and the cost. CBS claims that the elimination of the transformers also improves the amplifiers' fidelity since these components can cause distortion.

High quality, low price. Though Goldmark is most proud of the fine quality sound his compact stereo produces, he is almost as proud of its cost. The new unit will retail for about $250, far below the cost of most stereo units capable of the same high fidelity.

Peter Goldmark and his compact stereo

Communications

Rescue radio

To an airman downed at sea, the next best thing to a rescue vessel would be a radio beacon sending out a distress signal, loud and clear. It would be reassuring if he had some way of knowing that the equipment worked. If the set also allowed two-way talk with rescue parties, so much the better. And if a distress signal could be sent, even though the flier were unconscious, his chances for survival would be increased tremendously.

Advances in microelectronics are making all this possible. At the Naval Air Test Center, Patuxent River, Md., first models of a new pocket-sized two-way radio and beacon are being evaluated. Developed for the Navy by Sylvania Electronic Systems, a unit of the General Telephone & Electronics Corp., the AN/PRC-63 is designed around thin-film hybrid microcircuits. It is believed to be the first operational uhf transceiver using microelectronics.

The set weighs about 16 ounces and includes a self-contained helical antenna. There is no need for whip wires in airmen's flying suits or for protruding antennas. The aluminum helix is topped by a plastic radome. The 14-cubic-inch package also includes a rechargeable nickel cadmium battery. A silver cadmium cell under development for future models is about half the size of the nickel cadmium battery.

Vest-pocket size. Carried in a flier's life vest, the PRC-63 will operate automatically in the beacon mode. When a flier's chute opens, a switch activates the beacon. Even if the airman loses consciousness during ejection from a fast-moving jet the signal is sent. A distinctive chirp is emitted at the survival-call frequency of 243 megacycles. The chirp is initiated with square-wave amplitude modulation at 1,000 cycles per second. It is then dropped in frequency to 300 cps by frequency modulating the wave.

The beacon uses a side-tone monitor technique. Operating as a detector of output power, it "steals" only about one milliwatt, and provides the pilot with comforting proof that the unit is operating even before he succeeds in communicating with search parties.

In the beacon mode, the AN/PRC-63 puts out 250 milliwatts peak. On voice transmission, the carrier output drops to about 60 milliwatts. The battery can operate the beacon for at least 24 hours.

The microelectronic circuitry occupies only two cubic inches. It is designed to operate in temperatures from −60° C to 60° C. A metal case and the plastic radome allow the beacon-transceiver set to function even after exposure to the pressure under 50 feet of salt water or at an altitude of 40,000 feet.

Receiver and transmitter. The receiver is a superheterodyne unit including a radio-frequency preamplifier and a crystal-controlled local oscillator. Automatic gain control is designed into the receiver circuitry. Sensitivity of the receiver is about five microvolts, and band width about two megacycles.

The transmitter is crystal-controlled, and the overtone oscillator at 121.5 Mc drives the final stage at 243 Mc. Transmitter design includes provision for beacon modulation and also an audio amplifier for voice modulation.

Military electronics

Jungle sounds

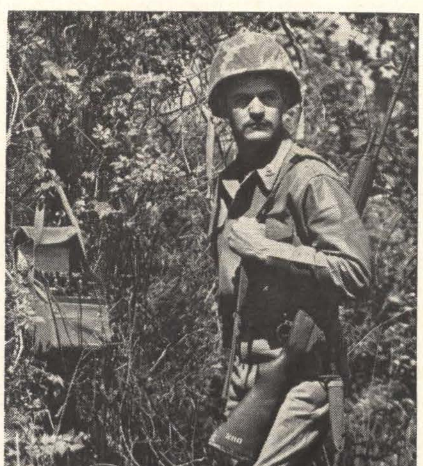
Do jungle creatures — animals, birds, insects—have specific vocal reactions to the presence of men? If they do, and if the differences can be identified, researchers will have a valuable tool for the development of equipment to detect the presence of enemy guerrillas.

In a research program conducted by the Army, Cornell University and the General Electric Co., men from GE's Advanced Technology Laboratory are recording natural jungle sounds on stereo microphones sensitive enough to pick up sounds inaudible to man. The sounds are recorded at the base station laboratory on a seven-channel tape recorder. Visual monitoring is accomplished with a four-channel oscilloscope, in addition to a regular headset listening device. After the natural sounds have been recorded, U.S. Army troops move into the jungle and the animal and bird reactions are recorded.

Warning alarm. In yet another program, Texas Instruments, Inc., has developed a device that it says can detect and warn of movements within an area of about six square miles. The SID-150—or seismic intrusion detector—monitors waves in the sub-audio range of 15 to 30 cycles per second, converts them to audible sounds through an am-fm modulator, and sounds a warning alarm to an operator.

The main console weighs eight pounds and operates on six flashlight batteries. It comes equipped with four seismometers, each weighing 13.5 ounces.

The company says that even the sounds of a man creeping through underbrush a mile away will be picked up by the device. It may not help much—the operator must decide whether the sounds are made by friend or foe.



People detector is tested in the field.

Solid state

Passivating transistors

Passivation—the growth of an oxide layer on the surface of a semiconductor—provides electrical stability by isolating the transistor surface from electrical and chemical conditions in the environment. Without passivation, normal mesa etching leaves the base-collector and emitter-base junctions exposed. This results in high reverse-leakage currents, low breakdown voltages, low betas at low currents and low power dissipation rating. Now, Hitachi, Ltd., a Japanese electronics firm, has developed a way to passivate silicon mesa transistors.

Most transistor makers use the planar technique, which eliminates the mesa etching process. But while avoiding electronic problems, they have run into patent problems with the Fairchild Camera & Instrument Corp. whose Semiconductor division claims the basic patent on the planar process. They have also had to make large investments in new facilities to mass-produce planars.

Hitachi avoids both pitfalls by using a passivated silicon mesa transistor which it claims is competitive with planar transistors in both cost and performance. Electrical characteristics include long life, collector breakdown voltages in excess of 200 volts, and gain maintained to low values of collector current. Heat dissipation ratings are 35 milliwatts for a TO-1 cold-seal can, 750 milliwatts for a TO-5 ring-weld can with no heat sink and 2 watts for a TO-5 can with a heat sink.

The new product line is aimed at the entertainment industry. A complete line of hermetically sealed transistors produced with the passivation process would have applications ranging from low-level d-c amplifiers through moderate power vhf amplifiers. Hitachi says its hermetically sealed transistors are more reliable than resin mold planar units now in use.

Avionics

Space-fuel gauge

A radioisotope gauge coupled to a microcircuit computer will be used aboard the Apollo spacecraft to give spacemen some vital information. It tells how much fuel they have.

Absence of gravity in space permits fuel to slosh around in the tanks; therefore conventional measuring techniques, based upon the fuel level, are unsatisfactory. Instead, 200 cobalt-60 sources are embedded in one side of a glass fiber blanket that surrounds the fuel tank. Scintillation detectors on the other side of the blanket measure the radiation rate, which increases as the fuel is used and the chamber empties.

The detectors convert the gamma rays from the cobalt into light pulses, and direct them to the base of a phototube which, in turn, sends out a series of electrical impulses that are routed to a small computer. The computer, designed by the Giannini Controls Corp. which developed the gauging system, includes about 2,000 diode-transistor-logic microcircuits manufactured by the Signetics Corp. Outputs from buffer amplifiers on the propellant tanks are fed to the computer.

Fuel levels are displayed digitally on Nixie tubes, after conversion from binary to decimal form. They are also telemetered to the ground.

A snap. The system is easy to install. It snaps into place on the propellant tanks, reducing the interface required between the tanks and the gauging system and eliminating the necessity of placing probes or other sensors directly into the fuel.

Giannini is developing the gauge under a contract with the Space and Information Systems division of North American Aviation, Inc.

Advanced technology

Bomb detectors

An average of six lives a year have been lost since 1933 as a result of bomb explosions on American civilian aircraft. Now the Federal Aviation Agency is testing two electronic methods of finding bombs before they can do any damage.

One method involves detecting tiny amounts of vapor that are given off by all types of explosives. The other uses a nuclear coincidence indicator to respond to nuclear tracers, such as cobalt 60, that would be placed in bombs' percussion caps.

Encouragement. Vapor detection is the subject of a $39,000 project at the IIT Research Institute in Chicago. The one-year study, scheduled for completion in December, aims at establishing some basic facts that may lead to a fool-proof bomb-finder. Results so far are "encouraging," according to Andrew Dravnieks, science adviser.

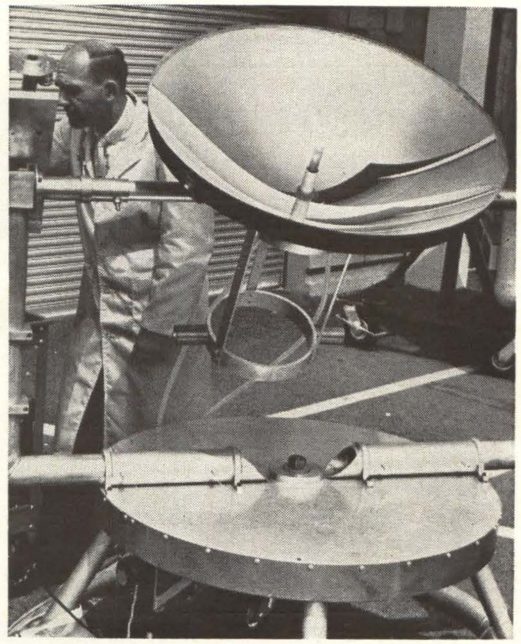
Dravnieks, a physical chemist by training, says feasibility studies are being made on a detection system "based on physico-chemical processes and electronic detection and information processing."

A report on the percussion-cap studies is due in about a month, according to William C. Richardson of the FAA's program-development services. The present phase of the studies deals with radioactive isotopes that are put into the caps.

Even if the isotope technique works technically, it will face formidable economic and logistic problems. All makers of percussion caps in this country and abroad would have to agree to insert the radioactive tracer material. Another problem is the possible danger to the manufacturers' employees from exposure to radiation.

Sun-pumped laser

Electro-Optical Systems, Inc., in Pasadena, Calif., has developed a sun-pumped laser that can be carried aboard a satellite and modulated to provide an optical communications system. The work was done under an Air Force contract.



Parabolic mirror concentrates sun to pump laser.

The sun-pumped laser weighs less than electrically pumped lasers that need power supplies, capacitor banks and flash tubes; and it eliminates the dangers inherent in present-day chemically pumped lasers, several of which have exploded during pumping.

The key to the sun-pumped device is a new laser crystal, an yttrium aluminum garnet crystal rod, which has a very low threshold and doesn't have to be cooled down to cryogenic temperatures, as did previous sun-pumped lasers. The special garnet is doped with neodymium to emit at 1.06 microns, and is surrounded by a water-filled cooling glass flask that serves as a liquid lens.

The sun's energy is concentrated by a paraboloidal mirror 30 inches in diameter. So far, this mirror has pumped up a continuous-wave laser to produce 25 milliwatts at 300° K in ground-level sunlight. The company says that in space, without atmospheric effects, a mirror of half that area could operate a continuous-wave laser at over one watt.

Manufacturing

Circuits by the yard

Take two facts: Silicon crystals can be grown in thin, narrow strips several yards long, called dendritic webs, and electron beams can expose the photo-resist needed to make integrated circuits on silicon crystal. Put these together with computer control and the automated production of one-of-a-kind microcircuits becomes an attractive possibility.

The web could serve as its own conveyor belt, going from the crystal-pulling furnace into a series of masking, etching, diffusion and deposition machines that would fabricate one circuit after another on the web. At the end, single circuits, or series of circuits connected as a subsystem, could be snipped off and packaged.

Such a production system is now only a far-off goal for researchers at the Westinghouse Electric Corp.'s labs near Pittsburgh. In 1959, when Westinghouse first proposed such a system, it wouldn't work with conventional photo-resist masking methods. But now Westinghouse believes it has nailed down that problem by exposing the photo-resist with electronically controlled electron beams. Operating transistors, including field-effect devices, have been made using the beam technique. In present experiments, as many as 12 integrated circuits are made on short pieces of web.

Electron-beam masking. The work on masking is part of a much larger, long-term project at Westinghouse. The company is concerned with the use of electron beams to make and test semiconductor devices automatically. The program, partly sponsored by the Air Force, has been under way for several years. The primary research tool is a scanning electron microscope [Electronics, July 28, 1961, p. 39].

The microscope's electron beam can be focused to a spot size of 0.1 micron and used to cross-link the polymers in thin layers of photo-resist. Thus, in a few seconds, complex patterns only a few microns square can be developed in the resist. The electron beam is synchronized with a flying-spot scanner that scans a large pattern on film. The electron beam goes on and off as the scanning beam sees opaque or transparent areas on the film.

This technique avoids the tiny, precision, mechanical masks generally used to optically develop photo-resist for etching and diffusing. Mechanical masks cost little per circuit when circuits are mass-produced, but can raise the cost of one-of-a-kind circuits to hundreds or thousands of dollars.

Even the inexpensive patterns used by the electron beam system may be eliminated. Westinghouse is completing a new microscope that is digitally controlled. With it, computer-prepared programs on punched cards could be used to control the electron beam.

The web. Dendritic webs aren't new. Westinghouse, for example, announced transistors made on webs in 1959 and the Philco Corp. was feeding germanium webs to its automated transistor production lines by 1960 [Electronics, Sept. 11, 1959, p. 98, and Nov. 11, 1960, p. 128].

Unlike the conventional rod-shaped crystals, webs don't have to be sliced, lapped and etched. They come out of the furnace with a mirror-like finish. A recent Westinghouse-Air Force report on the use of webs for solar cells and transistors estimates the cost of usable diced crystal as one-fifth that of conventionally prepared dice and says they're just as good.

But the shape of the web frustrates attempts to use them for integrated circuits. It is more efficient to use a large slice of crystal rod if hundreds of circuits are to be made at a time using optical masks. Also, a web is shaped like an I-beam. A web 0.3 inch wide may have dendrites, or side rails, 0.06 inch high. A mechanical mask can't sit directly on the web. Even if the rails are trimmed off, the web isn't perfectly flat. Both conditions distort the pattern developed in the resist when a mask is used. This becomes a serious problem when tiny, precise patterns are needed. It's no problem for the electron beam; it can be aimed directly onto the web.

Instrumentation

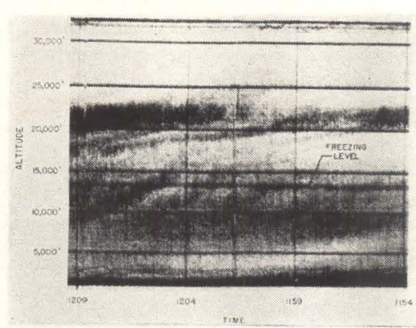
Cloud analyzer

Airports, which analyze clouds electronically to get weather forecasts, now have three technical advances for their radar equipment: a new magnetron, a receiver of added capability, and new facsimile recording equipment. They are designed to improve cloud pictures considerably.

Precise data on cloud size, density and altitude are necessary for flight-weather information. The new, integrated measuring system was developed for the Air Force by the Data and Controls division of Lear Siegler, Inc. Now the Federal Aviation Agency has ordered three systems for its own studies.

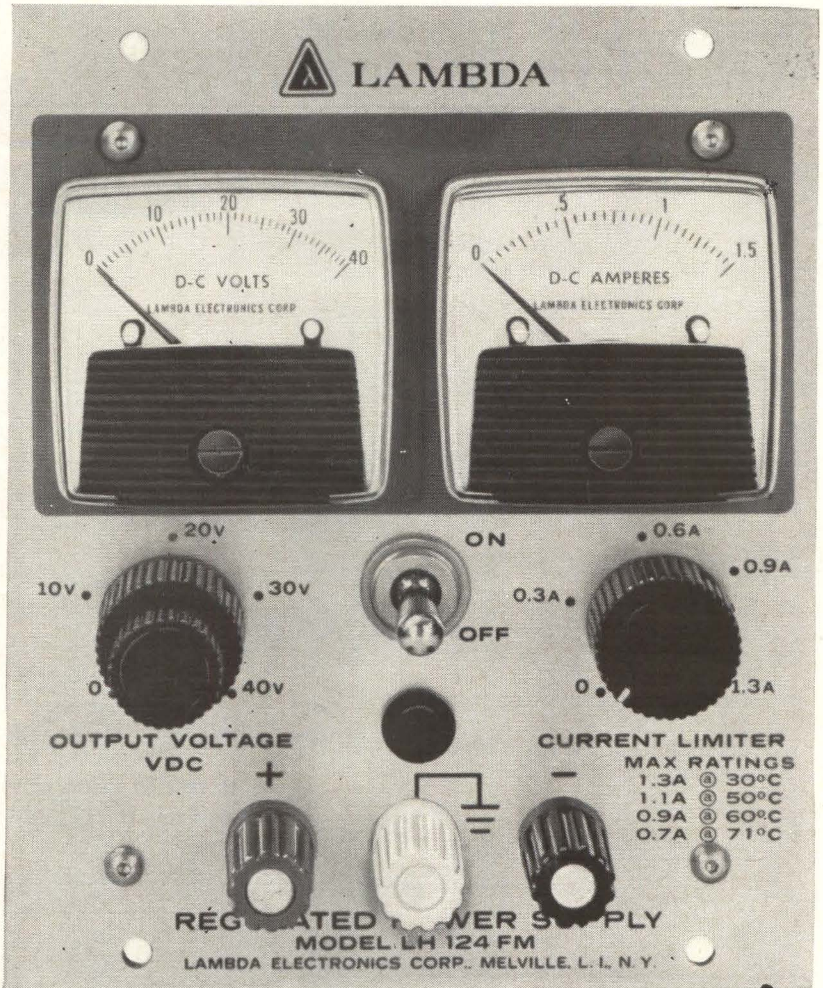
The integrated system gathers, processes, transmits and displays weather data. It starts with an AN/TPQ-11 radar making basic measurements. The radar signals are conditioned, processed and displayed, both on a cathode-ray tube and on a hard-copy facsimile recorder.

Inside the cathode. Probably the most radical change is in the design of the magnetron tube that generates the radar beam. The



A cloud profile facsimile recording made by the AN/TPQ-11. The moisture freezing level (dark line) is shown at 13,000 feet. Variations in cloud density are indicated by the white and black shading.

ACTUAL SIZE FRONT PANEL ¼ RACK LH MODELS



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- Size: LH 118, 121, 124, 127 – 5³⁄₁₆" x 4³⁄₁₆" x 15⁵⁄₁₆"; LH 119, 122, 125, 128 – 5³⁄₁₆" x 8⅜" x 15⁷⁄₁₆"

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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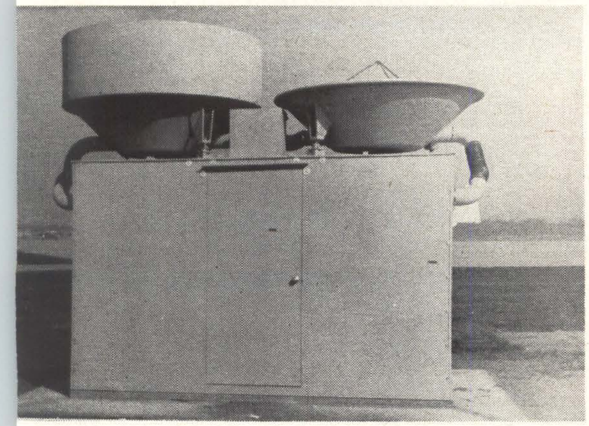
LA155

Circle 35 on reader service card



A side-lobe suppressor element has been added to the transmit antenna of the new AN/TPQ-11 weather radar installation at Hanscom Field, Mass. Both the transmit antenna (left) and the receive antenna (right), have improved de-icing and drying facilities.

cathode now surrounds the anode, instead of the opposite way.

This inverted approach increases the life of the tube. With a larger cathode area, cathode flaking—a major contributor to tube failure—is negligible because the larger area reduces the peak current density in the cathode. Two other tube diseases—loss of emission and cathode poisoning from arcing and high current density—are also cured by the new design.

Magnetrons operating in the Ka-band—where the weather radars function—are particularly sensitive to these ills because the working elements of the tube have to be so small. Tubes with the new design have operated more than 3,000 hours without failure.

The new tube, an inverted coaxial type, can generate 100 kilowatts of peak power at Ka-band propogated through the top of the tube by a circular waveguide. The r-f energy is coupled into the tube's cavity by slots through the anode.

No place to hide Adding a range normalization system to the receiver produces a target signal of the same amplitude whether the target is 1,000 or 30,000 feet from the antenna. Normalization is available in two stages: 500 to 15,000 feet and 500 to 30,000 feet. This permits forecasters to measure cloud density.

The receiver also offers a choice of linear or logarithmic output plotted against linear input. With logarithmic output, a forecaster can examine signal returns of large dynamic range.

In either case, the receivers have excellent characteristics: in logarithmic phase, within ±1 db of the theoretical curve from 5 to 65 db above the noise level; in linear mode, within ±1 db of the theoretical from noise level to 15 db above noise level.

Seeing the clouds. A forecaster can see a cloud formation immediately on a cathode-ray tube, or he can wait for a permanent record from a facsimile recorder. The new recorder operates in two modes instead of one: normal where the recorder dot is proportional to the intensity of the signal, and quantized where the recorder dot is a quantitative representation of it.

In the quantized mode, however, target density levels are recorded in only four densities: 0 to 10, 10 to 20, 20 to 30 and over 30 db above noise level. Three different shades of gray represent the first three. The fourth gray shade is white or iso-echo. Clouds are outlined by variations in the four gray shades.

Microelectronics

Plasma anodization

A simpler and more efficient way to manufacture better thin-film microcircuits is claimed by the General Instrument Corp.'s Applied Research Laboratory.

The two scientists who developed the method, George J. Tibol and William M. Kaufman, use plasma anodization instead of wet anodization to make passive thin-film circuits. The technique permits fabrication of the circuits in a single pass through a bell-jar system. With the wet-anodization method, the microcircuit must be removed from the vacuum system so it can be immersed in an anodizing bath. Carrying out this process, between two vapor deposition steps, increases the danger of contamination.

Method. Plasma anodization consists of using a low-pressure gas plasma of oxygen ions as the electrolyte to anodize evaporated aluminum films on a glass substrate. The plasma of charged particles is formed by a continuous electrical discharge in the bell jar at about 50-microns pressure. A d-c potential applied between an aluminum film and a cathode causes a current to flow and the surface of the aluminum film to be oxidized. Electrodes of aluminum are applied by vapor deposition without opening the bell-jar system to the air.

Higher capacitance per unit area can be obtained with multi-layer capacitors; these are made by alternating the deposition and anodization steps. Thus far, nearly 100% of the capacitors made this way have been free of pinholes.

Electrical characteristics. The aluminum-oxide film has a capacitance of 0.2 microfarads per square inch after anodizing at a 50-volt potential. The temperature coefficient of the capacitance is +340 parts per million per degree centigrade between 55°C and +150°C. The capacitance decreases 2% from one kilocycle to one megacycle while dissipation factor is 1% at one megacycle.

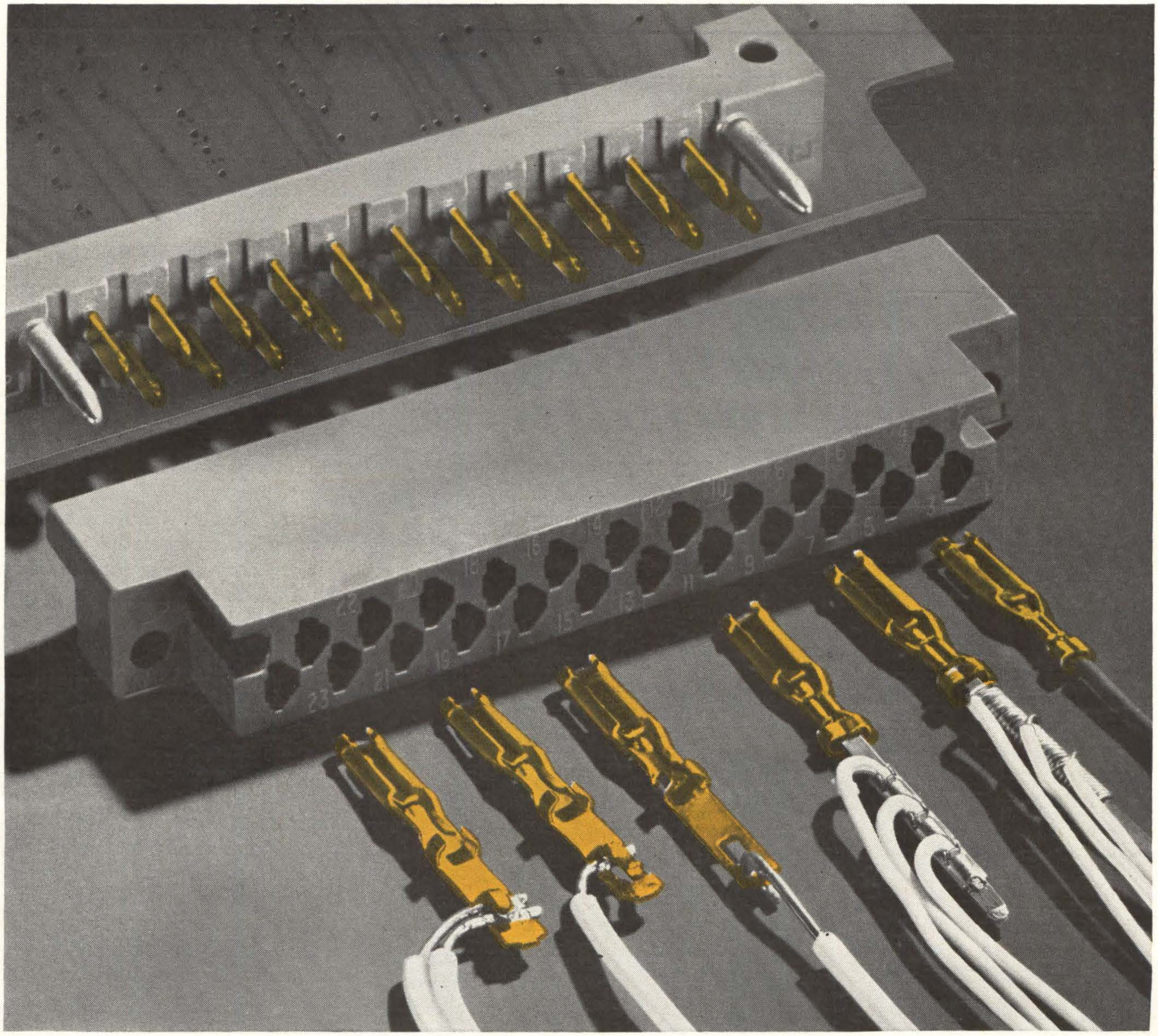
Space electronics

In a spin

On Sept. 8, when 19 of the 20 experiments aboard the Orbiting Geophysical Observatory were, at long last, working, the National Aeronautics and Space Administration called the satellite a success.

There had been a lot of breath-holding until then. Two of the six booms that should have extended fully, once the satellite went into orbit, failed to unfold.

One boom, 22 feet long, carried a magnetometer experiment at its end. The other, four feet long, was equipped with an ultrahigh-frequency omnidirectional antenna and carried a spherical ion and



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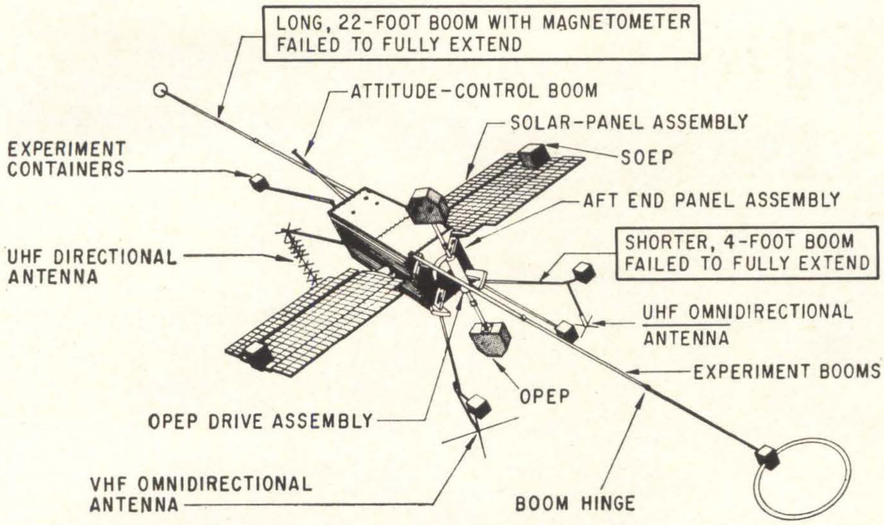
Circle 37 on reader service card



OGO ran into trouble when a partially extended four-foot boom obstructed the view of an infrared horizon sensor that controls attitude orientation. Another boom, 22 feet long, also failed to extend fully.

electron trap experiment. The four-foot boom is blocking the satellite's infrared horizon scanners. This prevents the satellite from locking onto the earth, so OGO is now spinning at the rate of five revolutions per minute. Nonetheless, NASA hopes to get the remaining experiment—a radio propagation experiment—working.

The cause of the failure of the two booms to extend fully is still undetermined. Nor is it known whether the spacecraft will produce full experimental data as programed. The quality of the data already received ranges from "outstanding to marginal."

Electronics abroad

One-gun picture tube

Early next year the Sony Corp. will market a color television set built around a new, 19-inch, one-gun picture tube. The initial price, in Japan, will be about $565. Later, Sony plans to sell the sets in the United States.

The picture tube is a Chromatron, a type of tube that has vertical color stripes and a deflection grid instead of the color dots and shadow mask of the conventional, three-gun color tube.

This is the second Japanese set using a Chromatron-type tube. Last spring, the Yaou Electric Co. introduced a transistorized color set with an eight-inch tube and a line-sequential system. The Sony set uses the dot-sequential system of U. S. color sets.

Tube advantages. Sony says the pictures seen on its set are at least twice as bright as those on conventional tubes. This, it explains, is because the wire deflection grid passes 80% of the electron beam energy to the phosphor color stripes. With the conventional tube, the shadow mask passes only 15% of each of the three beams.

Alternate vertical wires in the grid are connected to form a deflection system. Depending on the voltages between the two sets of wires, electrons passing through the grid are deflected so they hit only red, green or blue phosphor stripes to form the picture.

Research is under way at Sony for a three-gun Chromatron that is expected to be three times as bright as the one-gun tube.

Convergence problems are also eliminated by the use of one gun instead of three. The shadow-mask tubes require vertical and horizontal alignment to obtain color purity, while only horizontal alignment is needed in the Chromatron tube. This makes assembly of the Chromatron tube easier. And because the color stripes are vertical, variations in the earth's magnetic field—which shift vertical positions of the beam—do not affect color purity when sets are moved from one location to another.

The stripe pattern is red-green-red-blue, repeated 400 times across the width of the faceplate. The fundamental three-color element is on one-half of a green stripe, a whole red stripe and one-half of a blue stripe, providing 800 picture elements per line for black-and-white operation. In the actual set, however, the bandwith of the video amplifier limits resolution to about 300 lines horizontally and the beam spot size limits vertical resolution to about 400 lines.

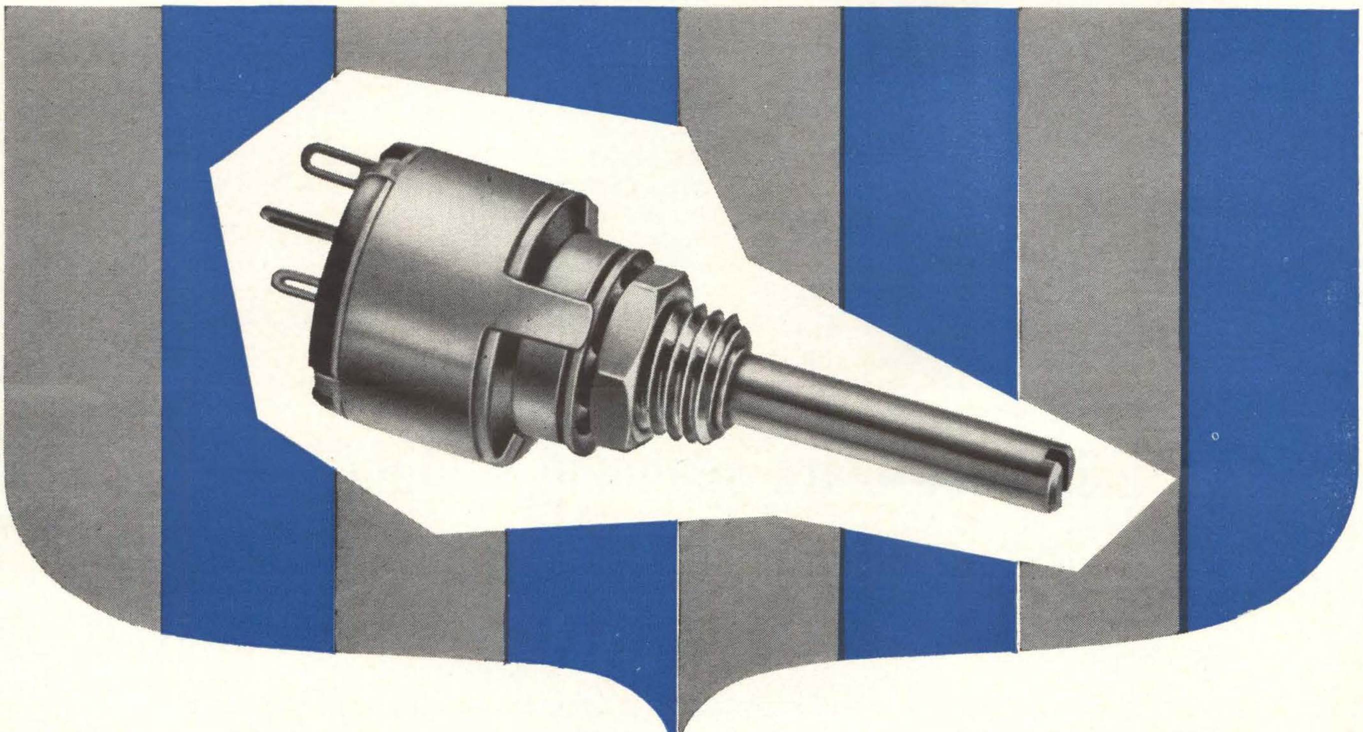
There are twice as many red stripes as blue or green because the efficiency of the red phosphor is lower.

Solving the problems. One of the tougher problems was the interference radiation that is emitted when the grid is driven by a high-power signal at a frequency of 3.58 megacycles. This was overcome by inserting a coil in the tube. The coil tunes out the effects of capacitance between the grids. Capacitance between the grids and coil forms a high-Q tuned circuit. Only losses in the circuit, typically five watts, need be supplied from an external circuit.

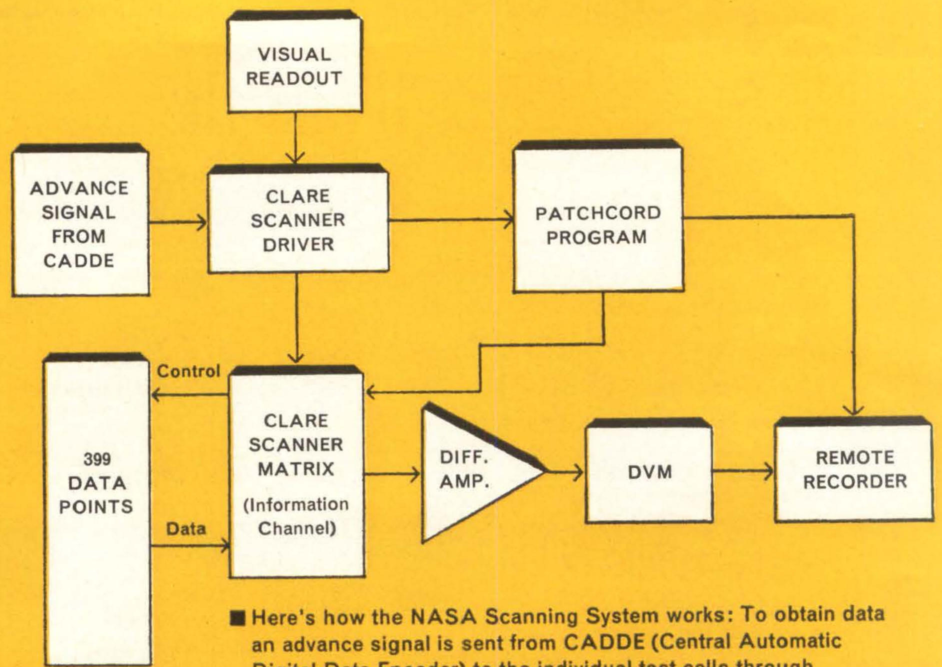
Side-by-side operation of two sets, tuned to different stations, proved that Sony's technique worked. One set did not interfere with the other. Had the sets been radiating appreciable amounts of power there would have been interference.

The tuned-circuit method also avoids another problem that can be caused by a high-power signal—heating and thermal expansion that would cause the grid to become loose and make the tube microphonic.

The Sony set uses a new re-encoding circuit to control electron-gun current, but it does the same job as earlier circuits developed in the U. S. The set has 27 other tubes in its circuits and is 20 inches deep.



Clare Control Modules provide both high level and low level switching circuits in the NASA-Lewis Scanner system.



■ Here's how the NASA Scanning System works: To obtain data an advance signal is sent from CADDE (Central Automatic Digital Data Encoder) to the individual test cells through the Clare Scanner Driver and Matrix. Low level signals from pick-up devices (usually thermocouples) are transmitted back through the Clare Scanner Matrix to a differential amplifier, then to a digital voltmeter where the signals are transmitted to the recorder for processing. The visual readout is actuated simultaneously through contact closures in the Clare Scanner Driver.

NASA uses Clare scanning system to double speed, eliminate maintenance, assure reliability and reduce system cost

NASA-Lewis Research Center applies inherent advantages of Clareed® Control to improve data-gathering techniques in space vehicle engine and fuel research

Design Problem: NASA required a system which would scan several hundred data-gathering devices, and provide:

...Speed to scan 40 points per second, with inherent capability to function at greater speed as required.

...High reliability with freedom from maintenance

...Compatibility with existing systems which used relays and solid-state devices

...Low cost

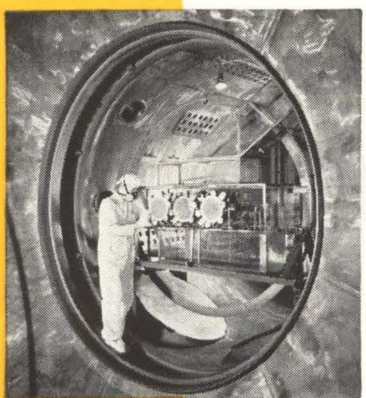
NASA evaluations indicated that spring-driven switches (which were previously used) and crossbar switching were too slow and presented mechanical maintenance problems; solid state devices, with the necessary peripheral circuitry, were too expensive for this size system.

NASA engineers asked Clare to propose a solution to the design problem.

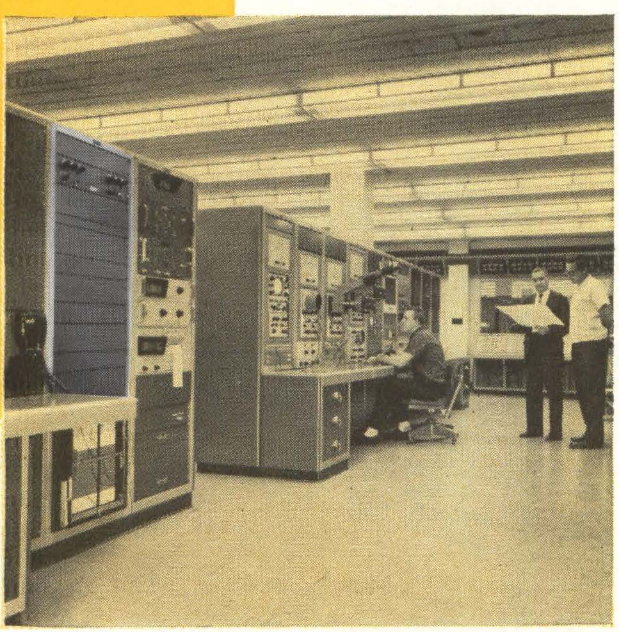
Clareed Solution: The NASA system, shown above, represents a typical Clare Scanner function. How does this system utilizing flux logic meet the requirements of speed, reliability, freedom from maintenance, compatibility, and low cost?

Clare designed Scanner Systems separate the matrix from the driver to increase versatility and permit a wider selection of functions in either unit. The driver, with Clare mercury-wetted contact modules providing the control logic, consists of decade counters with selectable set and reset inputs in each decade.

The matrix has a scanning speed capability of 100 cross points per second. This easily meets both present and future switching requirements. The present system sequentially scans 400 points at a speed of 40 points per second and effects five



Space vehicle engines are tested in individual cells similar to the one shown here.



Central Control Room at NASA-Lewis Research Center monitors activities of each test cell. Clare Scanner System shown at left is one of seven specified by NASA.

contact closures at each cross-point. Clareed Control Modules provide the high level switching; Clare Type F (Crystal Can) Relays handle low level circuits.

Clare design provides more versatile, flexible programming than is feasible with crossbar or semiconductor switching; and the system can be readily adapted, or expanded, as NASA system requirements change.

In addition, Clare Scanners provide manual access to any one of the 400 points, contact closures at each point to actuate control and program relays or a visual readout, and the capability to select and scan a number of prime interest points.

Simplified Clareed Control circuitry reduces overall costs, and (with the inherent reliability of sealed-contacts) assures greater over-all system reliability. The positive off-on characteristics of isolated contacts assure accurate test data results. Also, the system is virtually immune to inadvertent operation caused by transient noises and voltage fluctuations.

Clareed Control circuitry is compatible with previously used data handling procedures. The advance signal pulse generated by CADDE and the previously used stop-start control pulses are applied without re-design of the existing system.

Clareed Systems can be designed to meet the requirements of practically any instrumentation sampling, data logging or control system function requiring multiplexing. Evaluate Clareed Control capabilities; you'll see why Clare designed systems can provide reliable, maintenance-free control systems with practical switching speeds...and at low cost.

CLAREED CONTROL DESIGN CONSIDERATIONS

If you work with control systems, take a look at these Clareed advantages. You'll find the plus features you need for your system:

- multiple input and output capabilities, making possible logic at both input and output.
- switching capabilities from low level up to 15va, ac or dc.
- complete isolation between input and output. The output is the contact closure.
- data handling speeds up to 250 bits per second.
- modular printed circuit board construction compatible with modern electronic assembly techniques ...meets the requirement of almost any application or environment.

Standard Clareed Control Modules offer versatile, reliable, simplified means of performing these functions:

In counting: Three basic flip-flops which can be used in ring counters, bi-directional counters and shift registers for binary, binary-coded decimal, decimal, and radix$^{(N)}$ counters.

In selection: A variety of selection systems, using a single-mode matrix, a single-mode memory matrix, or a two-mode matrix (Mode 1: all crosspoints normally open; Mode 2: all crosspoints normally closed).

In logic: AND, inclusive OR, NOR, NAND, exclusive OR, exclusive NOR as well as more complex logic in a single module.

Want to know more about the versatile Clareed approach to modern control techniques? Write for Manual 400, (Clareed Control Modules), and Bulletin 1001 (Clare Scanners). We'll answer promptly. C. P. CLARE & CO., Group 9N4, 3101 Pratt Boulevard, Chicago, Illinois 60645.

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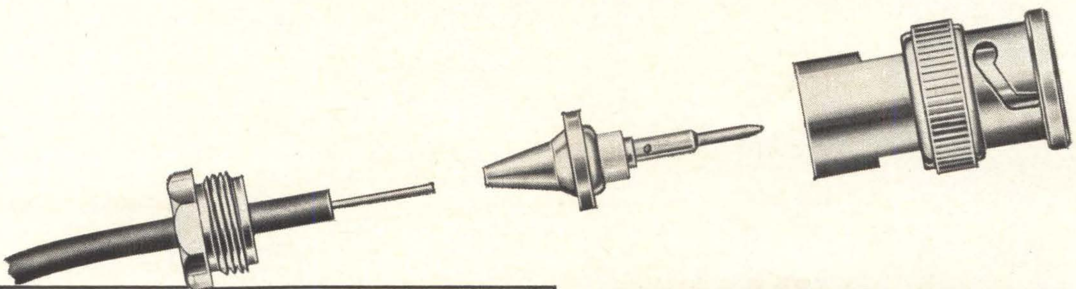
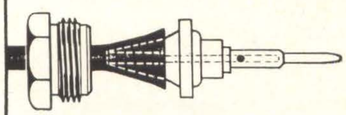
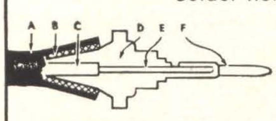


ASSEMBLY IS THIS SIMPLE:

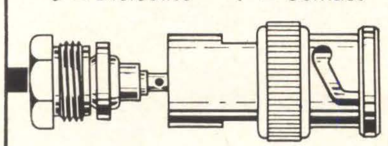
1. Take one clean square cut through cable insulation, braid and dielectric, exposing ¼" of conductor. Slip nut onto cable.



2. Insert conductor into tapered, self-clamping sleeve and contact sub-assembly; force edge of sleeve between dielectric and braid until insulation rides well onto taper. Solder conductor to contact at solder hole. See detail.



A = Insulation D = Self-Clamping Sleeve
B = Braid E = Conductor
C = Dielectric F = Contact



3. Fit contact sub-assembly into connector body; screw nut into body, binding insulation and braid tightly against tapered sleeve . . . thus forming a strong, weatherproof connection.

All illustrations enlarged for clarity

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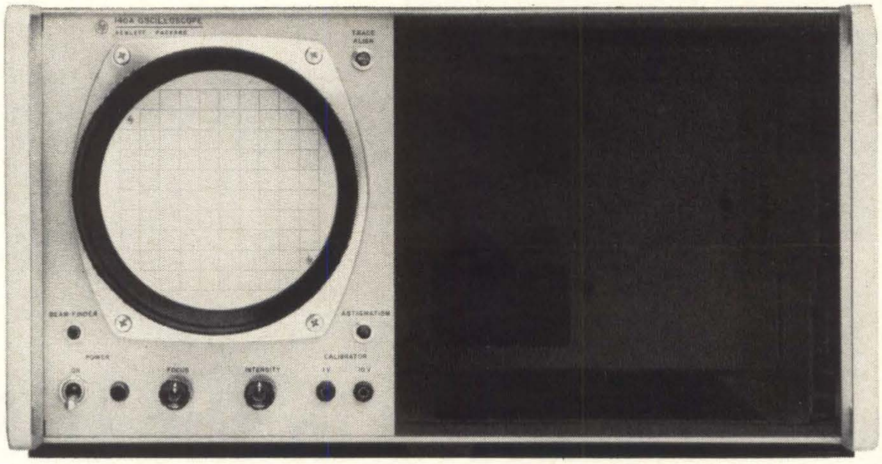
Circle 43 on reader service card

ALL THESE MEASUREMENTS MADE EASY BY A SINGLE SCOPE- hp 140A!



Measure to 20 mc. Measure to 10 μv/cm. Standard time base or sweep delay. Time domain reflectometry for measuring cable, connector, strip line and other broadband devices. And do it all with one scope—the Hewlett-Packard 140A!

New concepts in oscilloscope design give you a low-cost versatility you've never experienced...a unique plug-in arrangement that lets you buy what you need now, then add to your capability as your need expands. No longer need you buy 3 scopes, match your particular measuring needs against limited specifications. What you need today can be more tomorrow from today's most versatile...and promising scope!

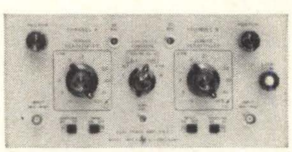
The 140A offers a unique dual plug-in design which permits use of two separate plug-ins, such as one for vertical presentation and one for sweep...or a single double-size plug-in for special-purpose applications. Plug-ins drive the crt directly, so there's no intermediate circuitry to become obsolete. Two vertical plug-ins may be used simultaneously for x-y measurements. With two dual-trace plug-ins, you can even display two x-y plots simultaneously.

What's more, the 140A gives you unmatched low-cost performance, in addition to its versatility. It does more for you than many of the bulkier and more expensive scopes available today.

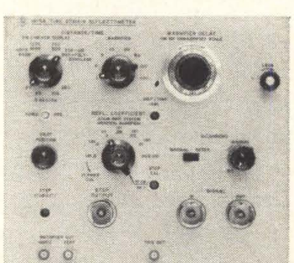
Your initial buy on the 140A, the main frame, gives you a bright 10 x 10 cm, no-parallax, internal-graticule crt offering big-picture viewing that makes even pulse applications simple and clear. Wide bandwidth, too, plus plenty of reserve in the solid-state heavy duty power supplies. Even a fan is included to assure low operating temperatures when the 140A is rack mounted.

As for plug-ins, Time Domain Reflectometry (TDR) alone is worth the main frame investment. With TDR, a double-size plug-in for your inexpensive 140A main frame lets you examine and locate discontinuities in connectors, measure Z_0 of cables, examine strip lines, tune broadband antennas and make a host of other measurements—all in a fraction of the time required by the familiar swr techniques. Save countless hours of engineering and production time on all types of broadband devices with a versatile basic scope and a TDR plug-in.

A look at the available plug-ins for the 140A ($575) indicates what you can measure today. More tomorrow. Why not investigate? Just call your Hewlett-Packard field engineer for a demonstration or for complete data. Or write Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva; Canada: 8270 Mayrand St., Montreal.



1402A 20 MC Dual Channel Plug-in



1415A Time Domain Reflectometer

Eight plug-ins available now:

1400A 100 μv Differential Amplifier — Sensitivities to 100 μv/cm at 400 kc bandwidth for low-level measurements, $210.

1401A 1 mv Dual Channel Amplifier — Sensitivities to 1 mv/cm at 450 kc bandwidth, $325.

1402A 20 mc Dual Channel Amplifier— Sensitivities to 5 mv/cm for pulse and cw work, built-in delay line for viewing rise of fast pulses,. $550.

1403A 10 μv AC Differential Amplifier — Sensitivities to 10 μv/cm at 400 kc bandwidth; adjustable bandwidth minimizes noise on low-level signals, $350.

1405A 5 mc Dual Channel Amplifier — Sensitivities to 5 mv/cm for TV and other general-purpose work in the 5 mc regions, $325.

1415A Time Domain Reflectometer—Analyze broadband devices; examine and identify discontinuities as close as 1 in. apart, $1050.

1420A Time Base — Sweeps from 5 sec/cm to 50 nsec/cm, triggers beyond 20 mc, $325.

1421A Time Base and Delay Generator — Sweeps from 1 sec/cm to 20 nsec/cm, delays to 10 sec, triggers beyond 20 mc, $625.

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

An extra measure of quality

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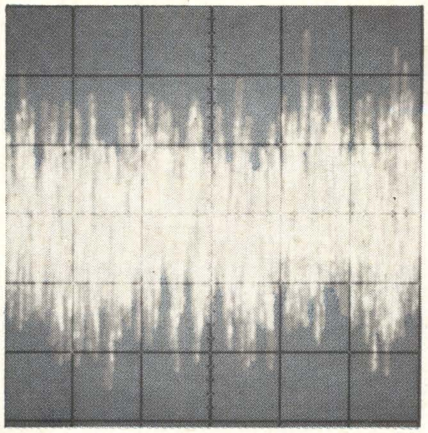
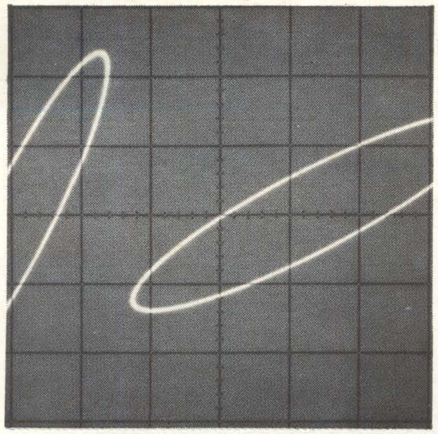
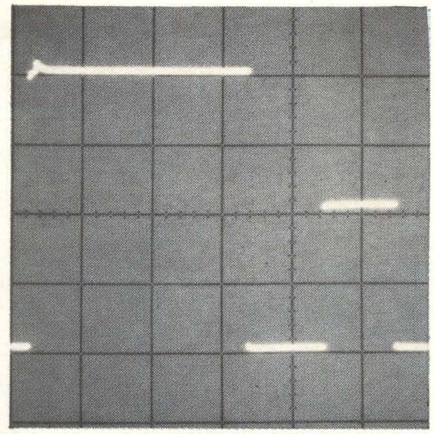


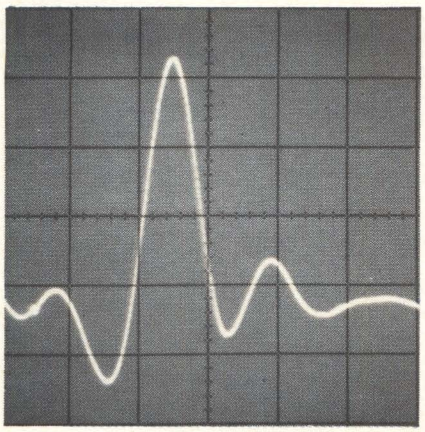
noise



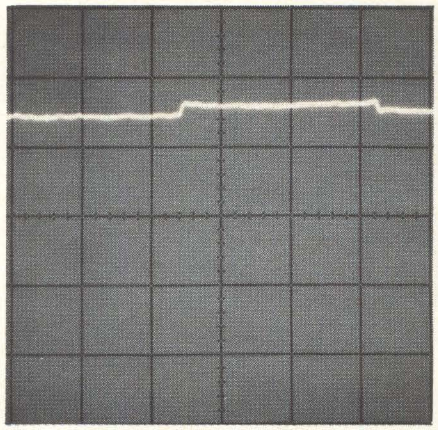
phase



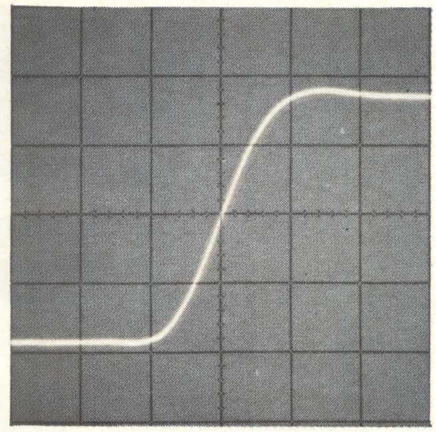
pulse codes



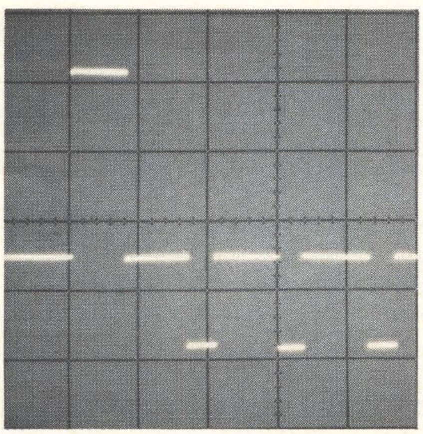
connector mismatch



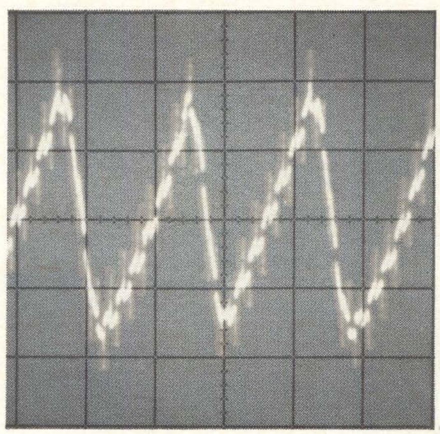
cable impedance



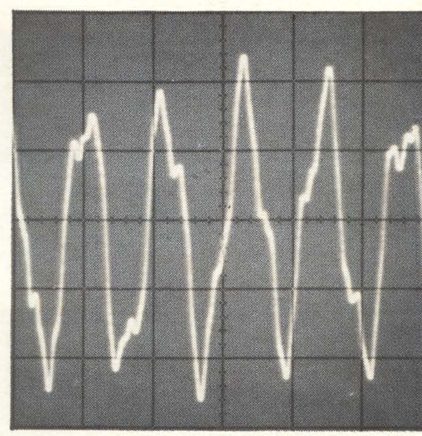
rise time



computer logic

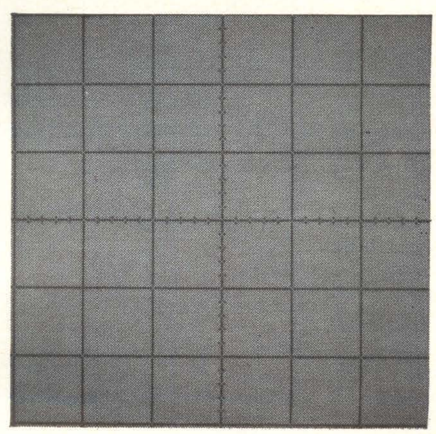


power supply ripple



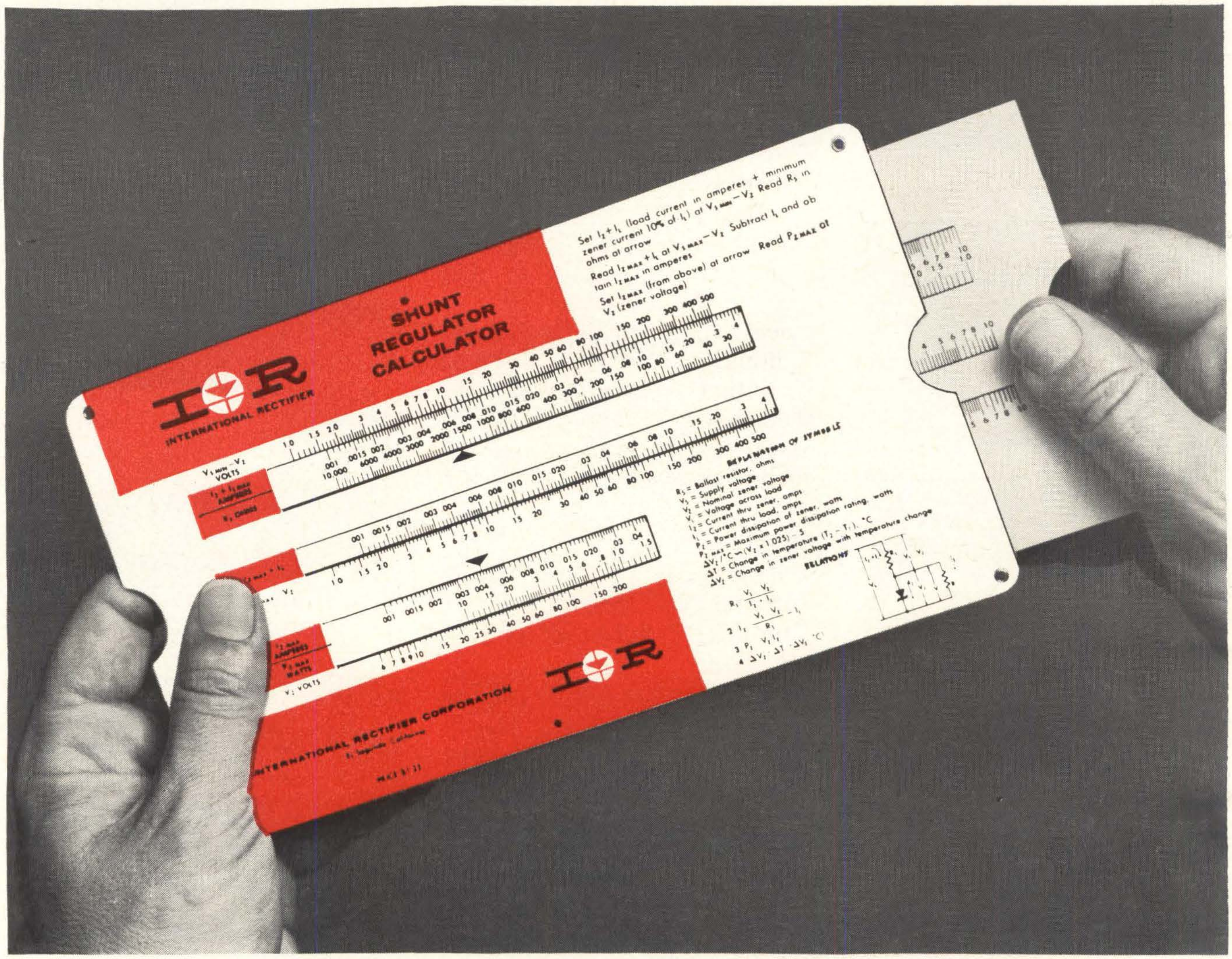
vibration

your trace?



INTERNATIONAL RECTIFIER ZENER CALCULATOR

Pinpoint Your Zener Diode Needs in Seconds



With just two quick slip-stick calculations, this new compact International Rectifier Zener Calculator gives you Zener diode specifications in terms of easy reference JEDEC numbers and case styles. You may obtain this circuit design aid without charge upon written request on your company letterhead to International Rectifier Corporation, 233 Kansas Street, El Segundo, California.

When you specify International Rectifier Zeners you have this unique assurance of performance... a demonstrated in-use reliability index of 99.988%. To meet a wide range of requirements, International Rectifier offers a selection of over 640 types. International Rectifier's sales offices and distribution network throughout the United States provide immediate customer service.

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Washington Newsletter

September 21, 1964

Inventory time for research labs

The first job of the special panel of President Johnson's Science Advisory Committee will be to take inventory. Government officials frankly concede that they have lost track of the extent and even the location of some of the research the government has tackled.

Under Emanuel R. Piore, of the International Business Machines Corp., the committee has been asked to examine the role of government in-house research. There is a suspicion that once begun, government research is self-perpetuating. Research and development firms have become increasingly hostile to the extent of the government's inroads into electronics, radiation, and the whole spectrum of defense, space and nuclear programs.

Government laboratories are created at a far faster rate than they expire. Additions on the way are the $50-million Electronics Research Laboratory authorized for Boston, and the $30-million Environmental Health Center to be built near Baltimore. Right now nearly 20% of the Federal research and development budget goes into the government's own research operations.

McNamara delays briefing sessions

The election campaign has upset Defense Secretary McNamara's plan to brief industry on the long-range defense spending outlook. Briefings scheduled for this month and next in New York, Chicago, Dallas and Los Angeles have been postponed.

McNamara feared that Republican candidate Barry Goldwater would be able to use the sessions as campaign ammunition. Goldwater is saying that McNamara's policies are undermining the strategic power of the United States. **If the Administration is returned to office, the briefings will be held in February.**

Bid-riggers face stiffer fines

The Justice Department is using a case involving three temperature-control makers—Honeywell, Inc., the Johnson Service Co., and the Powers Regulator Co.—to test a new way to level higher fines on companies convicted of fixing prices.

Fines in price-fixing cases are moderate compared with the amount of business usually involved in a big conspiracy case. The government collects considerably less than the treble-damages allowed private customers who suffer losses through price fixing.

The strategy of the Department of Justice is to skip the antitrust laws entirely when suing to collect for government losses. **Instead, it will bring civil fraud charges that provide for double damages, in addition to a $2,000 fine for each count.** The theory is that anyone who rigs bids on a government contract is defrauding the government in addition to violating the antitrust laws.

Last year, the three temperature-control makers declined to contest the bid-rigging charges and were fined $105,000. Then last September, the government filed a fraud complaint on the same charges. Everything in the case, including the complaint, has since been sealed. The Justice Department's investigation of hundreds of construction jobs involving control equipment is continuing. It will probably be another year before it gets out into the open.

Fair-traders revise plans

Backers of Federal fair-trade legislation, aimed at halting sharp discounting of such items as radios and television sets, are revising their strategy. Their chief supporter in Congress, Sen. Hubert H. Humphrey, as vice-presidential nominee, can no longer be counted on for help. **The Johnson Administration is strongly opposed to the fair-trade proposal. Its supporters know they would only embarrass Humphrey by expecting his assistance now.** If the Johnson-Humphrey ticket is elected in November, fair-trade advocates may give up the drive for Federal legislation. They'll concentrate instead on individual state legislatures, with the hope of getting beefed-up bills there.

Air Force Ass'n chides both parties

The Air Force Association, which has bluntly criticized the Democratic administration's military policies in the past, is taking a nonpartisan stance this year. A policy statement adopted at its annual convention last week **criticizes both Democrats and Republicans for insufficient awareness of the importance of three national security needs:** more national support for research and technological growth, a higher degree of "scientific literacy" on the part of the public, and making the military service as attractive financially and otherwise as civilian employment.

Study hits plans for R & D dispersal

The Stanford Research Institute disputes some widely-held notions about the structure and dynamics of the defense research and development industry. **The Institute's tentative conclusion, in a study made for the Defense Dept., will be tested in a larger sampling of the industry.**

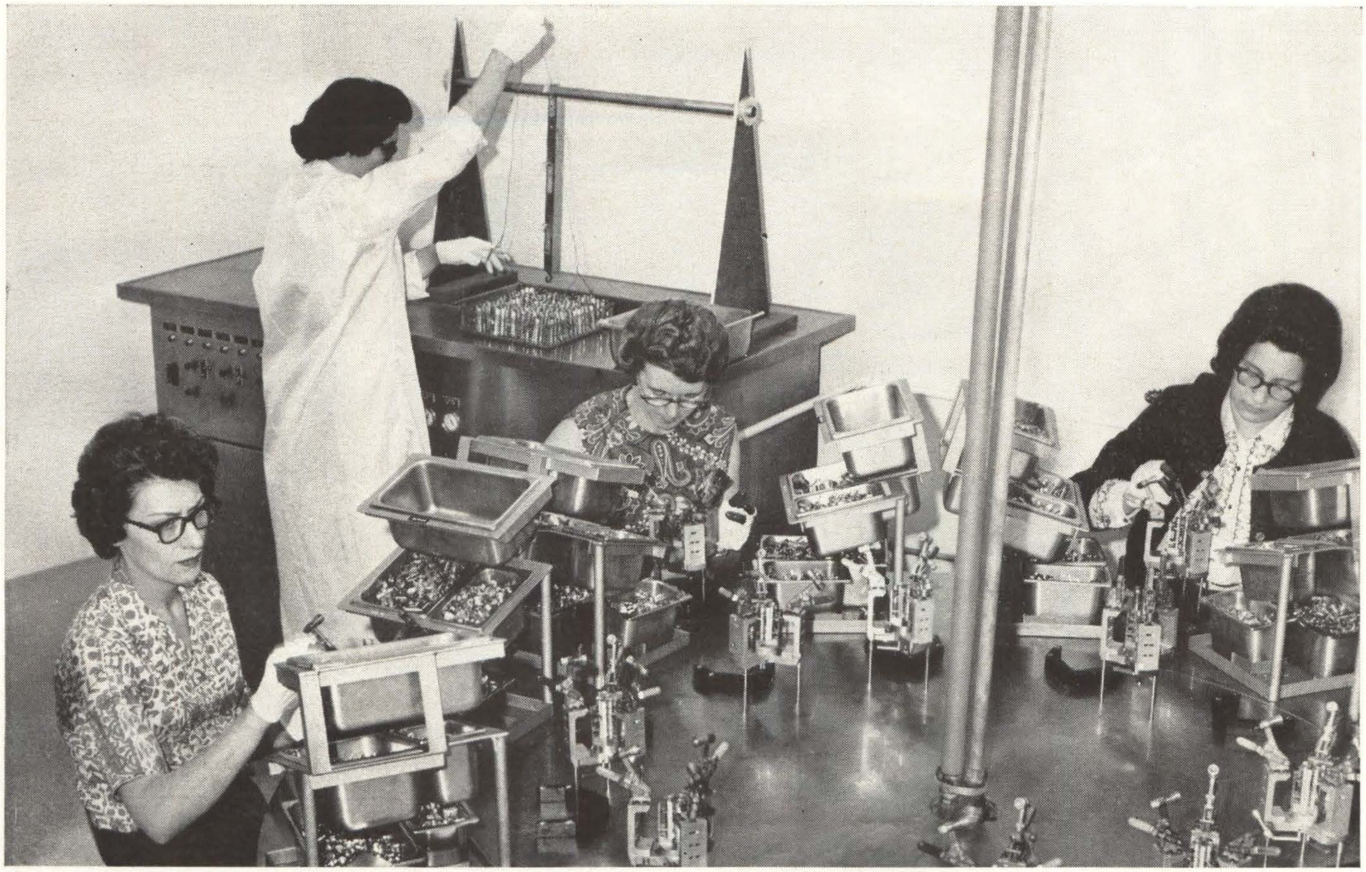
A view often expressed in Congress is that the Pentagon should use its contract-award power to force a dispersal of the R&D industry from its concentration in southern California, San Francisco, New York City-Northern New Jersey, Boston and Washington. The Stanford group says that economic and social forces accounting for this concentration are so powerful that the forced-dispersal efforts made so far have been largely ineffectual. **To persist in such efforts would be costly and require a lowering of standards of quality and efficiency as the basis for contract awards, according to the report.**

The study also knocks the assumption that a large, nearby university offering graduate courses and extensive research programs would, in itself, attract defense research and development plants. The researchers do say that such plants aid development of local universities by supporting advanced studies, providing part-time faculty members and students.

The report finds that although the turnover rate of the R&D work force is considerably higher than that for all industry, the movement of workers is largely from one military R&D company to another.

Defense companies keep tax credit

Pentagon financial watchdogs have turned down the Comptroller-General's proposal to take investment tax credits away from defense contractors. They will continue to receive the same credit—up to seven percent of the cost of productive equipment—as nondefense companies. Defense feared taking the credit away would blunt contractors' incentive.



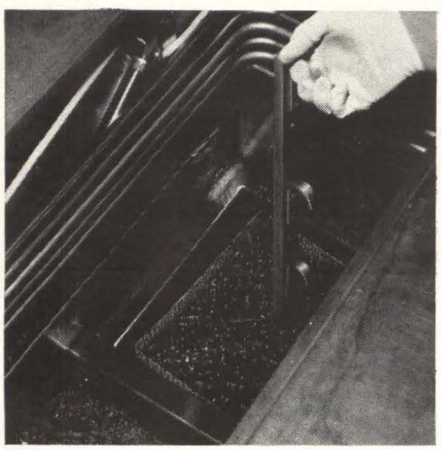
Because FREON solvents are nonflammable, virtually nontoxic and free from irritating odors, Rauland Corp. can safely locate its cleaning equipment directly at the end of its assembly line for maximum efficiency.

Rauland uses FREON® TF to "super-clean" color-TV picture-tube subassemblies

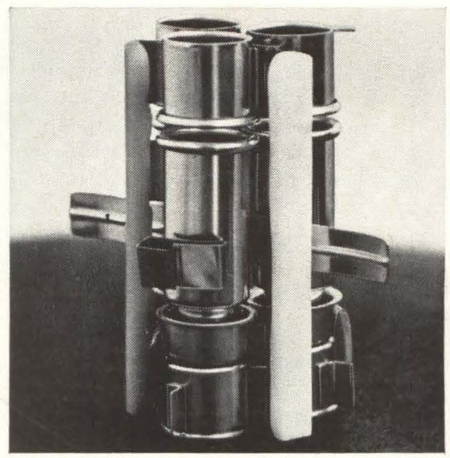
Cleaning of color-TV tube gun subassemblies is a critical operation because of the extremely high voltages to which they will be subjected. Any particulate matter not removed could cause arcing and a blown tube . . . any leftover lubricants would seriously affect the rise time and service life of the tube. For this critical cleaning operation, the Rauland Corporation, Chicago—a division of Zenith Radio Corporation—uses FREON TF solvent.

Now, cleaning of the subassemblies is a quick, simple, low-cost operation . . . thanks to a cleaning system engineered and installed by a FREON solvent sales agent. This cleaning system uses FREON TF. The combined action of extremely low surface tension and high density enables FREON TF to penetrate minute crevices and effectively release and float away soils . . . even particulate matter. This results in complete, residue-free cleaning.

If you would like to investigate the many ways you can use FREON solvents in your cleaning operations, mail the coupon at the right.



This combination cleaning system was engineered specifically for the Rauland Corporation by G. S. Blakeslee Co., Chicago, Illinois. It is just another example of the complete cleaning system engineering you can expect from your representative for Du Pont FREON®.



After being cleaned in quick-drying FREON TF, the residue-free subassembly is ready immediately for final processing.

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Company__________

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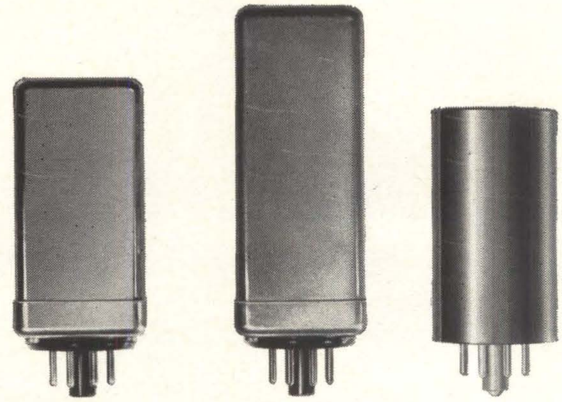


UNIQUE...

first low level solid-state unit joins industry's most versatile line of telegraph relays

Radiation's new solid-state low level to high level neutral relay is the first of its kind. The unit, Model 9338, is designed for such applications as conversion of low level computer outputs to higher telegraph levels, and for computer/computer switching.

This advanced relay features modular construction and unlimited service life without maintenance. Because it operates at an input level of $\pm$ 6 v at 50 to 100 μa, conducted and radiated RFI are greatly reduced.

Radiation Telegraph Relays are supplied with octal bases in three standard models (at right). They can replace all electromechanical units except in rare applications. These versatile units are completely solid state, and are powered by input loop current alone.

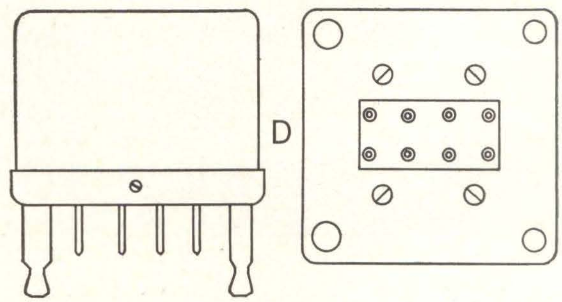
Special Plug-In Adapters are available in all popular types (examples at right), and permit you to update your present system easily and quickly. Radiation can also supply special adapters, units wired for direct replacement, or devices on plug-in printed circuit cards.

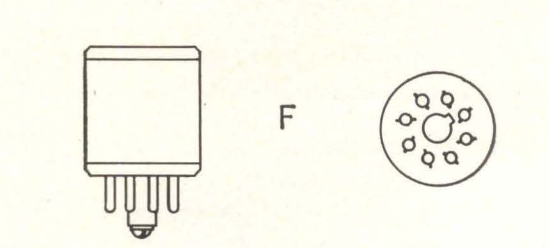
All Radiation Solid-State Relays operate at speeds up to 2400 bits/second with less than 3% distortion. Input is essentially resistive. They do not induce transients in the line as do electromechanical units. And a unique Radiation circuit protects inputs against abnormal line conditions such as spikes and overvoltages.

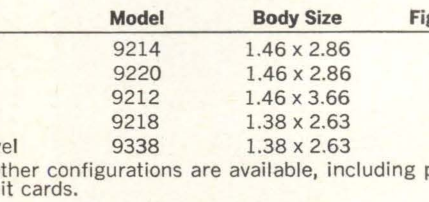
In addition, Radiation Relays are extremely resistant to environmental extremes. They require no adjustment, and will operate for an indefinite period of time without attention.

Radiation engineers will be glad to assist if you have a unique application or would like help in evaluating system requirements. Write for information, or describe your needs. Products Division, Dept. EL-09, Radiation Incorporated, Melbourne, Florida.

RADIATION
INCORPORATED







RADIATION SOLID-STATE RELAYS

Type	Model	Body Size	Figure
Neutral	9214	1.46 x 2.86	A
Neutral	9220	1.46 x 2.86	A
Polar	9212	1.46 x 3.66	B
Univ.	9218	1.38 x 2.63	C
Low Level	9338	1.38 x 2.63	C

Note: Other configurations are available, including plug-in circuit cards.

Standard Plug-In Adapters

Octal-to-Western Electric 255-A	D
Octal-to-Western Union 202-A	E
Octal-to-Octal	F

Note: Other adapters are available, or units can be wired for direct replacement.

Latest refinement in carbon film resistors made by Western Electric is a sleeve of Kynar,* Pennsalt vinylidene fluoride resin. Western Electric produces 30 million resistors of this type yearly for ANI (Automatic Number Identification) equipment.

Western Electric engineers selected Kynar for two principal reasons—strength and stability. Kynar won't melt, drip or burn, under the most severe overloads. Its superior stability assures freedom from degradation due to aging or environmental conditions. Kynar is completely compatible with high-speed production. Extruded tubing feeds readily through forming equipment, cuts cleanly, heat-forms easily, takes marking inks.

Kynar offers a unique combination of electrical strength, mechanical toughness and stability. If you have a problem where you need extra performance, write or call us for data. Plastics Dept., PENNSALT CHEMICALS CORPORATION, 3 Penn Center, Philadelphia 2, Pa.

Kynar...a fluoroplastic that's tough!

Pennsalt Chemicals®
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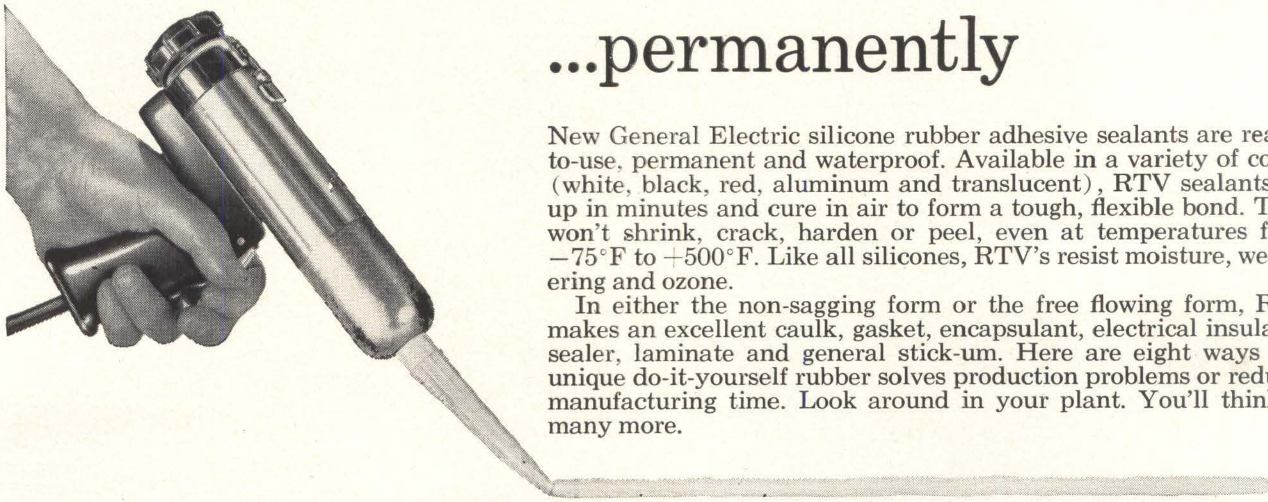
**Kynar is a Registered Trademark of Pennsalt Chemicals Corp.*

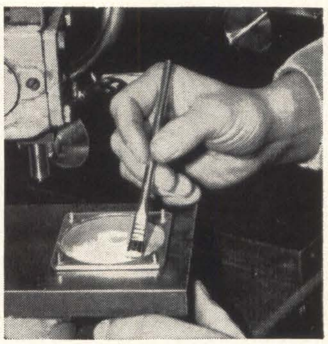
Silicone Rubber Adhesive/Sealan solves 1000 production problems ...permanently



New General Electric silicone rubber adhesive sealants are ready-to-use, permanent and waterproof. Available in a variety of colors (white, black, red, aluminum and translucent), RTV sealants set up in minutes and cure in air to form a tough, flexible bond. They won't shrink, crack, harden or peel, even at temperatures from $-75°F$ to $+500°F$. Like all silicones, RTV's resist moisture, weathering and ozone.

In either the non-sagging form or the free flowing form, RTV makes an excellent caulk, gasket, encapsulant, electrical insulator, sealer, laminate and general stick-um. Here are eight ways this unique do-it-yourself rubber solves production problems or reduces manufacturing time. Look around in your plant. You'll think of many more.

1. RTV-108 provides instant, "see-through" insulation as well as vibration resistance and environmental protection. RTV needs no pre-mixing; is applied directly from the tube.

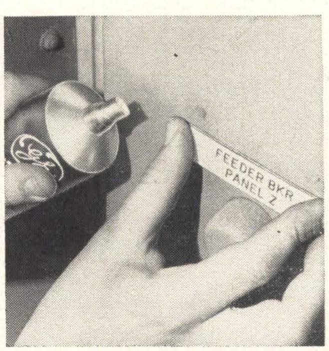


2. RTV seals filament condenser plates in dielectric heaters. Reasons: RTV resists high temperature, insulates electrically, locks out conductive contamination.

3. RTV seals AN connectors, terminals and wire harness joints and other flexible parts. It will absorb shock and vibration, eliminating the fatigue failure of connections.

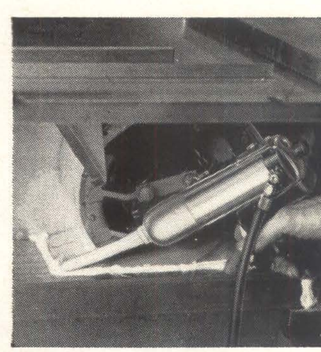
4. RTV bonds sheeting into desire configuration in low volume productior of cylindrical air ducts for dielectri heaters. Results: production costs cu more than 300%.

5. RTV laminates layers of mica sheeting and plates in production of plate condensers. Results: improved operational reliability, assembly time cut from 24 hours to 20 minutes.



6. RTV eliminates need for screws and drilling when used to affix name plates and decorative emblems on any surface. Results: no unsightly rust drainage; plates stay put indefinitely, but can be cut loose when desired.

7. RTV seals out moisture and dust, making cases, cabinets and chassis completely and quickly weatherproof. An excellent material for vibration dampening in electronic equipment.



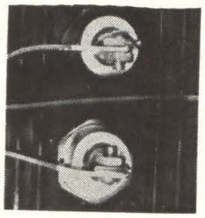
8. RTV bonds vent units and ducts in new Hotpoint range, seals areas of metal-to-metal contact to prevent escape of cooking vapors. RTV is damping medium for vent motor, reducing sound and vibration.

Will a dab of RTV in the right place shorten your production time? Find out. RTV comes in 3 oz. and 12 oz. tubes and in polyethylene cartridges for use with automatic pressure guns. For more information on these new silicone rubber adhesive-sealants, write to: Sect. N9124, Silicone Products Department, General Electric Company, Waterford, New York.

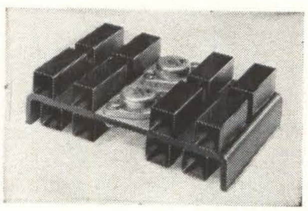
GENERAL ELECTRIC

Technical articles

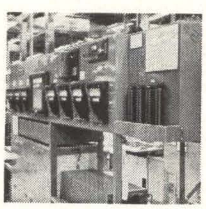
Highlights



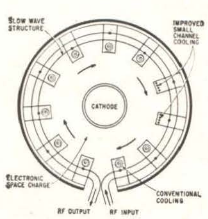
Inverting d-c to a-c with tunnel diodes: page 56
After having been a disappointment, the tunnel diode is finally coming into its own. Improved manufacturing techniques have reduced a lot of objections to its use. The tunnel diode appears promising in inverters: it is simple, reliable and efficient.



More for your money in solid-state equipment: page 66
Inadequate cooling drastically affects design parameters, so thermal design should be considered early in the game. You may have to use forced-air cooling instead of just plain heat sinks.



Widening world of the scr: page 78
The silicon controlled rectifier is popping up in applications from golfcarts to steel mills. It is replacing silicon diodes because it can do more.



A comeback for wireless power? page 86
Nikola Tesla first experimented with electromagnetic radiation as a source of power in 1889—and failed. Many others have followed Tesla to failure since. But now microwave technology has progressed to the point where power transmission by radiation is technically feasible.

Coming October 5

- Inside industrial computers
- Balanced bipolar circuits for shift registers
- A new kind of electronic ignition for autos
- Microwave equipment for televising the Olympics

Tunnel-diode circuits invert direct to alternating current

High-current tunnel diodes are simple, reliable and efficient; they invert 0.1 to 0.65 volts with efficiencies as high as 65%

By Fred M. Carlson

Radio Corp. of America, Applications Dept., Somerville, N.Y.

New energy sources, such as thermionic and thermoelectric generators, seawater batteries, fuel cells and solar cells, have created the need for an efficient means of d-c to a-c inversion at low-input voltages and high-input currents. Inverter circuits using high-current tunnel diodes satisfy this need; they operate with 0.1 to 0.65-volt d-c input and peak efficiencies as high as 65%. Power outputs of 100 watts are feasible.

When the tunnel diode first appeared in the literature about six years ago, it was expected to revolutionize the electronics industry. It offered the circuit designer a means of achieving oscillation, amplification, conversion, switching and even a combination of these properties all in one simple device. In addition, the device promised high-speed, high-frequency operation, low power consumption, resistance to nuclear radiation and temperature, small size and light weight. But disillusionment set in with the appearance of design and manufacturing problems. Now, many of these problems have been solved and the circuit designer is taking a second look. He is beginning to realize that the tunnel diode has some very useful properties that lend themselves to particular applications. Such an application is inversion of low d-c voltages put out by exotic power sources now being developed in many areas of our defense effort.

Although transistorized inverters have proved useful for the inversion of the output of d-c power sources, their conversion efficiency is severely reduced when the d-c source voltage is appreciably less than 1 volt—typical of the new energy sources. Under such conditions, tunnel-diode circuits have demonstrated greater efficiency as inverters. Additionally, the extreme simplicity of tunnel-diode circuits can offer greater reliability than possible with transistorized circuits. An evaluation of the design criteria and performance characteristics of several tunnel-diode inverter circuits indicates their applications.

Simple circuit arrangements for using high-current tunnel diodes as d-c to a-c inverters may be described as the single-diode circuit, the parallel circuit, and the push-pull circuit.

Single-diode circuit

The single-diode inverter circuit shown at the right is basically a tunnel-diode relaxation oscillator. For tunnel diodes operating as relaxation oscillators, the switching path on the static characteristic is shown on page 60. If the diode is d-c biased in its negative resistance region, the sequence of operation is as follows: if the action is assumed to start at point C, the diode switches very rapidly, in the order of nanoseconds, to point D. From D, the diode drops rapidly to E, and decays at a slightly slower rate to F. Upon reaching F, the diode very rapidly switches to A. From A, it rises rapidly to B, and then rises at a slightly slower rate to C, at which point the cycle is repeated. The output waveform is trapezoidal, or partly square.

The author

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Tunnel-diode inverter theory

In inverter applications, the tunnel diode is made to switch between its high-voltage ($\geqq V_v$) state and its low-voltage ($\leqq V_p$) state.[1] This switching effectively chops the d-c voltage, and the resultant diode output can be applied to a transformer to step up its voltage.

If a tunnel diode is d-c biased, as shown on page 60, and if it oscillates (switches) between its peak point and valley point with equal periods, a condition known as threshold operation prevails. For this condition, the d-c power input to the diode P_{in}, the a-c power output of the diode P_{out}, and the efficiency of conversion P_{out}/P_{in} are determined as follows:

$$P_{in} = \left[V_p + \frac{V_v - V_p}{2}\right]\left[I_v + \frac{I_p - I_v}{2}\right] \qquad (1)$$

$$= (1/4)\,(V_v + V_p)\,(I_p + I_v)$$

$$P_{out} = \left[\frac{V_v - V_p}{2}\right]\left[\frac{I_p - I_v}{2}\right] = (1/4)(V_v - V_p)(I_p - I_v) \qquad (2)$$

$$\frac{P_{out}}{P_{in}} = \frac{\left(\frac{V_v}{V_p} - 1\right)\left(\frac{I_p}{I_v} - 1\right)}{\left(\frac{V_v}{V_p} + 1\right)\left(\frac{I_p}{I_v} + 1\right)} \qquad (3)$$

where V_p is the tunnel-diode peak voltage (in volts), V_v is the valley voltage (in volts), I_p is the tunnel diode peak current (in amperes), and I_v is the valley current.

Diode efficiency versus peak-to-valley voltage ratios for several values of the peak-to-valley current ratios (shown on page 60) indicates two conditions that are essential for the achievement of high conversion efficiencies in tunnel-diode inverters: $I_p/I_v >> 1$ and $V_v/V_p >> 1$.

Present tunnel-diode inverters require that the following three conditions be satisfied if the tunnel diode is to switch alternately between its high-and low-voltage states:

1. The total d-c circuit resistance, including the diode series resistance, the power-supply resistance, and the wiring resistance, must be less than the negative resistance of the diode at its operating point; thus,

$$R_T < |-R| \qquad (4)$$

2. The total circuit series inductance must be greater than the product of the total d-c circuit resistance, the negative resistance, and the junction capacitance; hence,

$$L_T > (R_T\, C)\,|-R| \qquad (5)$$

3. The source voltage must lie between V_p and V_v; thus the diode must be biased in its negative-resistance region.

The third criterion presents no problem other than that of selecting the proper d-c source for the tunnel diodes. The second one is also easily met, primarily because $|-R|$ is so small. The first criterion is more difficult, however, because the diode series resistance Rs is $\leqq(\frac{1}{2})(|-R_{min}|)$. Therefore, to insure that the total d-c circuit resistance will not exceed $|-R|$, the circuit should be designed so that the sum of its resistances will not be greater than the diode series resistance.

The theoretical operating frequency for a symmetrically oscillating (equal positive and negative periods) loaded, single-diode inverter is given by the following equation:[2]

$$f = \frac{1}{4L}\left(\frac{V_v - V_p}{I_p - I_v}\right) \qquad (6)$$

where L is the inductance of the primary of the transformer.

More detailed theoretical analyses of the single-diode circuit are given by Hanrahan,[2] Storm and Shattuck,[3] and Wang.[4]

Parallel circuit

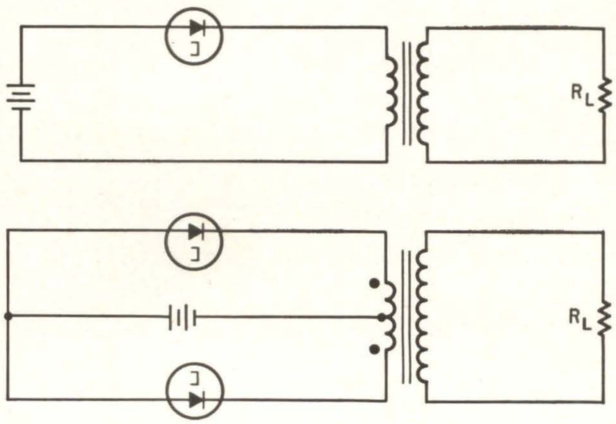
The parallel inverter circuit at the right is basically two single-diode circuits in parallel, both using the same transformer core and secondary. The primary is wound in opposite directions on each side of the center tap. The unique feature of this current is that the diodes become locked; they oscillate at the same frequency rather than independently. Thus, all the flux in the core is additive, and the diode outputs are summed.

The advantage of the parallel circuit over the single-diode circuit is that higher output power can be obtained without the use of higher peak-current diodes. It operates in the same manner as the single-diode inverter circuit.

Push-pull circuit

The push-pull inverter circuit differs from the parallel circuit only in the direction in which the two halves of the primary are wound. For the push-pull circuit, the two halves of the center-tapped primary are wound in the same direction. The transformer core material should be a square-hysteresis-loop type, although the push-pull mode of operation has been observed when standard core materials were used. This circuit may operate in either of two modes; the particular mode selected is determined by the transformer used and the value of the load resistor.

In the first mode of operation, if a large transformer is used, and the core is not driven to saturation the operation of the push-pull circuit is similar to that of the single-diode circuit except that the inverter is drawing a constant, rather than a pulsating current from the d-c source. Frequency stability is poor as the bias voltage changes.



Single-diode inverter circuit is simple and reliable and is recommended for use with d-c power sources that supply a varying voltage. Parallel inverter is useful when the output power required is greater than that obtainable from one diode. The push-pull inverter (not shown) differs from the parallel circuit only in the directions in which the primary is wound.

In the second mode of operation if a small transformer, with square-hysteresis-loop core material is used, then a unique mode of operation results when the core is driven to saturation every half-cycle. This mode differs from the non-saturating mode in that the output waveform is much more square, and the operating frequency is lower and more stable with changes in input voltage or load.

Both the nonsaturating and the saturating circuits have two possible forms of diode oscillation. The two diodes may either oscillate in phase (symmetrical mode), or 180° out of phase (asymmetric mode). When the diodes oscillate in phase, the resultant fluxes they produce in the transformer windings buck each other, and the output power is reduced to practically zero. In the asymmetric mode, the magnetic fluxes produced in the primary are additive, and the output power is high. The factors determining whether the diodes operate in or out of phase are: 1) the value of the load resistance, R_L, and 2) the coupling between the two primary halves of the transformer. It has been shown that the in-phase mode will predominate whenever the load resistor is reduced below a certain critical value given by:

$$R_L = 2n^2\left[\frac{(V_v + R_T I_v) - (V_p + R_T I_p)}{I_p - I_v}\right] \tag{7}$$

where n is the turns ratio and R_T is the winding resistance of the transformer primary, both measured from the center tap to one end.[5,6]

This property, unique to the push-pull circuit, provides excellent short-circuit protection. Whenever the load develops a short circuit (or overload), the inverter reverts to the in-phase mode, and its output power drops to zero. If the circuit is designed properly, it will return to the asymmetric mode as soon as the overload is removed.

Saturated-core inverter

The operation of the saturating core inverter in the asymmetrical mode is as follows: assume that one diode has just switched to its high state. This switching induces a voltage across the primary in such a direction as to force the second diode to switch from its high state to its low state. The induced voltage across the primary windings then has a polarity that maintains the first diode in its high state and the second diode in its low state. This induced voltage remains until the flux in the core cannot change anymore (the transformer becomes saturated). At this point, the induced voltages collapse, causing the diodes to switch to their opposite states. They remain in this state until the transformer again saturates. The cycle is then repeated. Unlike transistorized d-c to a-c inverters, there is no sudden, large increase in current through the diodes when the core saturates. The equation for the operating frequency of the saturating-core inverter is:[2]

$$f = \frac{1}{4}\left(\frac{E}{NAB_s}\right)10^8 = \frac{1}{8}\left(\frac{\Delta V}{NAB_s}\right)10^8 \tag{8}$$

where f is the operating frequency in cps, N is the number of turns on half of the primary, A is the area of the core in square centimeters, B_s is the saturating flux density in gausses, and ΔV is the voltage swing of the tunnel diode (generally $\Delta V \approx V_v - V_p$).

For the non-saturating mode, the operating frequency is given by[2]

$$f = \frac{1}{8L}\left(\frac{\Delta V}{\Delta I}\right) \tag{9}$$

where L is the inductance of the primary.

This mode of operation is similar to that of the single-diode inverter. This similarity is illustrated by a comparison of the frequency equations (equations 6 and 9) for single-diode and the non-saturating push-pull inverters.

The equations used to predict the performance of both single-ended and push-pull tunnel-diode inverters are summarized below.

Theoretical equations are used to predict the performance of both single-ended and push-pull tunnel-diode inverters.

		Single-ended inverter	Push-pull inverter
Parameter	Symbol	Equation	Equation
Power input (watts)	P_{IN}	$1/4\ (I_p + I_v)\ (V_v + V_p)$	$1/2\ (I_p + I_v)\ (V_v + V_p)$
Power output (watts)	P_{OUT}	$1/4\ (I_p - I_v)\ (V_v - V_p)$	$1/2\ (I_p - I_v)\ (V_v + V_p)$
Diode efficiency (%)	η_o	$\left[\frac{(I_p - I_v)\ (V_v - V_p)}{(I_p + I_v)\ (V_v + V_p)}\right]100$	$\left[\frac{(I_p - I_v)\ (V_v - V_p)}{(I_p + I_v)\ (V_v + V_p)}\right]100$
Frequency (cps)	f_o	$\left(\frac{1}{4L}\right)\frac{(V_v - V_p)}{(I_p - I_v)}$	$\left(\frac{1}{8}\ \frac{\Delta V}{NAB_S}\right)10^8$
Critical load (ohms)	R_C	....	$2N^2\left[\frac{(V_v + R_T I_v)\ (V_p + R_T I_p)}{(I_p - I_v)}\right]$

L = primary-circuit inductance (henries)
N = transformer turns ratio (CT to end)
B_S = saturated flux density (gausses)
R_T = circuit resistance (ohms)
A = core area (sq. cm.)

Advantages and disadvantages of various types of tunnel-diode inverter circuits are compared.

Type of Inverter	Advantages	Disadvantages
Single-diode circuit	Simplicity and reliability. No critical load resistance. Wide load and voltage operating range. No starting or hysteresis problems. Maximum output power occurs at point of maximum efficiency. Only slight variation in output power over a relatively large bias-voltage range. Higher operating frequency.	Lower conversion efficiency. Poor frequency stability. Pulsating current drawn from d-c source. Output waveform requires more filtering if rectified.
Parallel circuit	Same as the single-diode circuit; in addition, it will twice the amount of output power than that obtainable from the single-diode circuit.	Same as the single-diode circuit.
Non-saturating push-pull circuit	Allows higher frequency operation than the saturated push-pull circuit.	Poor frequency stability. Larger and heavier core required.
Saturating push-pull circuit	Highest conversion efficiency Greater frequency stability. A relatively steady current is drawn from the d-c source; thus, provides highest efficiency from standpoint of available power from the d-c source. Output waveforms are approximately square, which eases filtering requirements.	Smaller load and source-voltage operating range. Lower frequency operation. Operation affected by starting problems and hysteresis effects under certain conditions. Wide variation in output power with changes in source voltage. Maximum power output does not occur at maximum-efficiency bias point. Load resistance has a critical value (may be advantageous in some applications).

Comparison of circuits

Of the tunnel-diode inverter circuits discussed, the single-diode circuit is the simplest and most reliable. This type of inverter is recommended for applications in which the output waveform and frequency are not critical and for use with d-c power sources that supply a varying voltage. For example, single-diode inverters can be advantageously employed in flasher beacons at sea that are powered by seawater batteries (batteries with magnesium and nickel electrodes that using seawater as the electrolyte; the loaded output voltage of such batteries is approximately 0.2 to 0.3 volt).

The parallel inverter, except for being more complex, has all the advantages of the single-diode circuit. This inverter is useful when the output power required is greater than that obtainable from one diode.

There are few, if any, applications for which the nonsaturating push-pull circuit would be recommended. The use of the saturating push-pull inverter, however, is desirable whenever maximum conversion efficiency is needed or when the inverter output is to be rectified to provide a relatively ripple-free d-c voltage. For example, this type of circuit would be preferred for supplying the power to a radio transmitter.

The advantages and disadvantages of each type of inverter circuit are listed above.

Design procedure

Tunnel-diode inverters are much simpler to design than are transistorized inverters, primarily because no base-current feedback or starting circuits are needed. The initial steps are to establish what the primary d-c source will be and to determine its output voltage, the expected variations in that voltage, and its series resistance. These factors automatically limit, to some extent, the type of diode and circuit configuration that can be used. For example, if the source voltage is in the range of 0.1 to 0.2 volt, only germanium tunnel diodes operated in a single-ended or parallel circuit would be satisfactory. If the source voltage is in the range of 0.40 to 0.6 volt, only gallium-arsenide diodes should be used. Two germanium diodes operated in series could provide the higher-voltage operation, but the circuit arrangement would be much more complicated; therefore, the use of the higher-voltage gallium-arsenide diodes is desirable. If the source voltage is greater than 0.7 volt, transistorized inverters are preferred. The experimental data that is presented graphically will aid in determining the proper operating voltage for the various circuits and diodes. The comparison of various types of tunnel-diode inverter circuits above may be used to help select the optimum type of circuit configuration for a given application.

After the type of circuit to be used is determined, the tunnel diode must be selected. The peak-current (I_p) requirement of the diode is dependent on the required output power. For the single-diode stage the required peak current is, approximately,

$$I_p = 23 P_{out\ (max)} \text{ (for germanium diodes)} \qquad (10)$$

for a push-pull circuit, the peak current per diode is one-half that obtained by equation 10. If gallium-arsenide diodes are used, multiply equation 10 by 0.5. Equation 10 is derived from equation 2 by substituting typical values for V_p (peak voltage), V_v (valley voltage), and I_v (valley current). Once the approximate peak current is calculated, the commercially available tunnel diode that most nearly provides this value can be determined. From the data sheet for the selected tunnel diode, the worst-case values of V_v, V_p, and I_v may be substituted in equation 2 to determine if the tunnel diode will be adequate. Also, if the d-c source voltage is expected to vary, allowance will have to be made for the resultant changes in the output power.

Once the I_p of the tunnel diode is known, the diode negative resistance may be approximated by the empirical relation:

$$|-R_{\min}| \approx 0.12/I_p \qquad (11)$$

where R is in ohms and I_p in amperes. A check should now be made to see if the series resistance of the power supply is small enough to permit oscillations by using equation 4.

The final steps are to use equation 6 or 8 to determine the transformer requirements needed for a given frequency of operation and to establish the primary-to-secondary turns ratio based on the desired output voltage. If a push-pull circuit is used, equation 7 should be used to check whether the turns ratio, n, or the load resistance R_L, are too high or too low, respectively. When using equation 7, the term $R_T I_v$ may usually be neglected, while the $R_T I_p$ term is generally less than 0.1. Thus $R_T < -R \approx 0.12/I_p$ and $R_T I_p < (0.12/I_p)\ (I_p) = 0.12$. The preceding design techniques will now be applied to the construction of a single-ended and a push-pull inverter.

Design example

A d-c source having an output of 0.25 v ± 10% and a source resistance of one milliohm was available. Two inverters using available 10-ampere germanium tunnel diodes were to be built to evaluate the single-diode circuit and the push-pull circuit. An output voltage greater than 20 volts was desired. The frequency for the single-diode inverter was not specified because it changed readily with bias variations. A frequency of 15 cps was required for the push-pull inverter circuit. Maximum power output was desired from both circuits.

Since the parameters of the diodes to be used were already known from previous experiments, the output power expected from the single-diode circuit was computed, using equation 2 rather than equation 10, as follows:

$$P_{out\ (max)} = 1/4\ (.345 - .104)\ (8.9 - 0.8) = 0.49 \text{ watt}$$

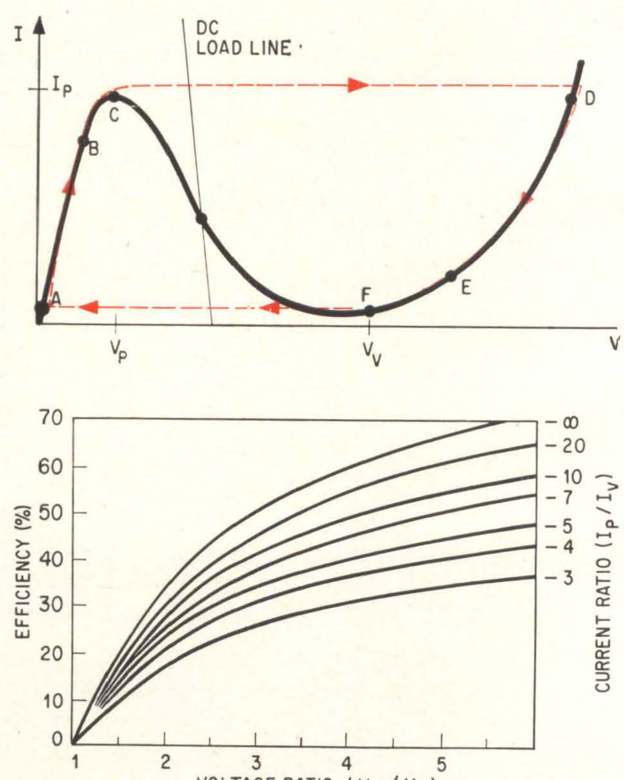
From the curves at the right, the efficiency was found to be 44%. For the push-pull circuit, P_{out} was computed to be approximately 1.0 watt; the efficiency was found to be 41.5%.

The negative resistance of 10-ampere diodes is typically 12 milliohms. Since the supply had an internal resistance of 1 milliohm, equation 4 was easily satisfied.

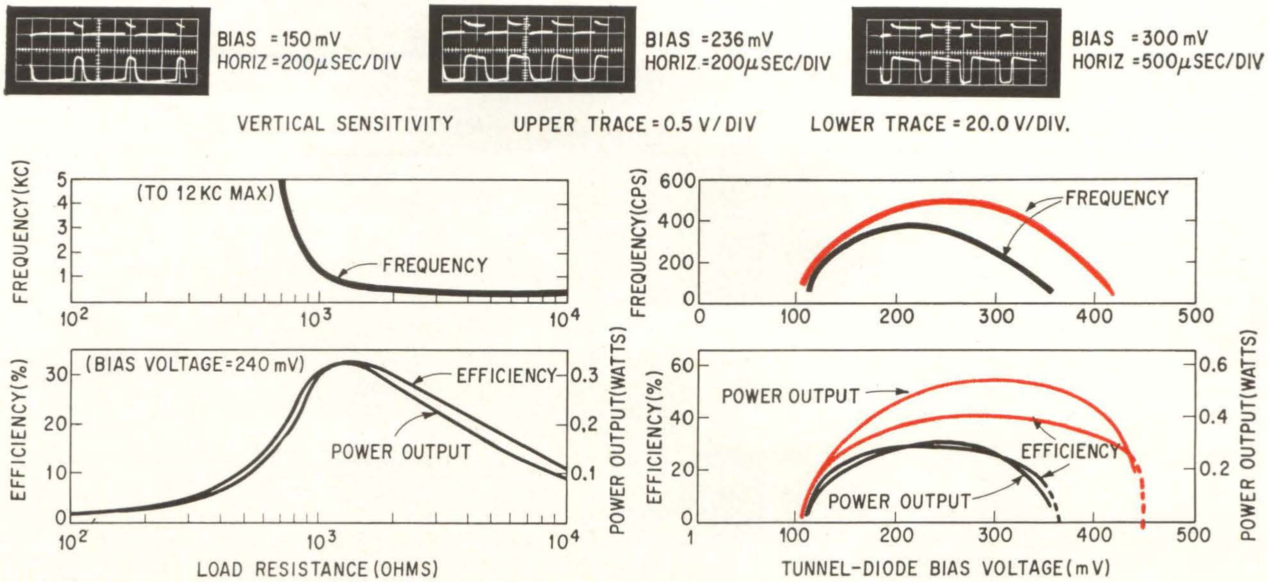
For the push-pull circuit, a frequency of 15 cps was desired. From equation 8, $15 = \Delta V\ (10^8)/8\ NAB_s = 0.25\ (10^8)/8NAB_s$, $NAB_s = 2.1 \times 10^5$. Special materials with nearly square hysteresis loops should be used for the transformer core. These materials saturate easily and produce squarer output waveforms. Either 79 Square Mu or Permalloy 80 would be a suitable choice. However, for this case, only Carpenter 49 material was available. This material has a B_s of approximately 14,000 gauss. Core area was selected to be 0.5 square inch. For these values, the transformer turns ratio (N) is determined as follows: $N(0.5)\ (2.54^2)\ (14{,}000) = 2.1 \times 10^5$, or, $N = 5$ turns. Operating frequencies may be increased: 1), by using more materials that have a lower B_s; 2), by using gallium-arsenide diodes (which have a ΔV, equal to twice that of germanium diodes); and 3), by reducing core area. Frequencies greater than 400 cps are easily obtained.

To insure an output voltage greater than 20 volts rms, a turns ratio of 100 to 1 was used for the single-diode circuit. This value should provide a peak voltage of approximately 40 volts. For the single-diode circuit, a good first approximation of the rms voltage is 0.7 of the peak if the waveform is perfectly square. Because of the irregular nature of the output waveform, the exact rms voltage is hard to calculate, and is best determined experimentally. For the push-pull inverter, a turns ratio of 60 to 1 (secondary to half primary) was used. The critical load for the push-pull inverter was calculated to be:

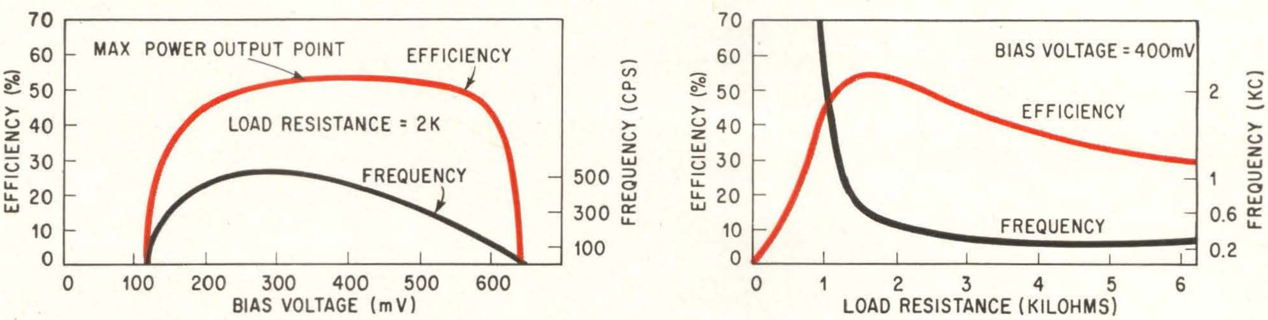
$$R_L = 2\ (60)^2 \left[\frac{0.33 - (0.1 + 0.02)}{8.8} \right] = 172 \text{ ohms}$$



Tunnel-diode relaxation oscillator switches between its high-voltage state, V_v, and its low-voltage state V_v. Switching path is in color. Diode efficiency varies with peak-to-valley voltage ratio for a given peak-to-valley current ratio.



Single-ended inverter using a germanium tunnel-diode has input and output waveforms (top). Variations in efficiency, frequency and power output are a function of the load resistance for a fixed bias voltage (left). The variation of the same parameters when the bias voltage is changed and the load held constant is at the right. Characteristics improve when operated at —196°C (color) with load resistance held constant.



Single-diode inverter circuit uses a 6-ampere GaAs diode to get an approximately flat power output over a wide range of bias voltage. Curves show efficiency as a function of bias and load.

Experimental circuits and techniques

The power source used in most of the experiments described in this section was a transistorized, regulated, 15-ampere d-c power supply with an internal impedance of one milliohm.

The input power to the diodes was computed from direct-current and voltage measurements. The transformer secondary was connected to a precision decade-resistance box to provide a resistive load; the output voltage across the load was measured with a true rms-reading voltmeter, and the a-c output power was computed from

$$P_{out} = V_o^2/R_L \tag{12}$$

The I^2R power losses in the primary windings and connecting leads were not included in measurements of P_{in} because the use of sufficiently large connecting leads and transformer windings make such losses negligible.

Single-diode inverters

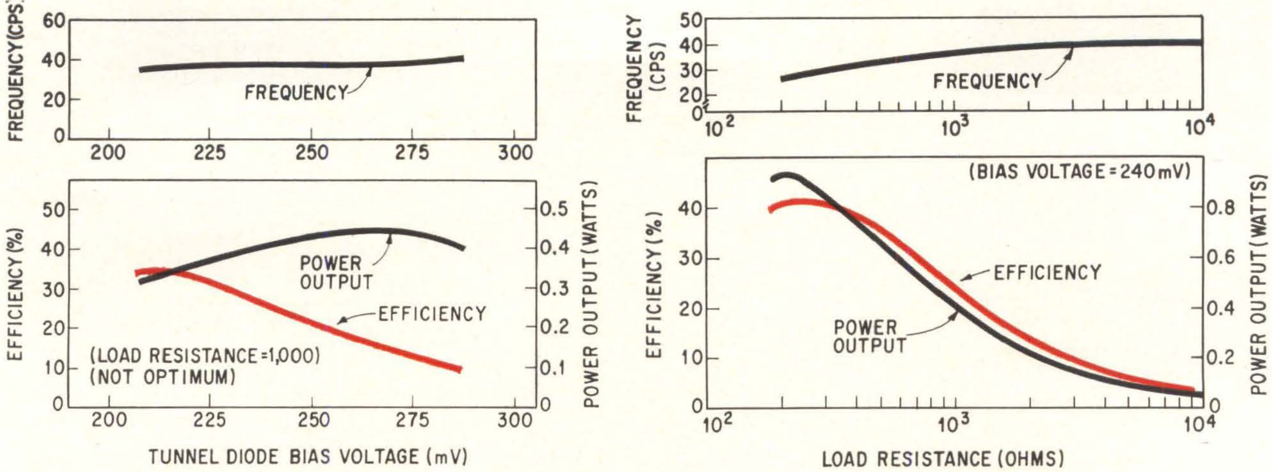
A single-diode inverter circuit was constructed using a transformer with a turns ratio of approximately 100 to 1. The primary was wound from AWG No. 14 wire. Both germanium and gallium-arsenide high-current diodes were operated in this circuit. The electrical parameters of the diodes used in these tests are listed below.

The results of the tests are presented graphically above. The variations in efficiency, frequency, and power output are shown as a function of the load resistance for a fixed bias voltage. The variation of the same parameters when the bias voltage is changed and the load is held constant shows that peak efficiency is obtained for a bias voltage that is

Electrical characteristics of germanium (Ge) and gallium-arsenide (GaAs) high-circuit diodes in inverter circuits.

Type	I_p (amp)	V_p (mv)	I_v (amp)	V_v (mv)	η_o (%)
Ge	8.9	104	0.84	345	44.5
Ge*	10.5	102	0.40	455	58.7
GaAs	6.6	110	0.30	660	65

The asterisk denotes a diode at —196°C case temperature.



Germanium diodes used in the push-pull inverter circuits have variations in efficiency, frequency and power output with load resistance at a fixed bias level (left) and variations in the same parameters with bias voltage at a fixed load resistance (right). Short-circuit protection is ensured by symmetric mode (zero power output).

Characteristics of the germanium diodes used in the push-pull inverter circuits.

I_p (amp)	I_v (amp)	V_p (mv)	V_v (mv)	η_o (%)
9.2	0.97	108	333	41.5
9.8	1.00	107	330	41.5

Characteristics of the gallium-arsenide diodes used in push-pull inverter circuits.

I_p (amp)	I_v (amp)	V_p (mv)	V_v (mv)	η_o (%)
5.8	0.275	105	640	65
6.6	0.300	110	660	65

approximately midway between the peak- and valley-voltage points. At this value, the diode oscillates with equal positive and negative durations. The variation in efficiency with load resistance is caused by the impedance mismatch that is created when the load resistance is other than the optimum circuit output impedance. The efficiency curve could be flattened to some extent by adjusting the bias level each time the load resistance is changed.

The frequency of the single-diode circuit changes by an order of magnitude over the operating bias range. This large change is attributed to the following factors:

1. The negative-resistance region of the diode is non-linear; thus, as the bias is changed, the negative resistance presented to the circuit varies.

2. As the bias is changed from the optimum point, the diode dwells at either the peak or the valley point for more extended periods; as a result, the frequency drops.

Variations in efficiency, frequency, and power output as a function of bias voltage, at a constant load are shown on page 61 when the inverter is operated at −196°C. Results to be noted are the significant increase in efficiency, the shift in the bias voltage for which maximum efficiency is obtained, and the increased operating bias range. These effects are caused by a large reduction in I_v, which increases I_p/I_v from 10 to 26 and an increase in V_v which increases V_v/V_p from 3.5 to 4.5. These changes increase the theoretical diode-conversion efficiency from 44.5% to 58.7% with a corresponding increase in power output. These results clearly show the desirability of using tunnel diodes with high current and voltage ratios.

A gallium-arsenide diode was also tested in the single-ended inverter. The performance curves (shown on page 61) exhibit the same general shape as those of the single-ended circuit with germanium diodes. The most significant difference is the wider operating bias range obtainable with gallium-arsenide diodes. Also there is little variation in power output over a wide range of bias voltage.

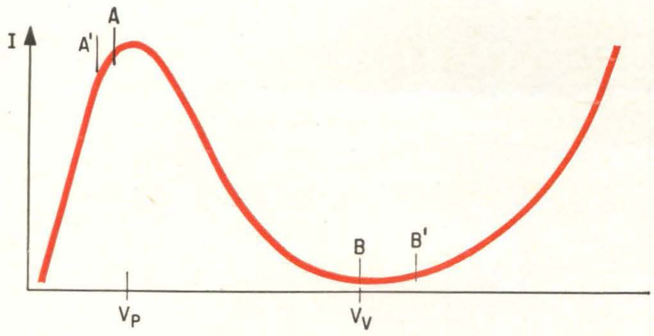
A comparison between the measured efficiency and calculated efficiency for the single-diode inverter shows a large discrepancy. Even when allowances are made for transformer losses, the measured efficiency is still significantly lower than that calculated. The reason is that the diode remains for an appreciable percentage of each cycle at a voltage greater than V_v, increasing the diode power dissipation. Thus, the diode is not operating in the mode assumed in the derivation of the efficiency equation (equation 3).

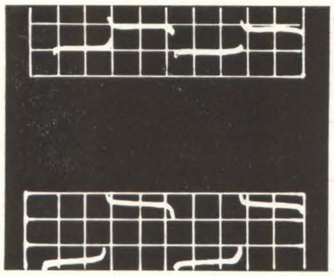
The solution of the Van der Pol equation[4] gives an efficiency of 87.5% of that obtained by use of equation 3. This method, with allowances for transformer losses, gives good agreement between theoretical and experimental values.

The parallel inverter essentially consists of two single-diode inverters in parallel. The general shapes of the curves for efficiency as a function of bias and load are the same as those for the single-diode circuit; hence, no operating characteristic curves for the parallel inverter need be presented.

Push-Pull Saturating Inverters

The advantages and disadvantages of saturated





Theoretical (A,B) and actual diode operating points (A',B') of a push-pull saturated core inverter explain discrepancies between measured and calculated results. Input and output waveforms for the push-pull inverter circuit that uses two 10-ampere germanium tunnel diodes.

and nonsaturating push-pull inverter operation are summarized on page 59. Based on preliminary data, it was decided that the saturated push-pull mode of operation would be more advantageous than the nonsaturated mode; hence, all data presented here refers to the saturated mode.

The main disadvantages of the nonsaturated mode are the larger weight of transformer iron required, and the wide variation of frequency with changes in load and bias. Its main advantage is that it is capable of operation at higher frequencies, as indicated by equation 9, provided the current levels are not too high.

A number of different push-pull, saturating inverters were constructed to determine the optimum transformer size and number of primary turns required for maximum efficiency and optimum frequency. All transformers were constructed using L- laminations of Carpenter "49" material. This material is not an optimum square-loop core material. For best performance, true square-loop tape-wound cores would be more desirable.

The operating characteristics of the germanium diodes used in the push-pull circuits are shown on page 62.

The theoretical efficiency (η_o) of such diodes is rather low, but it is possible to make germanium tunnel diodes with more than 50% efficiency. Variations in efficiency, frequency, and power output with load resistance at a fixed bias level and variations in these same parameters with bias voltage at a fixed load resistance are shown on page 62.

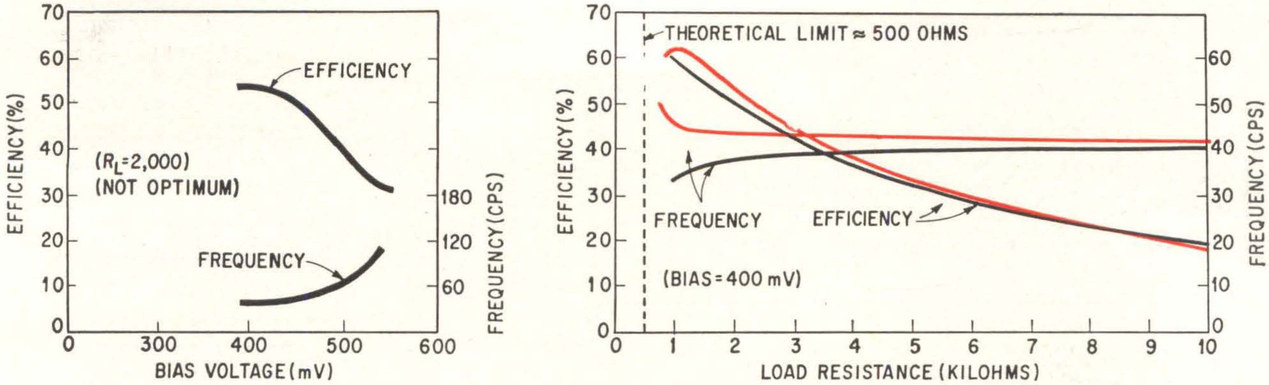
The measured peak efficiency of the push-pull circuit approaches the calculated efficiency, which would seem to indicate a transformer efficiency of nearly 100%. A possible explanation for the closeness in the values of measured and theoretical efficiency is indicated by the fact that the diodes do not switch between points A and B, as is assumed in the calculation of the theoretical efficiency, but rather at points A′ and B′ (see left) where the effective value of V_v/V_p is greater than that at A and B. Thus, the theoretical efficiency is increased. This increase in η_o partially compensates for the circuit losses, and the result is an experimental efficiency that is approximately equal to the theoretical efficiency computed initially.

The graph of efficiency versus load stops abruptly at 190 ohms. This resistance was the experimentally determined value of the critical load resistance, R_L. If the load resistance is reduced below the critical value, the mode of operation changes from asymmetric to symmetric, reducing the output power to zero. This feature of the push-pull circuit provides excellent short-circut protection and means that practically no condition can occur on the secondary side of the transformer that can damage the tunnel diodes or the d-c source on the primary side.

The calculated and measured values of frequency differ by a factor of approximately 2. This discrepancy is the result of two factors: a core stacking factor is not included along with core area in equation 8 and the actual voltage swing, ΔV, is larger than $V_v - V_p$. A more exact expression for the voltage swing that the diode actually undergoes would result in a more accurate frequency calculation.

Performance parameters of a 100-ampere GaAs tunnel-diode push-pull inverter operated from a thermionic generator.

Input current (amperes)	Input voltage (volts)	Load resistance (Ohms)	Output voltage volts (RMS)	frequency (CPS)	Power output (watts)	efficiency (%)
45	0.45	200	45	36	10.1	47.9
52	0.425	150	40	36	10.6	48.0
60	0.41	100	37	36	13.6	55.2
65	0.42	100	38	33	14.4	52.8
72	0.42	75	37	33	18.2	60.3
85	0.45	65	37	33	21.0	55.0



GaAs 6-ampere diodes as push-pull inverters have efficiencies greater than 60% (right). Data at left was taken with the inverter at other than optimum load conditions thus causing reduced efficiencies. The use of capacitors greatly improves starting characteristics of some inverters and reduces efficiencies only 3% (color).

The push-pull inverter, unlike the single-diode circuit, was found to operate over only half of its negative-resistance region. If the source voltage becomes too low, the inverter reverts to the symmetric (zero-output-power) mode. The minimum permissible source voltage is approximately half the valley voltage of the diode. A high circuit resistance on the primary side reduces the operating voltage range; hence, it is good design practice to keep the primary circuit and transformer winding resistance as low as feasible.

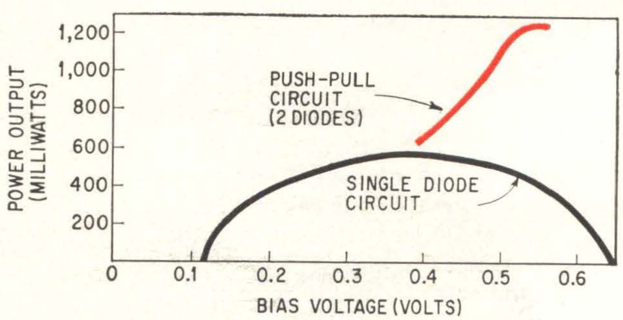
The parameters of the gallium-arsenide diodes used in the push-pull inverters are given on page 62.

There are two major reasons why gallium-arsenide tunnel diodes may be preferred over germanium units in push-pull inverters: First, because the voltage swing for GaAs is twice that in germanium diodes, the operating frequency of the inverter circuit will be doubled, as indicated by equation 8. Second, higher conversion efficiencies can be realized with GaAs diodes because of their higher current and voltage ratios. In addition, GaAs tunnel diodes have a higher operating voltage range. The d-c source voltage normally will be the determining factor as to which type of diode will be used.

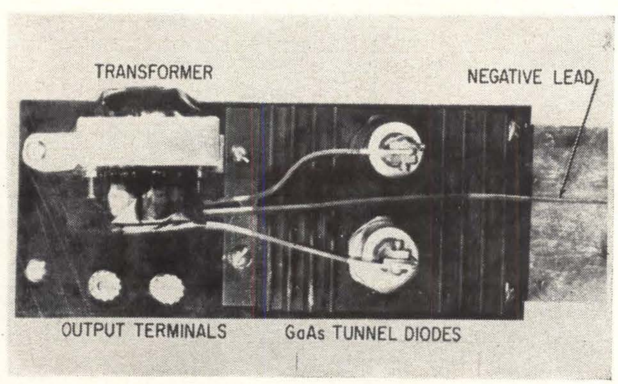
Efficiency and frequency versus bias voltage and load resistance, respectively, for a push-pull inverter using GaAs tunnel diodes are shown above below. Efficiencies greater than 60% have been achieved.

Some inverters when operating at their critical load resistance may exhibit a form of hysteresis when an overload is applied. That is, if an overload is placed on the inverter output (causing the diodes to operate symmetrically and reducing their output to zero) and then removed, the power output remains at zero. To reestablish the out-of-phase (power-producing) mode, the load resistance must be increased to well above the critical value. Furthermore, it is possible that the circuit, when turned on, may start in the symmetric mode rather than the asymmetric mode. A large-value capacitor connected across each diode reduces the hysteresis effect and greatly improves the starting characteristics. A comparison of the operating characteristics of an inverter with and without a capacitor across each diode shows a loss in conversion efficiency of about 3%. Apparently the capacitors suppress the characteristic higher-frequency mode of in-phase inverter operation and thus allows the inverter to operate in the low frequency asymmetric mode.

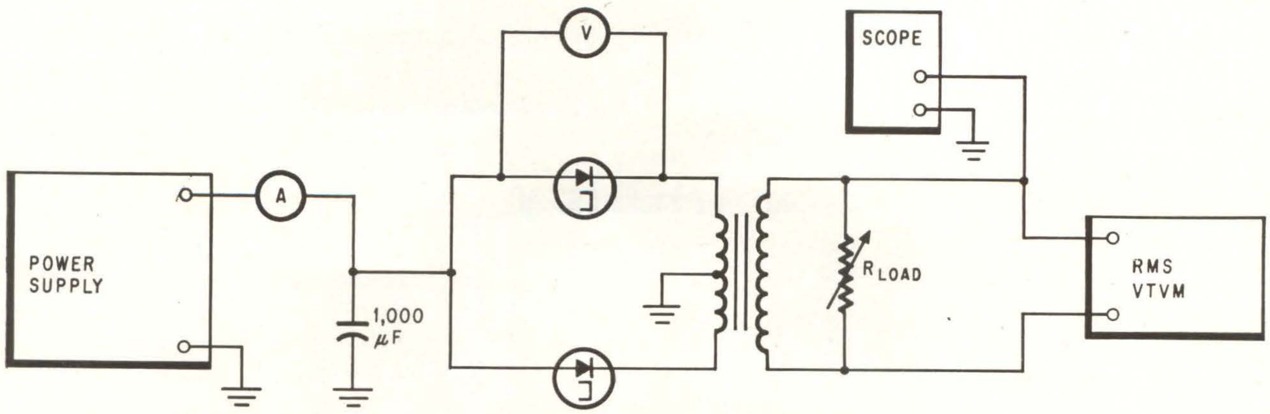
It is apparent from the results and graphs presented that both the single-diode and push-pull circuit have some unique features. These features are summarized in the table on p. 59. Additional



Power output versus bias voltage at a fixed load is compared for the two main types of inverters. Six-ampere GaAs diodes are used.



Ten-Watt, 400 cps inverter uses two 60-ampere GaAs tunnel diodes. Output voltage is greater than 130 volts rms.



Test circuit was used to evaluate all the tunnel-diode inverter circuits. A large capacitor across reduces circuit transcients caused by the inverter. An RMS voltmeter at the output determines the true power output regardless of waveshape. The variable resistor, a precision decade resistance box, provides a load resistance known to 1%.

comparison data between these two forms of tunnel diode inverters (see p. 64) is presented in a graph of output power versus bias voltage.

Thermionic Thermolectric Sources

Experiments which thermionic and thermoelectric power sources were mated with tunnel-diode inverters were conducted. Successful d-c and a-c inversion was obtained in both cases. Practical use of tunnel-dode inverters with seawater batteries has also been demonstrated.[7]

A thermoelectric generator was connected to a low-current tunnel-diode inverter. Because of the relatively low output current and voltage of this generator, two 5-ampere germanium tunnel diodes were used in a push-pull circuit. (GaAs diodes could have been used in a single-diode inverter circuit). After connecting the inverter to the d-c source, a square-wave output was obtained at a frequency of 10 cps. The frequency could have been increased at least 50 times if a smaller transformer core and fewer primary turns had been used.

A large thermionic converter was connected to a saturating push-pull inverter containing two 100-ampere gallium arsenide tunnel diodes. GaAs diodes were used because the operating voltage of the thermionic converter was approximately 0.5 volt. The transformer used four turns of copper sheet, center-tapped, for its primary, and 210 turns of No. 24 wire for its secondary. With the power source connected to the inverter a square-wave output similar to that shown on page 63 was obtained. The results obtained are summarized in a table on page 63. The theoretical maximum diode efficiency was approximately 61%. Cumulative measurement errors probably were less than ±5%.

The inverter was operated for approximately one hour at several power levels with good overload recovery. Each diode was bolted to a black, aluminum, heat sink.

Two 200-ampere GaAs tunnel diodes were also inserted in this inverter. Oscillation was obtained, but because the circuit was not designed to operate at such high currents, it ceased after about one minute. This was attributed to excessive circuit series resistance, the heating effects of the high primary current, and power source voltage drift.

A 10-watt, 400-cps inverter circuit that uses two 60-ampere gallium-arsenide tunnel diodes is shown at left. The output voltage of this unit is greater than 130 volts rms. The physical size of this inverter circuit could be considerably reduced by use of different transformer core material such as tape-wound cores. The heavy connecting leads are necessary to cut down the I^2R heating losses.

The test circuit shown above was used to test all the inverter circuits described in this article. An RMS voltmeter at the output determines the true power output regardless of the waveshape. The oscilloscope is used to observe the waveform and output frequency.

Acknowledgment

The author gratefully acknowledges the assistance of P.D. Gardner and A.E. Roswell, who were responsible for the design and development of the high-current tunnel diodes; A.J. Herd, E.M.Strouse, and P.M. Britt, who fabricated the diodes; H. Krautter, who was responsible for the packaging of the devices and R. Glicksman, who initiated the project.

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This article was presented in greatly abbreviated form at the 1963 Power Sources Conference. An article similar to this, but with much more emphasis on tunnel-diode device design and less emphasis on circuit performance, has been published in the Proceedings of the 1963 Power Sources Conference.

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More for your money

Circuit designers can cut costs by early consideration of heat-transfer problems

By Edward Trunk

The Staver Co., Bay Shore, N.Y.

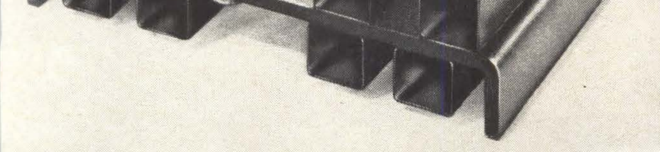
At an early point in the design of solid-state circuitry, a method must be chosen for removing the heat generated by the semiconductor devices. This may be done by providing for adequate heat removal in the basic structural design of the equipment or by incorporating dissipation devices into the design. The equipment designer must decide which road to follow.

If his decision is to use dissipators, the next question is: Which is the best dissipator to use from both an economical and a technical standpoint?

Whether the engineer chooses dissipator-assisted cooling or natural cooling, a choice should be made as early as possible. If the decision is to use dissipators, their selection should also be one of the first steps in the design. Otherwise, unnecessary problems are introduced.

A typical dilemma

For example, let's consider the fictional case of the Whoops Electronic Equipment Co. Whoops' circuit designers came up with a new equipment item containing new circuits. Then they built a breadboard model. It performed brilliantly. Because it was a commercial item intended for a highly competitive market, germanium transistors were used in the circuits. The maximum junction temperature rating for the transistors was 90°C, but to insure thermal stability (prevent thermal runaway) the circuit was designed to hold the maximum operating junction temperature to 70°C. It was anticipated that the ambient temperature would



The laminated heat sink eliminates the standoff insulator usually used to prevent electrical conduction between a transistor and a heat sink. The two sections of the heat sink are electrically separated by the hard anodized coating on the top plate.

Effect of temperature upon thermal conductivity of metals and alloys*

[Main body of table is k in Btu/(hr)(sq ft)(deg F per ft)

Temperature Deg. F. / Deg. C.	32 / 0	212 / 100	392 / 200	572 / 300	752 / 400	932 / 500	1112 / 600	Melting point (Deg. F.)
Aluminum	117	119	124	133	144	155		1220
Brass (70-copper, 30-zinc)	56	60	63	66	67			1724
Cast Iron	32	30	28	26	25			2192
Copper	224	218	215	212	210	207	204	1976
Graphite (longitudinal)	97	87	76	66	58	53	48	None
Lead	20	19	18	18				621
Nickel	36	34	33	32				2642
Silver	242	238						1760
Steel, mild		26	26	25	23	22	21	2507
Tin	36	34	33					450
Wrought iron, Swedish		32	30	28	26	23		2741
Zinc	65	64	62	59	54			786

*William H. McAdams, Heat Transmission, McGraw-Hill, N.Y., 1954 and International Critical Tables, McGraw-Hill, N.Y. 1929.

not rise above 45°C. Even so, this meant a temperature difference of only 25°C between the junction temperature and the ambient temperature.

When the circuit designers were through, the packaging engineers took over. By the time they finished, some of the transistors had been placed at the interior of the set where they would be subjected to a local environmental temperature considerably higher than 45°C. Moreover, the physical arrangement of the circuit components was more confining and the air flow more hampered than in either the breadboard model or the prototype which followed it.

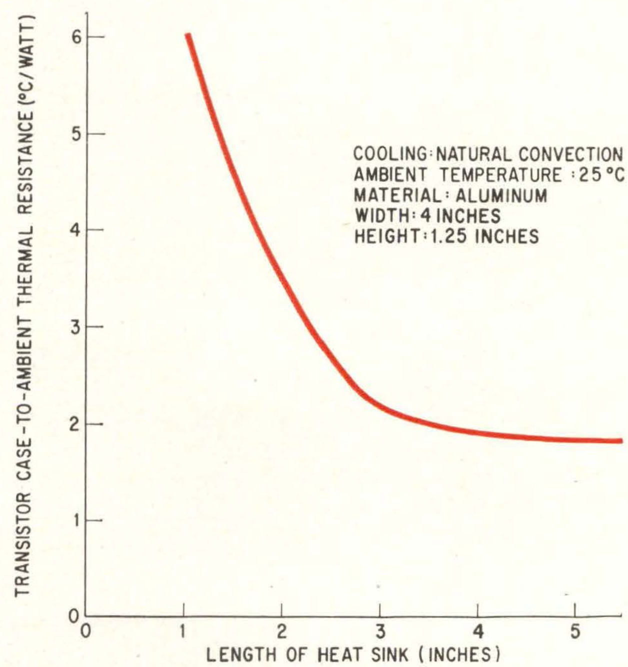
Next, overheating and premature failure of the transistors was discovered during the testing of the first production models. Transistor dissipators were purchased in a hurry and squeezed into place. They were the last step in the design. The result was that dissipators were not used to their best advantage. Fortunately, they provided enough cooling to permit the marketing of the equipment.

It's conceivable that if the use of dissipators had been planned early in the design, heat dissipators costing considerably less could have been used. The competent designer has learned that the dissipator is a fundamental design component just like the capacitor, resistor, or transformer.

Chassis as heat sink

One economical solution of a heat dissipation problem is to use the chassis or an outer surface of the cabinet as a heat sink. Frequently this approach works—especially if the chassis or surface material is aluminum, if the thermal conditions are not severe, and if the surface chosen is not subject to appreciable heating by other components. On the other hand, if the material is a thin-gauge steel and has numerous mounting holes filled by other components, its use as a transistor heat sink could be disastrous. Copper, aluminum, and magnesium surfaces may be acceptable as heat sinks, depending on the application. Brass and steel surfaces are usually poor choices for use in this manner.

It is essential to construct a full-size model of the cabinet or chassis proposed for use as a heat sink, and to duplicate the actual conditions which will exist for the production model. Suppose the



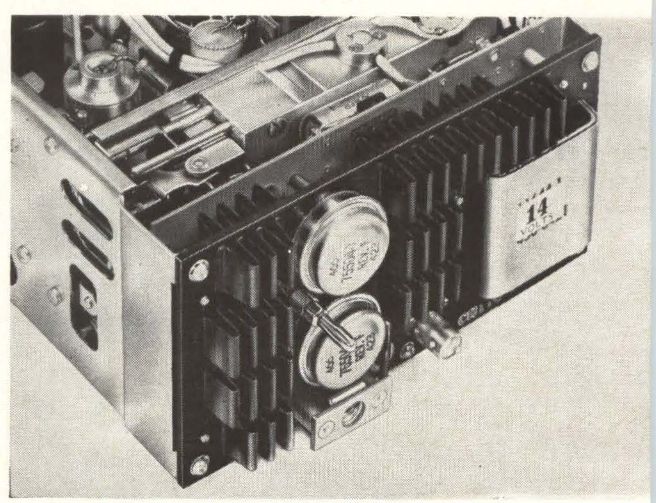
Variation of thermal resistance with heat sink size

Thermal conductivities of metals*

[k = Btu/(hr)(sq ft)(deg F per ft)]

Substance	Deg. F.	k	Substance	Deg. F.	k
Metals:			**Metals:**		
Antimony	32	10.6	Mercury	32	4.8
Antimony	212	9.7	Nickel alloy (62Ni, 12Cr,		
Bismuth	64	4.7	26Fe)	68	7.8
Bismuth	212	3.9	Platinum	64	40.2
Cadmium	64	53.7	Platinum	212	41.9
Cadmium	212	52.2	Tantalum	64	32
Gold	64	169.0	**Alloys:**		
Gold	212	170.0	Admiralty metal	86	65
Iron, pure	64	39.0	Bronze, commercial		109
Iron, pure	212	36.6	Constantan (60Cu, 40Ni)	64	13.1
Iron, wrought	64	34.9	Constantan (60Cu, 40Ni)	212	15.5
Iron, wrought	212	34.6	Nickel silver	32	16.9
Iron, cast	129	27.6	Nickel silver	212	21.5
Iron, cast	216	26.8	Manganin (84Cu	64	12.8
Steel (1 per cent C)	64	26.2	4Ni		
Steel (1 per cent C)	212	25.9	12Mn)	212	15.2
Magnesium	32–212	92.0	Platinoid	64	14.5

*L. S. Marks, Mechanical Engineers' Handbook, McGraw-Hill, N.Y., 1951.



Advance planning allowed integration of the heat sink into this equipment design. The equipment is a distance-measuring unit, model UDI-3, manufactured by the National Aeronautical Corp., Fort Washington, Pa.

test results show that the chassis or cabinet is not adequate to the cooling job. Before specifying dissipators, consider a different chassis material. The heat dissipation problem might be solved by replacing the aluminum material under consideration with a more-conductive or heavier-gauge type. Another solution might be to coat the bare aluminum surface with black paint. This could increase the dissipating ability of the aluminum by about 15%.

Allow air flow

If an internal surface is used as the heat sink, ample openings in the cabinet in addition to internal air flow passageways may be the answer. In the example of the Whoops Electronic Equipment Co. such an approach might have eliminated the need for dissipators entirely. It is even possible, although not often done, to add fins to the cooling surface to provide greater heat convection. If a cabinet surface is to be used as a heat sink, the vertical exterior surfaces are best.

If the use of a chassis or cabinet surface is not adequate, the designer will have to employ individual heat sinks. With printed circuits employed in plastic or thin-gauge steel cabinets, he has to use dissipators. His next step is to calculate the thermal resistance figure required for the heat dissipator.[1] The curve on p. 67 shows how the value of thermal resistance changes with changes in the size of the heat sink. For lengths beyond three inches, further increases in length still have some effect on thermal resistance but add considerably to the dissipator cost.

Usually, the lower the thermal resistance of a dissipator, the higher its price and the greater its size. Specifying a lower thermal resistance than needed is costly in terms of both space and dollars.

Include safety factor

Therefore, the designer shouldn't go overboard when designing-in safety factors. If he uses 250% when 25% will suffice, he's not gaining much in additional reliability or lifetime, but he's losing a lot in terms of space, weight, and cost. He's well past the optimum point, where his dollar is buying the most it can get in cooling capability.

To determine the optimum dissipator to use, a useful tool is the price-thermal resistance figure of merit. This indicates how many watts can be dissipated per dollar spent for a given temperature rise. The table shows how this thermal figure of merit is obtained.

Dissipator	(a) Price (cents)	(b) Thermal resistance (°C/watt)	[1/(a) (b)] Thermal figure of merit [watts/(dollarsx°C)]
No. 1	.38	5.5	.48
No. 2	.40	6.4	.39
No. 3	.90	5.0	.22
No. 4	.95	3.5	.30

Making a comparison

From the table, dissipator No. 1 appears to be a much better value than No. 3 although its thermal resistance is slightly higher. The correct use of the thermal figure of merit requires that the user test each dissipator under identical conditions. The manufacturer's data sheet values will probably not be acceptable for direct comparison of dissipators since thermal resistance values vary considerably according to the testing conditions. For example, a heat sink with a thermal resistance of 1.9°C/watt (when measured for a 57°C temperature rise and 30 watts dissipation) can provide a thermal resistance of 2.4°C/watt if the dissipation is reduced to 10 watts (the corresponding temperature rise from 25°C with this dissipation is 24°C). This illustrates that the relationship between temperature rise and power dissipation is not linear. Typically, the temperature increases by the 0.83 power of the increased dissipation.

Avoid insulator

There are also other ways in which the cost of providing for adequate heat transfer can be kept down. When possible, the use of an electrical insulator between the transistor and the heat dissipator should be avoided. Insulators add 0.5° to 1.0°C per watt to the total thermal resistance which may require the use of a larger dissipator. One way to eliminate the insulator is to isolate the heat sink from the chassis ground. This practice is advantageous from a thermal standpoint but it may present a safety hazard. Another way to eliminate the insulator is to use a two-layer or laminated dissipator which has a hard anodized coating on one layer to prevent electrical conduction [Electronics, June 15, 1964, p. 84]. Such a dissipator is shown on page 66.

Early consideration and selection of the method and devices to carry off the heat from solid-state circuitry is important. A last-minute discovery that dissipators are needed can mean high costs. The discovery can be particularly expensive if fabrication is so far along that only a custom-made shape can fit the available space. Remember that early integration of large dissipators into the design sometimes allows their use as structural supports.

The author

Edmund G. Trunk, a professional engineer, is acting as consultant to the Staver Co. He holds a master's degree in electrical engineering from the Polytechnic Institute of Brooklyn. His fields of specialization are servomechanism systems and solid-state circuitry. A sailing enthusiast, Trunk has been experimenting with the conversion of wind into electrical energy—perhaps to power his boat.

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Components

Cooling high-power equipment by forced-air convection

Selection of the right fan for the system is critical.
Here are some guidelines for the equipment designer

By Leonhard Katz

President, Astro Dynamics, Inc., Burlington, Mass.

Forced-air cooling is one solution to the growing problem of cooling high-density equipment. The need to cool electronic equipment containing an ever-increasing number of transistors, semiconductor diodes or silicon controlled rectifiers is forcing engineers to turn from free-convection cooling to other methods. In some cases, liquid cooling is effective but not always practical because of the requirement for bulky pumps and heat exchangers. For very compact high-power equipment, natural convection is especially impractical because it requires large heat sinks.

Design goals

Forced-air convection is usually the method chosen. To do the job properly, however, a compact heat-sink assembly using forced convection must meet the following design criteria:

1. The individual dissipator (or heat sink) package should be modular, so that several can be stacked together to form a modular package.
2. The dissipator should provide a mounting surface for the transistors that permits external wiring and easy testing of circuits.
3. The heat sinks, when mounted in place, should be electrically insulated from each other. However, if the use of an electrical insulator between the transistor and the heat sink can be avoided, heat flow will be improved.
4. The dissipator must be designed to provide minimum temperature difference between the transistor and the air which surrounds it.
5. The heat-sink assembly and the fan should be of integral design so that maximum output from the fan can be effective.

The forced-convection system should also be designed around commercially available components. Avoiding the use of custom-made products not only allows savings in time and cost but also permits design on the basis of known performance.

First Step

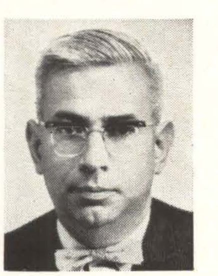
The first consideration in the selection of components for a forced-convection system is the right fan. Electronic circuits involving power transistors or semiconductor rectifiers typically require 5 to 20 transistors. The power dissipation for each transistor usually does not exceed 20 watts. The assembly, for a typical 15-transistor system may thus be required to dissipate about 300 watts. For this particular system, the fan must provide enough air movement so that the air temperature, when 300 watts are dissipated, will not rise excessively. Ideally, to restrict significant shortening of the transistor lifetime, the air temperature should not be permitted to rise more than 10°F to 20°F.

The first law of thermodynamics defines the rate at which heat is carried off by forced air convection as:

$$Q = W\,C_p\,\Delta T \text{ or } W = Q/C_p\,\Delta T \qquad (1)$$

where Q = heat dissipation rate in BTU/hr
W = weight flow of air in lb/hr
C_p = specific heat of air in BTU/(lb)(°F)
ΔT = temperature rise of the air in °F

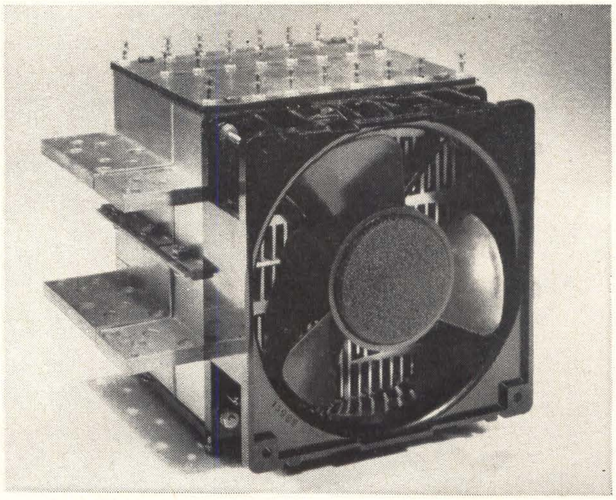
The author

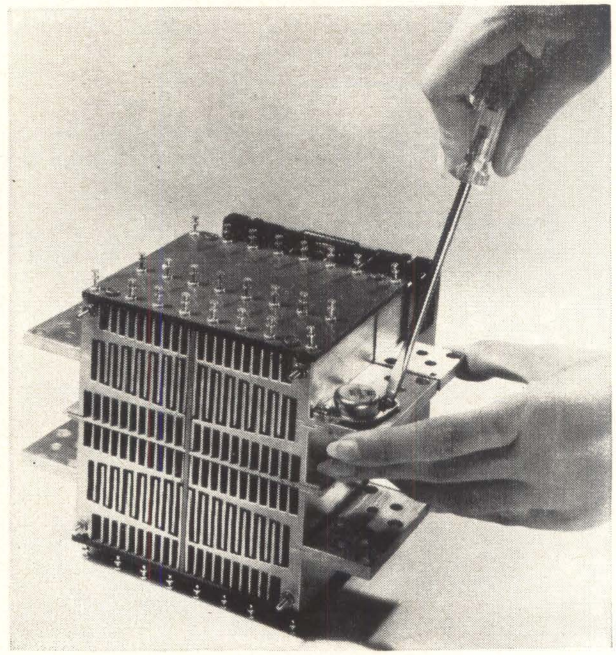


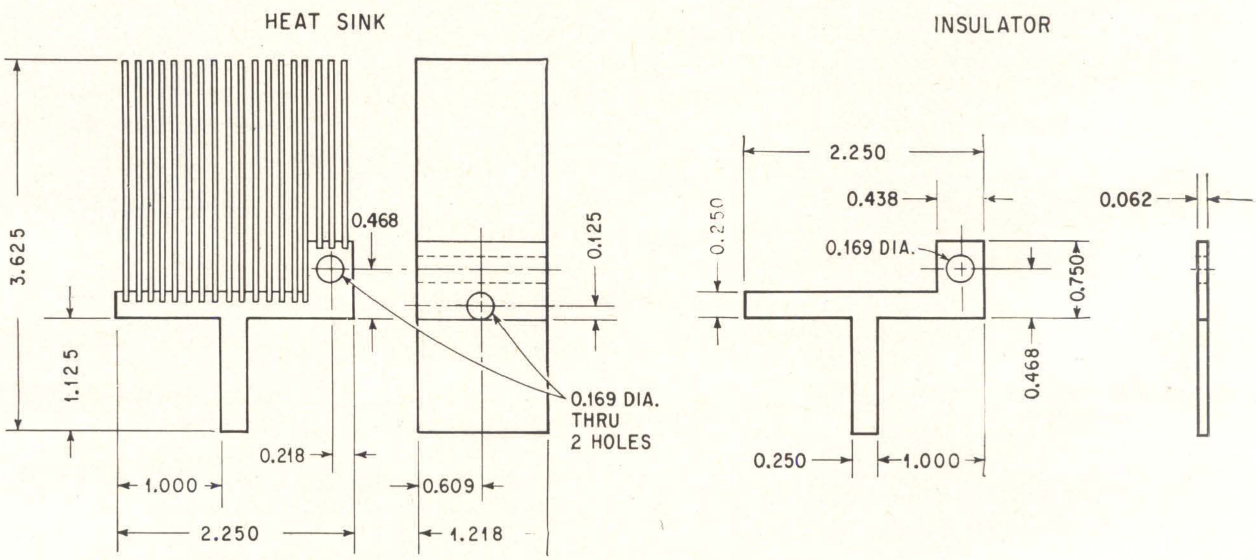
Leonhard Katz, has been a consultant for many years in the fields of heat transfer, mass transfer, television, telemetering, and radar. His company manufactures electromechanical devices, heat sinks and heat exchangers. He is a consultant to the President's Science Advisory Committee and is teaching a graduate course in heat transfer at Northeastern University.

Front view of a modular heat-sink assembly capable of mounting 12 power transistors.

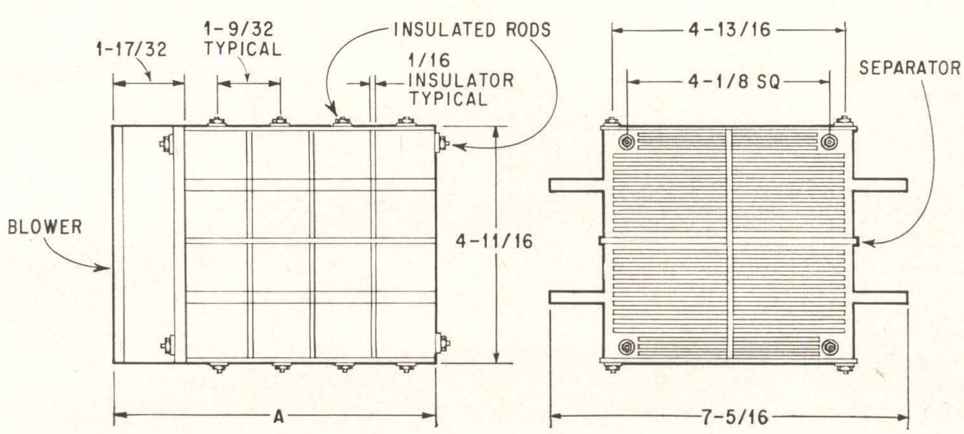
Rear view of a modular heat sink assembly. The fan is a fundamental structural component of the package.







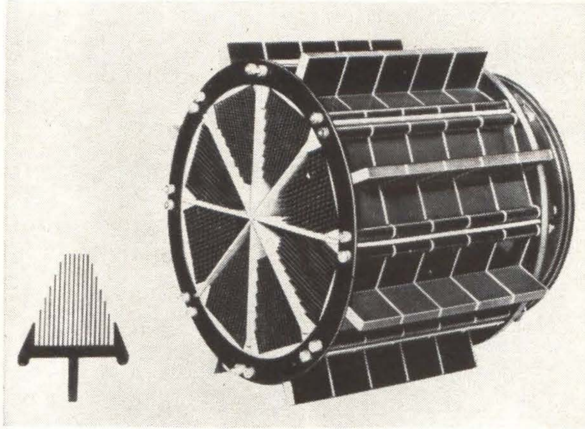
The basic heat sink used as a building block

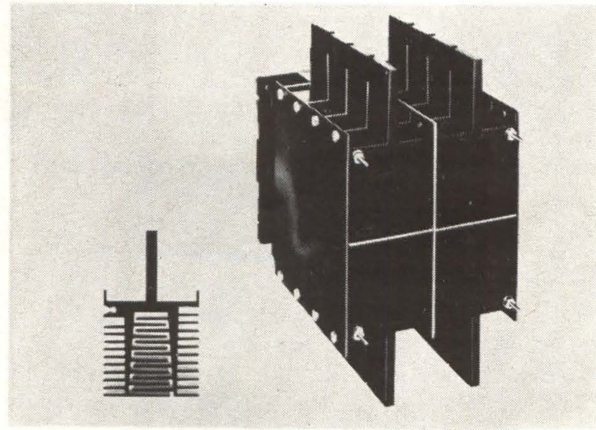


A	TRANSISTORS
2-3/4	4
4-1/32	8
5-5/16	12
6-19/32	16

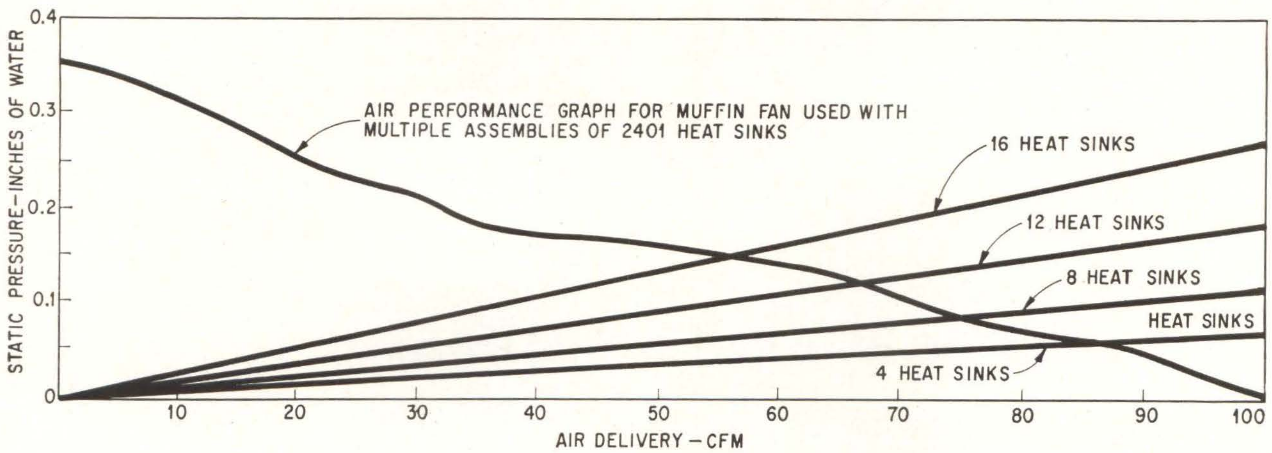
DIMENSIONS IN INCHES

A forced convection system with 16 heat sinks





Circular assembly for mounting 40 power transistors, left; rectangular assembly for 16 power transistors, right



Performance of fan

Since 1 watt = 3.41 BTU/hr and 1 cubic foot per minute (CFM) = 4.2 lb/hr, the required air flow may now be determined for the typical system.

$Q = 300$ watts $= 300\ (3.41)$ BTU/hr
$= 1023$ BTU/hr
$C_p = 0.24$ for air at 100°F
If $\Delta T = 10$°F
From equation 1:
$W = 1023/0.24\ (10) = 426$ lb/hr
$= 426/4.2$ CFM $= 100$ CFM

For $\Delta T = 20$°F, eq. 1 yields $W = 213$ lb/hr = 50 CFM. Therefore, a fan capable of providing between 50 to 100 CFM is required.

Another requirement influencing fan selection is that the power needed to drive the fan should not exceed 10% of the power to be dissipated. For this example, the fan power should not exceed 30 watts. Several compact fans which can deliver 100 CFM of air are commercially available. A typical fan, made by the Rotron Manufacturing Co., Woodstock, N. Y., is approximately five inches square and consumes approximately 13 watts. The four corner-mounting holes of the fan can be used as the mounting holes for the whole assembly. The pressure drop obtainable from the fan is about 0.15-inch water pressure at 50 cubic feet per minute which is approximately equal to the pressure drop for the equipment.

Pressure drop is an indication of the ability of air to flow through the equipment being cooled. The larger the pressure drop, the higher the resistance presented by the equipment to the flow of air. For a fan to be effective, its pressure-drop rating should be equal to or greater than the pressure drop measured for the equipment.

This fan allows the mounting of four heat sinks in a layer, each heat sink occupying one quadrant. Up to four layers of heat sinks can be stacked, thereby providing accommodations for 4, 8, 12, or 16 transistors. Since the application being discussed employs 15 transistors, four layers are required.

Second step

Theoretically, the next step is the design of the individual heat sink—determination of the size, shape and number of fins, their thickness, spacing and length, together with the design of the fin base and the shelf for transistor mounting. Actually, the equipment designer will rarely conduct this part of the design. Each heat-sink manufacturer has one or more basic dissipators specifically designed for use in forced-convection cooling systems. The use of a standard dissipator assures the equipment designer that losses in the form of temperature drops in the system have been previously studied and minimized. Those temperature drops which must be minimized are:

ΔT_1 = drop between air and fins
ΔT_2 = drop along the fin, due to conduction
ΔT_3 = drop in the fin base, due to conduction
ΔT_4 = drop in the shelf
ΔT_5 = interface loss between transistor and shelf

Drop ΔT_1 is determined by the magnitude of the heat-transfer coefficient h [Electronics. Sept. 7, p. 101] between the air and the fins, while ΔT_2, ΔT_3, ΔT_4, are determined by the heat-transfer properties of the conduction material. The interface loss ΔT_5 is a function of the surface area of the transistor base.

Building block

A recommended dissipator configuration which satisfies most forced-convection requirements is shown on p. 70. The complete assembly shown uses this dissipator as a building block with the fan previously described.

Typical values (in °F/watt) of temperature drops obtained using this arrangement are:

$\Delta T_1 = 0.5$ $\Delta T_4 = 0.2$
$\Delta T_2 = 0.3$ $\Delta T_5 = 0.2$
$\Delta T_3 = 0.2$

The total temperature drop associated with the heat-sink assembly alone is $\Delta T_1 + \Delta T_2 + \Delta T_3 + \Delta T_4$ or 1.2 °F/watt, equivalent to 0.67 °C/watt. (ΔT_5 is determined by the mounting surface of the transistor used.)

The air flow that can be expected is obtained from the curves shown on p. 71. If only one layer (four heat sinks) is used in the assembly, air flow at 87 CFM can be expected (75 CFM for 8 heat sinks, 67 CFM for 12 heat sinks). Since 15 heat sinks are required in the example discussed, the air flow is about 55 CFM. This is within the desired 50 to 100 CFM range.

Circuit Design

Insurance against transistor failure

Automatic cutoff protects semiconductor devices from damage or destruction by heat

By Henry Epstein and Charles Flanagan

Texas Instruments, Inc., Attleboro, Mass.

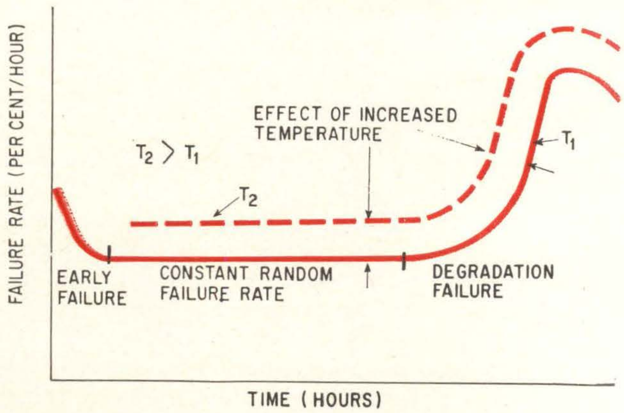
Extensive studies of the failure of electrical-magnet wire insulation as a function of conductor temperautre have shown that for every 10°C change in temperature the projected insulation life halves (for a temperature increase) or doubles (for a temperature decrease). A similar pattern appears to apply for semiconductor devices.

R. H. Norris and J. E. Drennan have reported a range of 8° to 15°C for the halving (or doubling) of lifetime depending on the type of semiconductor device and the application.

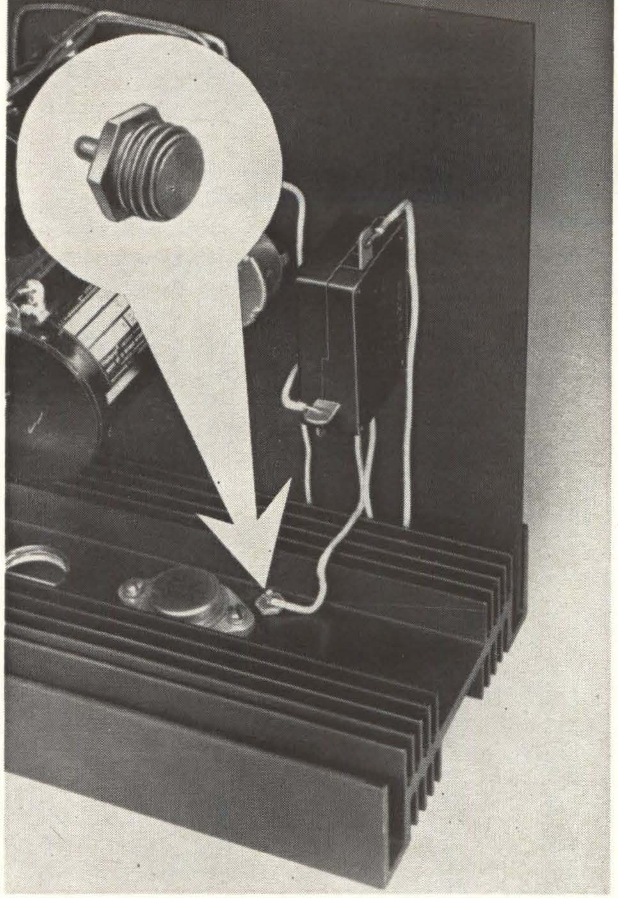
The failure-rate pattern shown indicates the effect of operation at an increased temperature on a semiconductor device.

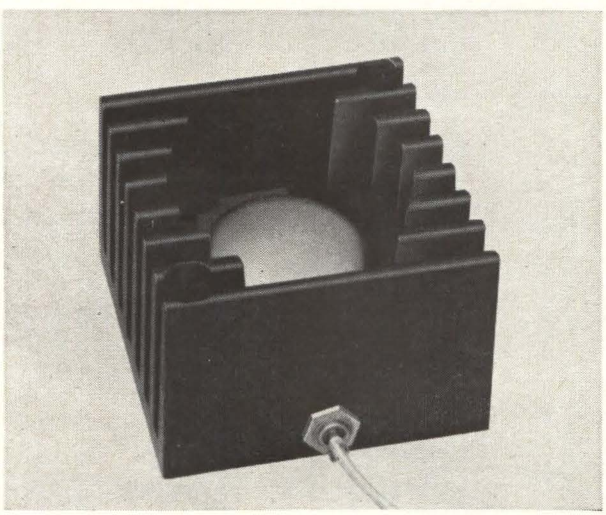
The effect of the operating temperature on the failure rate of semiconductor devices is further illustrated by the curve shown on p. 73. This curve reveals that a typical silicon device operated at a junction temperature of 160°C will have a lifetime of about 500 hours. However, the same device operated at a 100°C temperature can provide more than 10,000 hours of service.

There are a number of ways to prevent heat from damaging or destroying the transistors in solid-state equipment. These include adding an

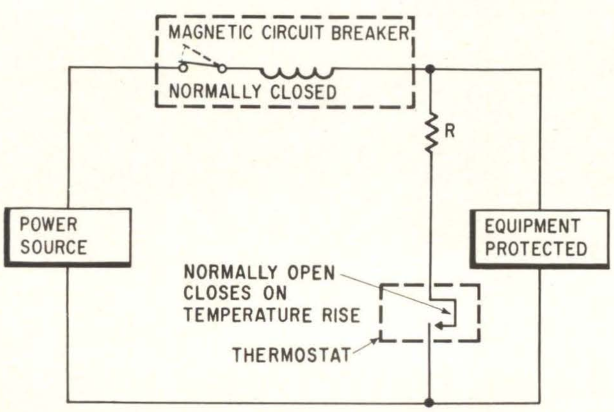


Typical failure pattern for semiconductor devices.

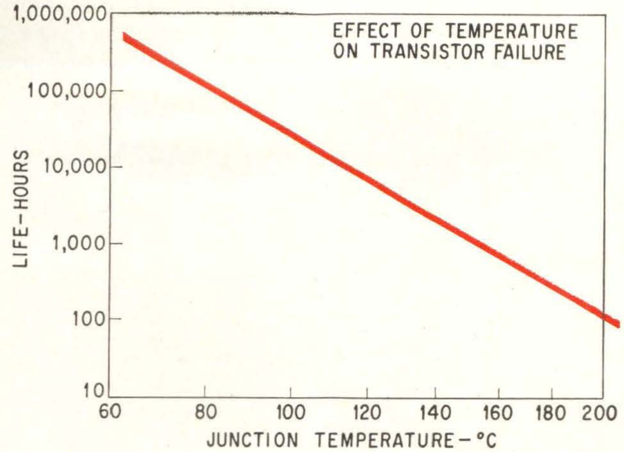




Thermostat mounted on heat sink shuts off circuit or sounds alarm when temperature exceeds safe level.



Protection circuit for guarding solid-state equipment against temperature and current overloads



Transistor lifetime as a function of junction temperature

alarm circuit to indicate the overheating of the transistor, provision for automatically bypassing or attenuating of harmful power transients, protection by effective cooling systems, and system interruption before excessively high temperatures are reached. A combination of two or more of these methods promises added protection.

For example, an ideal two-level protective system would work as follows: The first level would energize an alarm system and permit corrective action when the approach to failure is slow. The second level would de-energize the equipment being protected or initiate corrective action if the rate of approach to failure is rapid.

Thermal monitors

A transistor which is expected to operate under conditions that may cause it to overheat, will probably be used with a heat sink. The heat sink, therefore, may be used in conjunction with a thermostat to protect the transistor. For example, a small thermostat can be mounted directly on the heat sink near the transistor. When the heat-sink temperature exceeds a safe value, the thermal monitor can be set to open or close an electrical circuit. At the critical temperature it can activate an alarm, shut down the system, or both.

Two typical mounting arrangements for thermal monitors are shown at left. In both cases, the temperature protective device used is a Texas Instruments model 3BT3.

Thermal monitoring may also be used in conjunction with a circuit breaker to provide a protection scheme for all conditions of current and ambient temperature. The thermal monitor is designed to close at a certain temperature. In typical use, it is connected across the line on the load side of a magnetic circuit breaker coil as shown. Closing of the circuit by the thermal monitor causes an overload which trips the magnetic circuit breaker. The system cannot be re-energized until the thermal monitor and the equipment being protected have cooled to a safe operating temperature.

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.

Diamond circuit measures phase shift

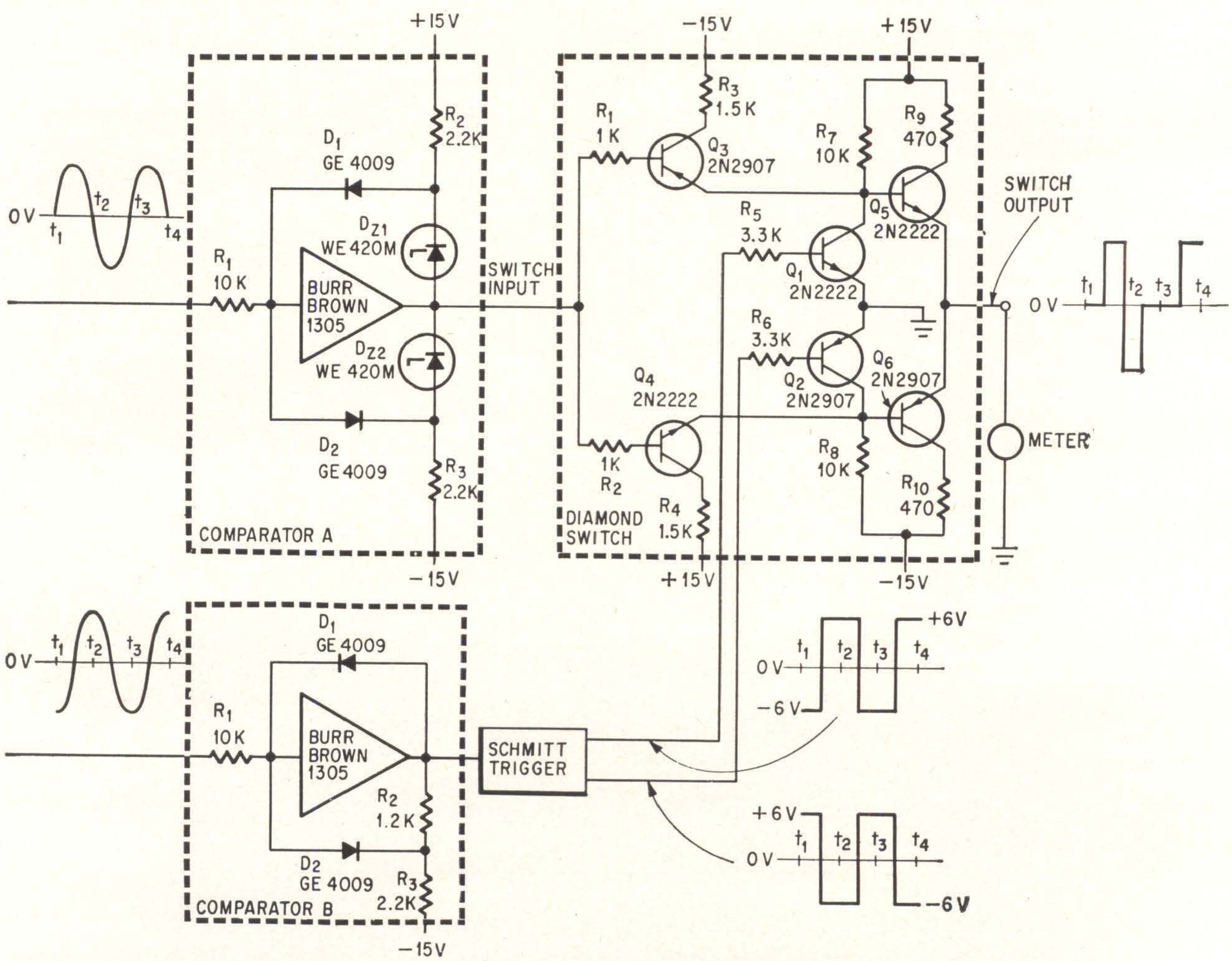
By Harry R. Deveraux

University of Wyoming, Laramie, Wyo.

A circuit utilizing the diamond switch[1] can measure phase shift with accuracies of 1% at frequencies up to 2,000 cycles per second. This circuit can be useful for high-speed analog instrumentation and computers.

The diamond switch is a follower circuit. For a sine wave input, the output will be a sine wave of the same magnitude and phase. Transistors Q_1 and Q_2 are control transistors that turn the switch on and off. The switch in the on condition (Q_1 and Q_2 off) has an input impedance of approximately 450 kilohms. For a transistor β of 75, the output impedance is about 10 ohms; the voltage gain is approximately unity, and the current gain is approximately 4,000. The bandpass is from 0 to 9 mc.

Turning on Q_1 and Q_2 causes the output of the switch to go to zero. When the inputs to the bases of Q_1 and Q_2 are positive and negative, respectively, the bases of Q_5 and Q_6 see a low impedance path to ground through the saturated transistors, Q_1 and Q_2. This causes Q_5 and Q_6 to be cut off, resulting in zero output. The input to the control transistors is supplied through a comparator and a Schmitt trigger. The waveshapes show the results when the input to the Schmitt trigger is in phase



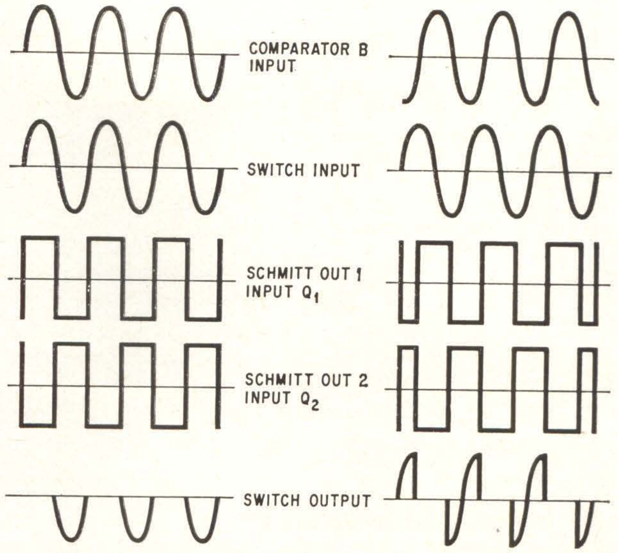
The diamond switch used to measure phase shift. Output waveshape is for 90° phase shift.

with the input to the switch, and when the input to the Schmitt trigger is phase-shifted 90° with respect to the switch input. The shape of the output of the switch is a measure of the phase difference between the input to the Schmitt trigger and the input to the switch.

A d-c zero-center ammeter, placed across the output of the switch, will read the average value of the output wave. For the two outputs shown (bottom waveshapes), the meter indicates a negative value for zero phase shift and zero for 90° phase shift. When the input to the Schmitt causes the control transistors to be on, the output of the switch is zero; and while the control transistors Q_1 and Q_2 are off, the output equals the input. Therefore, the ammeter will read some minimum value for zero phase shift, zero for 90° shift, and some maximum value for 180° shift. The output of the switch is a linear function of the phase shift. The meter can be calibrated accordingly.

To use a normal, linear scale meter, the sine wave input to the diamond switch should be converted to a square wave. This conversion is accomplished by comparator A in the circuit diagram on page 74. Comparators A and B make the switch output amplitude independent of the input signal amplitude.

In the circuit tested, the accuracy and sensitivity of the system were limited by the meter used to indicate the phase shift. The meter had a zero center scale reading with $+10\mu a$ and $-10\mu a$ full scale deflections, where $-10\mu a = 0°$, $0 = 90°$, and $+10\mu a = 180°$ phase shift. Resolution was limited by the smallest division on the meter which was $0.25\mu a$, equivalent to 2.15° phase shift.



The waveshapes for 0° phase shift (left) and 90° phase shift (right) between the input to the Schmitt trigger and the diamond switch

Reference:

1. R.H. Baker, M.I.T. Lincoln Lab, Lexington, Mass., "The Diamond Circuit," 1963 International Solid-State Circuits Conference, Feb. 1963.

Tunnel diode multi recovers quickly

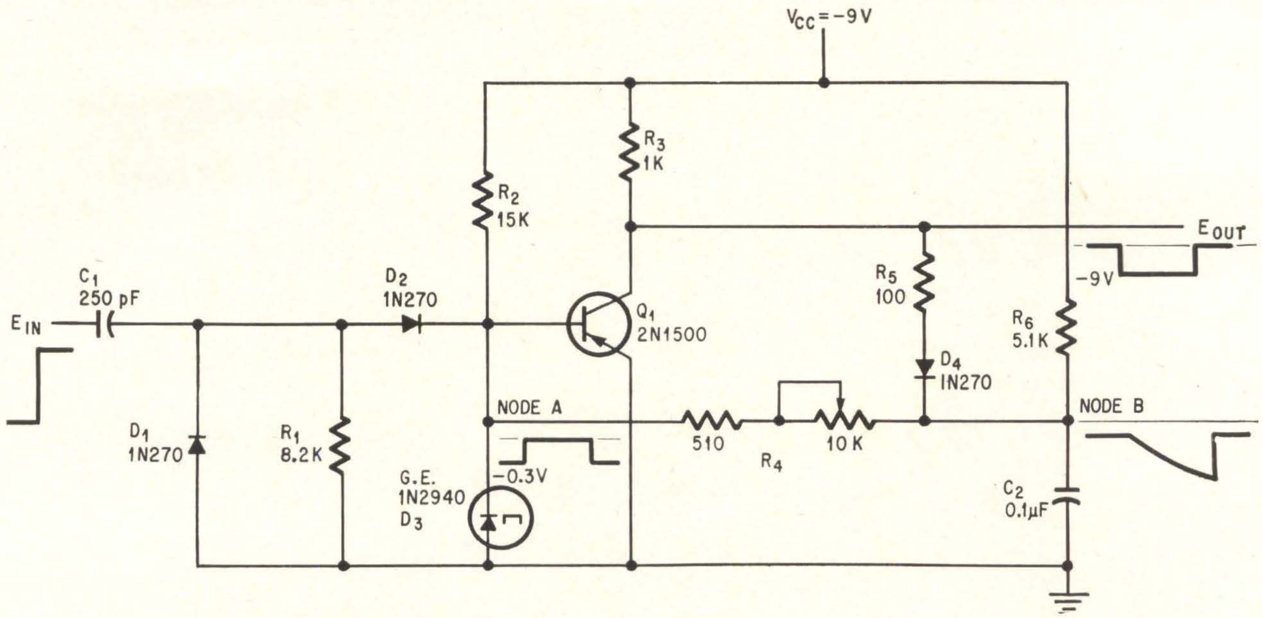
By Paul Heffner

Goddard Space Flight Center,
National Aeronautic and Space Administration,
Greenbelt, Md.

This monostable multivibrator employing a tunnel diode has the following advantages over monostable circuits with two active devices: 1) a greater duty cycle (0.90); 2) a faster output rise time as transition from the quasi-stable to the stable state takes place, and 3) the ability to vary the time delay continuously by a proportion greater than 100-to-1. The rise time at termination of the delay period is independent of the delay time or the value of capacitance chosen to determine the delay. Instead, the rise time is a function of the tunneling process in the tunnel diode and the switching time of a common-emitter transistor switch. The time delay may be varied continuously over a large range because the transistor bias current remains essentially constant, regardless of the value of resistance used to establish the delay time.

The tunnel diode across the base and emitter of a transistor switch acts as a current-controlled threshold detector. The supply of current to the tunnel diode depends upon the potential impressed across timing capacitor, C_2. Before an input to the circuit is received, the capacitor is uncharged, the tunnel diode is held at a high voltage by a fixed bias current, and the transistor switch is on and kept on by the tunnel diode and a base bias current. When an input is applied to the circuit, the tunnel diode is switched to its low-voltage state, turning off the transistor. While the transistor is off, the timing capacitor C_2 is allowed to charge until the potential across the capacitor delivers enough current to the tunnel diode to switch the diode back into its high-voltage state, turning the transistor on, thus terminating the monostable period of the multivibrator.

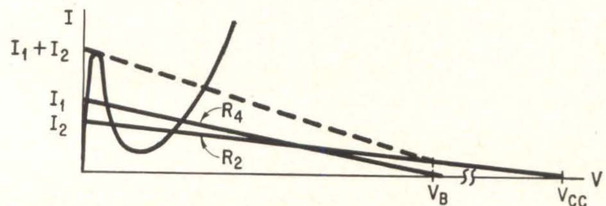
In the steady-state condition, the tunnel diode is in the high-voltage region of its characteristic, and Q_1 is saturated. The value of R_2 is so chosen that it is small enough to supply the current necessary to maintain both the tunnel diode and Q_1 in this condition. But, when the tunnel diode is switched to the low-voltage region, the value of R_2 must be large enough to prevent the peak current that switches the tunnel diode back to the high-voltage state. The collector of Q_1 will be at ground



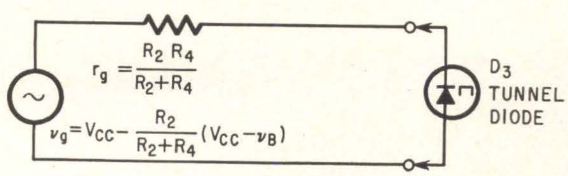
Tunnel diode monostable multivibrator

potential since Q_1 is saturated. The voltage across the capacitor at node B will be the sum of the saturation voltage drop across Q_1, the drop across R_5 and the forward-voltage drop across D_4. Resistor R_6 provides the current path necessary to maintain this initial voltage at node B.

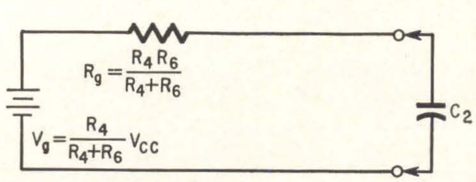
The application of a positive step voltage at the input to the circuit provides a positive differentiated pulse to the tunnel diode which switches it to the low-voltage state, turning Q_1 off. The duration of the quasi-stable state of the monostable multivibrator is governed by R_2, R_4, R_6, and C_2. With D_4 back biased and presenting a high impedance to node B, capacitor C_2 begins to charge. Two superimposed currents, one from V_{cc} through R_2 and one from the voltage at node B through R_4 (fixed resistor of 510 ohms in series with the variable 10,000 ohm resistor) contribute to the switching of tunnel diode D_3. The current through R_2 is insufficient to supply the necessary switching current to D_3. The current through R_4 increases proportionally with the voltage across capacitor C_2 until the sum of the two currents reaches the peak current value for D_3. The tunneling process is initiated and the diode switches to the high-voltage state. Since the voltage across D_3 is impressed across the base-to-emitter junction of Q_1, the transistor switches to its saturated state, terminating the quasi-stable state of the multivibrator. Capacitor C_2 then discharges through the low impedance of the now forward-biased diode D_4, the current limiting resistor R_5, and saturated Q_1, quickly establishing the steady-state condition necessary before a new quasi-stable period can be initiated. This provides the high duty cycle ability of the multivibrator.



Tunnel diode characteristic curve and superposition of contributing currents



Equivalent circuit seen by tunnel diode



Equivalent circuit seen by C_2

The tunnel diode characteristic curve and the manner in which the two currents are superimposed is shown at left. The current I_1 is governed by R_4 and the voltage across the capacitor at node B. The current I_2 is contributed through resistor R_2 and is nearly constant, regardless of the state of D_3. The algebraic sum of the two load lines is shown by the dotted line. In this illustration, the peak current has been reached so that the tunnel diode would switch through the negative resistance region into the high-voltage region. The quasi-stable period may be controlled by R_4 and C_2.

To determine the delay time as a function of circuit parameters consider the Thevenin equivalent circuit seen by the tunnel diode, D_3. During the quasi-stable state, transistor Q_1 will be off and the tunnel diode will be in the low-voltage state.

The high impedance seen looking into the base of transistor Q_1 and the high impedance seen looking into back-biased diode D_4 is neglected. The instantaneous voltage at node B is denoted by v_B.

Because $r_g >> R_{D3}$, the current delivered to the tunnel diode during the quasi-stable period can be expressed as:

$$i_{D3} = \frac{V_g}{R_g} = \frac{V_{cc}(R_2 + R_4) - R_2(V_{cc} - v_B)}{R_2 R_4} \qquad (1)$$

The tunnel diode will switch into its high-voltage region when the input current to D_3 reaches the peak current value, I_p, of the diode. Expressing the voltage at node B when transition takes place, as V_B, and expressing it in terms of I_p gives

$$V_B = R_4 I_p - \left(\frac{R_4}{R_2}\right) V_{cc} \qquad (2)$$

The equivalent source driving the capacitor during the quasi-stable period at node B is shown on page 76. The circuit neglects the impedence of the tunnel diode since $R_{D3} << R_g$. An initial voltage, V_i, is impressed across C_2 before the delay period begins and can be expressed as:

$$V_i = V_{SAT} + \frac{R_5}{R_5 + R_6} V_{cc} + V_{D4} \qquad (3)$$

where V_{SAT} = saturation-voltage drop across Q_1
V_{D4} = forward-voltage drop across D_4.

During the quasi-stable period v_B is:

$$v_B = V_i + (V_g - V_i)(1 - e^{-t/R_g C_2}) \qquad (4)$$

When $v_B = V_B$, $t = \Delta T$, and the delay period ends. Equating relations 2 and 4 and expressing the result as a function of the quasi-stable period, the delay time ΔT, in terms of the circuit parameters:

$$\Delta T = R_g C_2 \ln \frac{V_g - V_i}{V_g + \frac{R_4}{R_6} V_{cc} - R_4 I_p} \qquad (5)$$

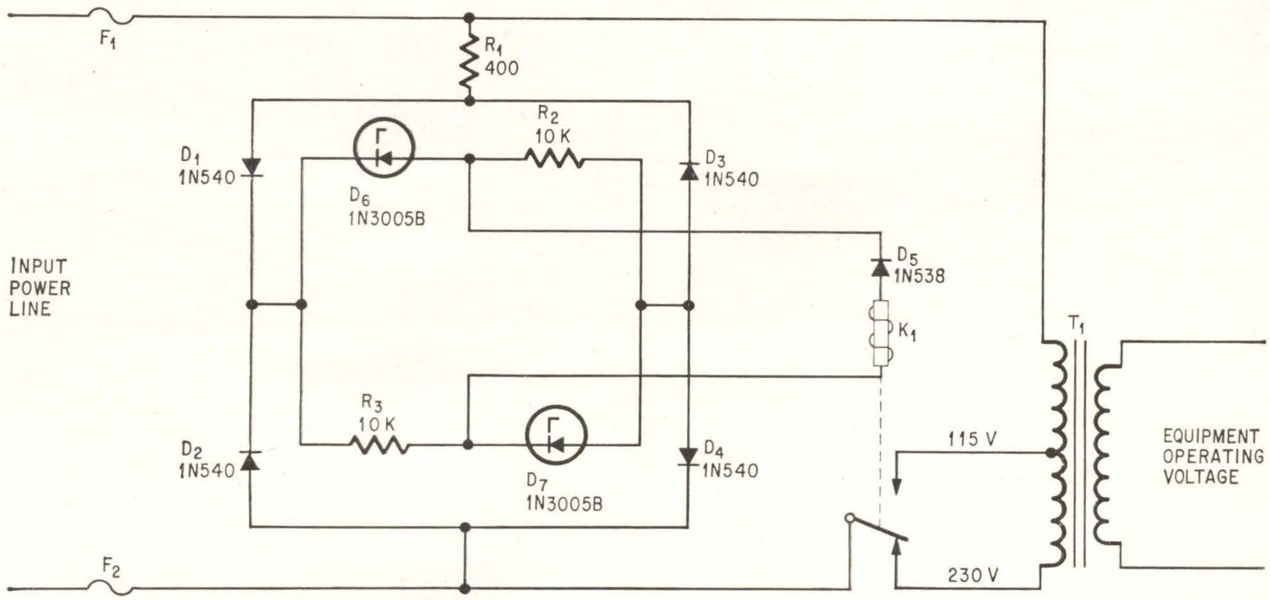
Circuit always applies correct operating voltage

By Lando K. Moyer
Bedminster, Pa.

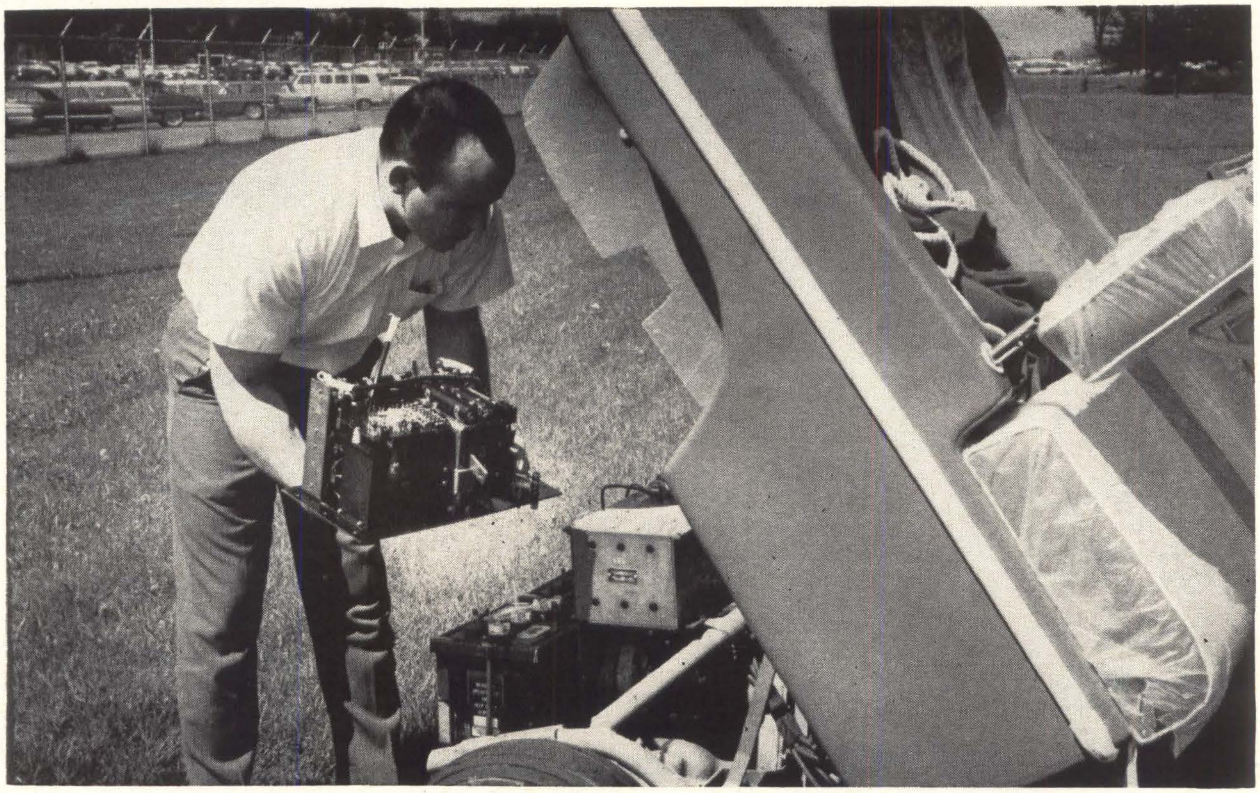
The simple, inexpensive circuit below can be used to prevent the accidental application of the wrong voltage to equipment, when both a 230-volt and 115-volt power line are available. The output of a bridge rectifier feeds a zener diode-resistor bridge having a relay across it. When 230 volts are applied to the input, the voltage developed across the zener diodes and resistors back-biases diode D_5, preventing the relay from being energized. This connects the input voltage to the 230-v terminal of transformer T_1. When 115 volts are applied at the input terminals, the voltage developed across the zener diodes and resistors will cause the diode, D_5, to conduct. The relay becomes energized, connecting the input voltage to the 115-v terminal of the transformer.

The values of R_2 and R_3 and the relay sensitivity determine the actual voltage which energizes the relay. The transformer is selected on the basis of the voltage and power required to operate the equipment. If any components short or open (except D_6 and D_7), the input remains connected to the 230-volt terminal.

Developed in association with American Electronic Laboratories, Inc., Colmar, Pa.



Relay senses supply voltage and connects input line to proper transformer terminal.



Industrial electronics

The widening world of the scr

Silicon controlled rectifiers are finding many new uses, from powering golf carts to controlling steel mills

By John C. Hey

General Electric Co., Rectifier Components Dept.

At an iron mine in the Mesabi range in Minnesota, a huge shovel gulps tons of earth at a time. On a manicured golf course in Georgia, a golf cart quietly follows a straight-line route to the spot where a ball landed after its arced flight from the tee.

In both machines, the power—10,000 watts for the shovel and 1,200 watts for the cart—is controlled by a device about the size of a sparkplug. The device is a silicon controlled rectifier, and it's finding its way into new fields almost daily—in industry, transportation and building services.

Like silicon diodes, their immediate predecessors, scr's regularly handle thousands of watts of power in the 400-ampere range. They're available with blocking voltages of above a kilovolt.

Steel and paper

In Porter County, Ind., the Bethlehem Steel Co. is building a computer-controlled mill to produce 80-inch-wide strips of steel for automobiles and railroad cars. The drive machinery for all the steel-handling equipment will be powered by compact, scr controllers with a capacity said to exceed 63 million watts.

The papermaking industry also has been invaded. In Snodland, England, C. Townsend Hooke, Ltd., is using an scr system to control a machine that rolls out 1,000 feet of paper, 144 inches wide, every minute (Electronics, June 29, p. 42).

For both industries—as well as in cement plants, lighting installations and other uses—the scr power-control elements include voltage regulators, static inverter-frequency changers and adjustable-speed drives for a-c and d-c machines.

On the golf course

An scr application in a battery-vehicle controller is the golf cart. This vehicle uses a controller similar to a fork-lift truck's—designed to operate for 100 holes between battery chargings—more than double the normal 36-hole expectancy.

The speed of a d-c series motor can be varied efficiently by chopping the d-c voltage delivered to it at either a constant pulse width and variable frequency (frequency modulation) or at constant frequency and variable pulse width. To chop the d-c suitably, a fast-acting switch is needed, one that is able to handle sizable amounts of power. The scr is an excellent choice.

In the power circuit of a controller for a battery-powered vehicle (right), when the main scr is triggered, voltage is applied to the load and to the transformer. The voltage at the transformer secondary charges the commutation capacitor. The pump-up diode holds the capacitor charge until the auxiliary, or commutating, scr is triggered. When the auxiliary scr is triggered, the capacitor voltage is placed directly across the main scr. This reverse bias turns it off. The load current transfers to the auxiliary scr and the capacitor is provided with a discharge path.

When the capacitor is charged to a peak (opposite to that shown), the current attempts to reverse, cutting off the auxiliary scr. Voltage is now removed from the load, and the "off" period continues until the main scr is triggered again.

Although the main scr must be capable of handling full-rated motor current (called stalled armature current), the auxiliary scr and pump-up diode can have much lower current capacity because they conduct current pulses for only a relatively small fraction of a cycle.

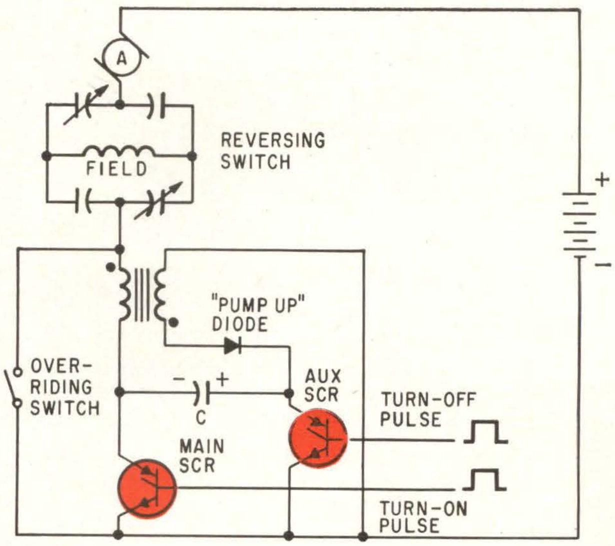
A light approach

Mechanical moving components are susceptible to wear and tear. Replacing them with a solid-state device increases their lifetime and eliminates contact bounce. The schematic in the middle of page 80 is one such approach, using a light-activated scr (Lascr).

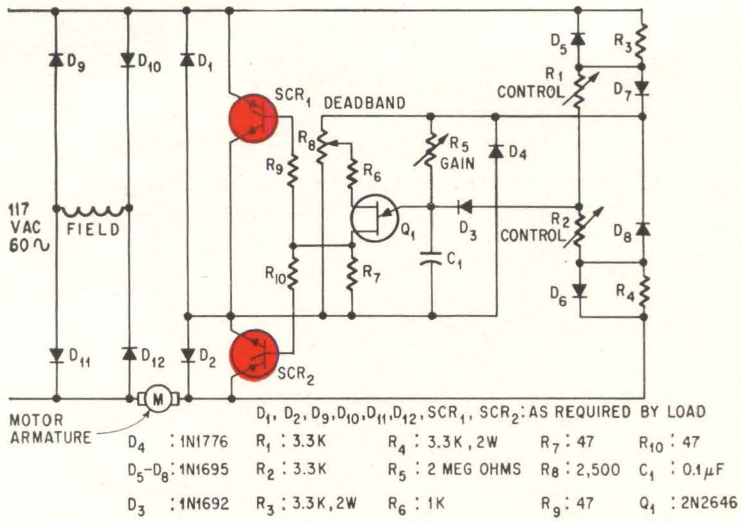
The Lascr is identical to an scr, except that there are two ways of triggering it (Electronics, May 4, p. 53). Current can be delivered to the gate terminal, or a light beam can be flashed on a light-sensitive part of the semiconductor pellet.

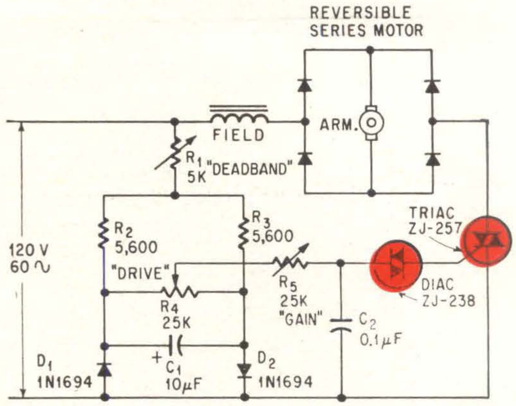
When light is the actuator, the power-handling and actuation circuits are electrically isolated in much the same way as if a mechanical relay were used. With this approach, switching is usually faster and triggering is usually more sensitive.

When an activating signal is applied to terminals 1 and 2, the lamp—operating at a reduced voltage—provides enough light to trigger the Lascr.

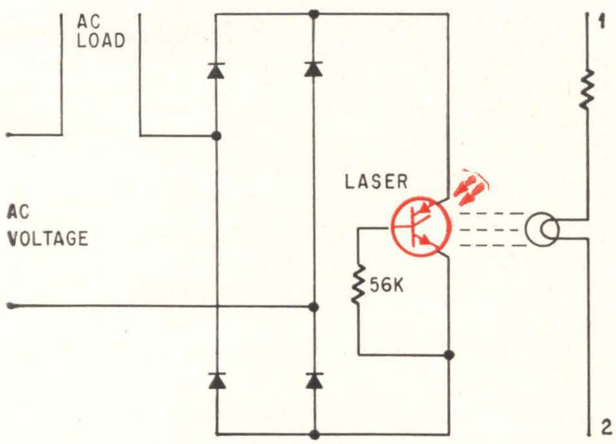


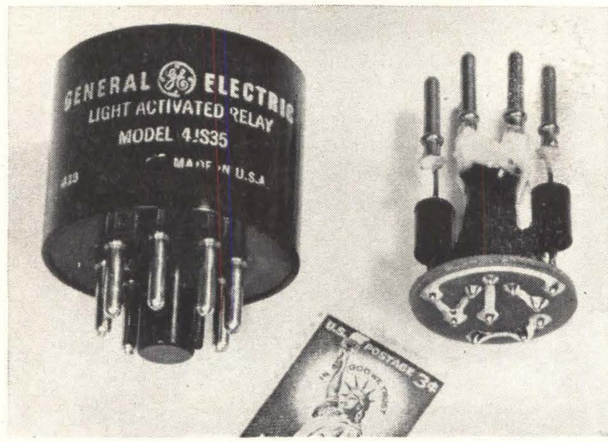
The name's the same, whether the scr controller is used in the golf cart at the beginning of this article, or in the fork-lift truck above. Below is a speed-controller circuit with main scr turn-off controlled by the auxiliary scr (both in color).





Best-known use of scr's is in adjustable speed drives for d-c motors. At left is a typical circuit of a reversing drive for a a shunt-wound motor (reversing the direction of rotation of the motor). The unijunction determine transistor and which scr (in color) conducts controlling pots R_1 and R_2. At right is a reversing drive for a series d-c motors but instead of scr's, a Triac (color) is the power controller with a Diac (color) as the triggering device.





A light approach for a relay circuit replaces a mechanical relay with the light-activated silicon controlled rectifier (Lascr) shown in color. Besides increasing trouble-free operating time and eliminating contact bounce, this approach usually increases switching speed and triggering sensitivity. On the right is a plug-in Lascr that uses the circuit at the left.

The photo, above right, shows a plug-in light-activated relay that uses the circuit described.

Reversing drives for d-c motors

One of the largest fields for scr's is adjustable-speed drives for d-c motors. Many applications call for reversing the direction of motor rotation by reversing the polarity of the voltage applied to the armature or the field winding. A half-wave reversing drive for a d-c shunt motor is shown in the upper left schematic above.

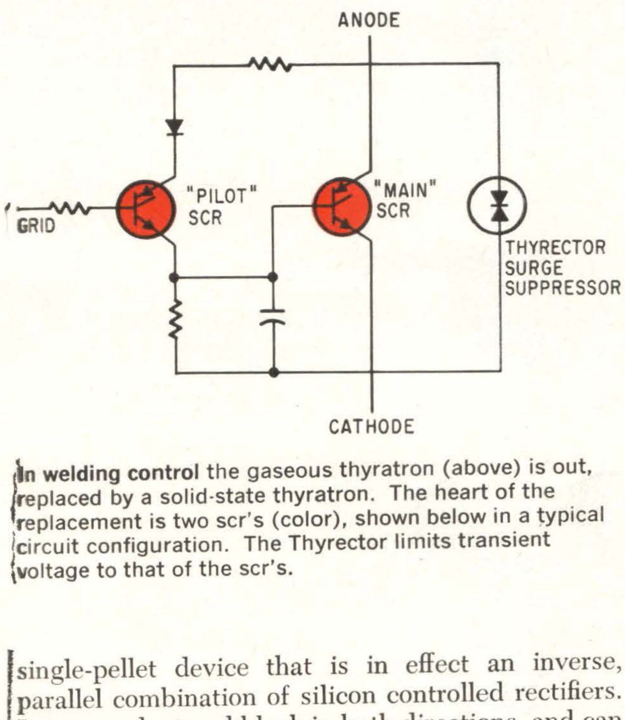
The trigger circuits are designed so that the unijunction transistor will not conduct on both half-cycles of the a-c line voltage for a given setting of the controlling elements, R_1 and R_2.

During the half-cycle in which pulses are being delivered to both scr's, only one is forward-biased so it can conduct. If scr_1 is forward-biased, during the triggering half-cycles the half-wave voltage can be delivered to the motor armature via scr_1 and D_1. If the control uses scr_2 voltages of opposite polarity are delivered via D_2.

Potentiometer R_8 sets the minimum speed of the motor. Variable resistor R_5 sets the circuit gain. A full-wave rectified d-c voltage is applied to the field winding.

The top right schematic shows a simple approach to a reversing drive for d-c series motors. A constant voltage polarity is applied to the armature; the field winding sees a reversible half-wave voltage. Here, rather than scr's, a Triac is the power controller with a Diac as the triggering device.

The Triac (for tri-lead a-c switch) is the latest addition to the power-semiconductor field. It is a



In welding control the gaseous thyratron (above) is out, replaced by a solid-state thyratron. The heart of the replacement is two scr's (color), shown below in a typical circuit configuration. The Thyrector limits transient voltage to that of the scr's.

single-pellet device that is in effect an inverse, parallel combination of silicon controlled rectifiers. It can conduct and block in both directions, and can be triggered into conducting in either direction with a positive or negative gate current signal. The Triac is commutated with inverse voltage in a manner similar to that used with inverse parallel scr's.

Where you find a Triac, you'll often find a Diac (for diode a-c switch) nearby. This triggering device couples a discharge pulse from a capacitor to the Triac gate. The Diac is a two-lead a-c switch that breaks over, or conducts, at about 35 volts and then switches to some lower voltage. The Diac, like the Triac, is symmetrical—that is, it switches in both directions.

The sensing element is R_4; deadband and gain are determined by R_1 and R_5 respectively.

This drive can just as easily be controlled automatically by transducers instead of manually operated potentiometers and variable resistors. Photoresistors, thermistors, even strain-sensing elements can be substituted

The solid thyratron

Gaseous thyratrons, in a given application, can be replaced by a semi-conductor assembly designed for direct plug-in substitution. This substitute is not universably applicable. Each application must be considered separately.

A solid-state thyratron offers the following advantages over gaseous types:

- Reliability and long life because there is no inherent "wear-out" mechanism. This means less down-time and lower inventories of spare parts.
- Absence of filament and heater means a saving in power; less heat is dissipated in the package; the operation is instantaneous, with no warmup needed.
- Rugged construction.
- Higher efficiency with less heat dissipated because of lower operating voltage.

A typical solid-state thyratron's circuitry is at the left. The heart of the thyratron is a power-switching scr. To achieve a gate sensitivity comparable to gas-filled thyratrons a pilot scr—a highly sensitive, low-current type—is used in this circuit. When a signal is applied to the pilot scr gate (analogous to the grid of a gas thyratron), it switches into conduction, providing gate current to the main scr. When the main scr switches into its conduction state, the voltage on the pilot scr is removed, turning it off.

The grid resistor provides a stabilizing gate bias for the pilot scr when the grid has a negative potential. When the line is positive, the pilot scr draws a maximum current of about 200 microamperes, triggering the pilot scr into conduction.

The over-all current handled by the main scr is determined by the pilot scr, a feature that allows this solid-state thyratron to be used in controlling highly inductive loads.

The diode in the anode lead of the pilot scr prevents a transistor type of reaction in the pilot scr when a positive grid voltage coincides with a negative anode voltage.

A thyrector surge-suppressor limits transient voltages to the voltage ratings of the pilot and main silicon controlled rectifiers used.

The photo above on the left shows a maintenance man comparing the solid-state thyratron, which

The author

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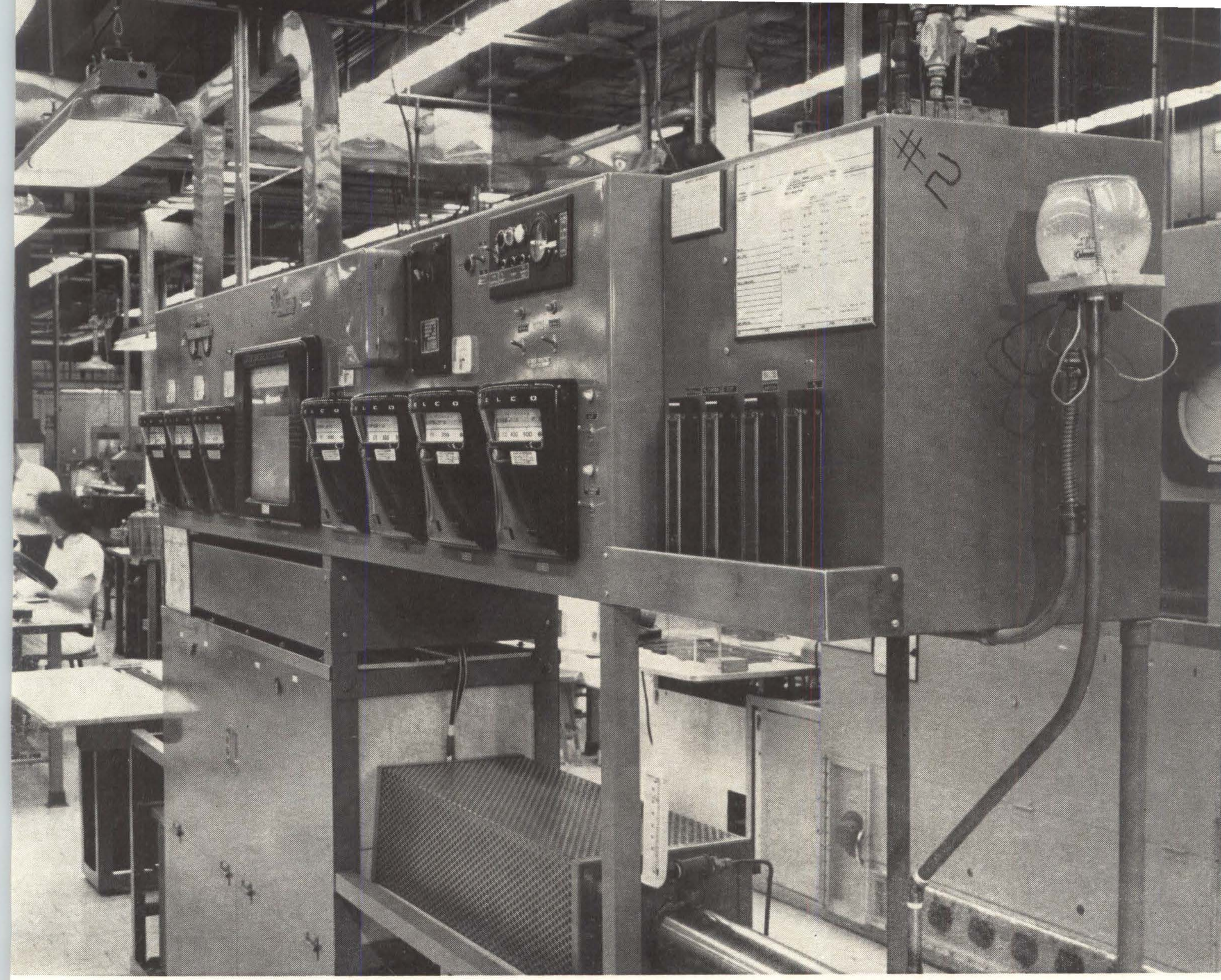


Evolution of an idea

In September, 1956, the Proceedings of the Institute of Radio Engineers published a paper entitled "PNPN transistor switches." The reaction of the electronics industry was decidedly below the furor level.

That article, by four engineers at the Bell Telephone Laboratories, led—via labs of the General Electric Co.—to the silicon controlled rectifier. Last year, scr sales nationally totaled about $20 million.

The IRE article described work on small devices such as signal transistors. But at General Electric, the article stirred visions of cheap, reliable control of power for industrial uses.

R. A. York, manager of engineering at GE's rectifier plant in Clyde, N. Y., set out to find out whether Bell's "transistor switches" might be used to control large amounts of electric power. His research staff consisted of young men, all under 40 years of age, but all veterans in the infant semiconductor business.

One of these bright young engineers, Gordon Hall, came up in 1957 with the three-lead silicon controlled rectifier. The Bell article had described a device with only two leads, a cathode and an anode, and suggested three leads. Hall's third lead proved that the Bell idea was practical for power-handling.

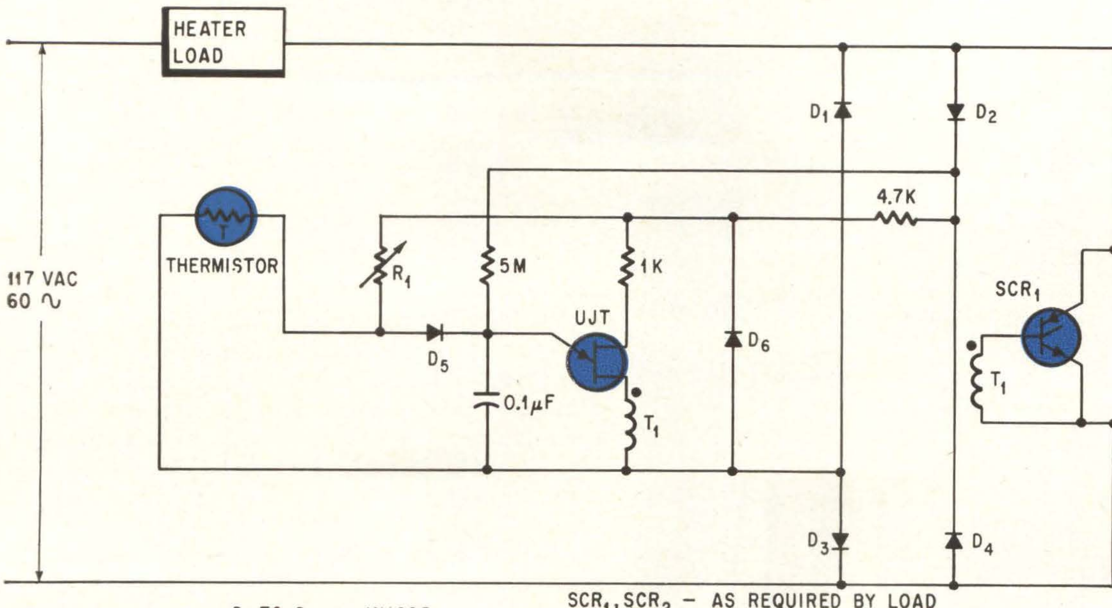
The switching device had been achieved. But there still remained the problem of finding a practical way to use it. This task was given to another GE project engineer, F. W. Gutzwiller, then 30 years old.

Gutzwiller's first move was to the local hardware store. He bought a six-volt windshield fan used in automobiles. Recently he recalled the breadboard demonstration that followed. He said, "With the fan and the scr I whomped together a phase control to vary the speed of this fan by the use of the "scr".

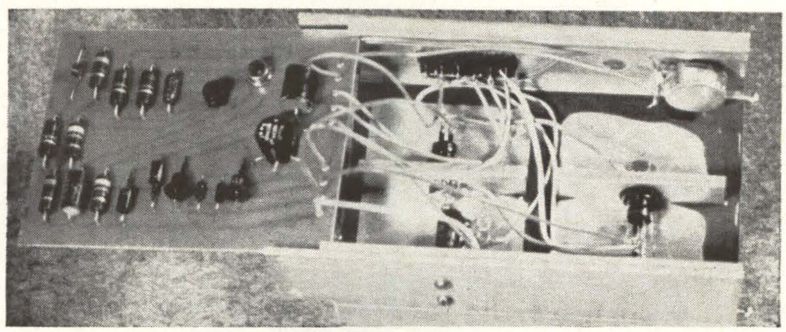
After Hall and Gutzwiller demonstrated that their new device could control motor speeds, it was clear that a solid-state equivalent of the thyratron tube had been built, and that the device had vast potential in industrial control.

GE was lavish with development funds. More engineers were employed to develop products and find new applications.

The growing acceptance of the scr in industry indicates that all the efforts were worthwhile.



Temperature control is one of the largest potential field for scr's. The seven-zone tunnel oven (right) for making semiconductors is one example. In the circuit above, the thermistor (color) senses load temperature. As the temperature rises, thermistor resistance falls, causing the unijunction transistor (color) to trigger, firing the scr's (color) that deliver the required power to the load. At the right is a typical scr temperature-controller assembly with the cover removed.



he's holding, with the gaseous version that is to be replaced.

Temperature controllers

Scr's are even used to promulgate their own species. The General Electric Co.'s rectifier components department in Auburn, N. Y., uses a tunnel oven for making semiconductors including scr's. The oven's seven different temperature zones are under precise scr control.

The temperature controller is a closed-loop system. A sensor measures temperature of the heater load and controls the powder-delivering scr's.

Temperature control is an area where scr's are especially applicable. In the schematic above, the thermistor has a negative temperature coefficient; as the temperature goes up the resistance goes down, and visa versa. As the load temperature increases, thermistor resistance decreases, causing the uninjunction transistor to be triggered later in the line voltage cycle, controlling the scr's that deliver load power. As the load cools the opposite occurs.

In this design, a milliwatt thermistor controls either medium- or high-current scr's that deliver thousands of watts of power. The photos above show a 1,000-watt temperature controller ready to be installed on page 82 is a tunnel oven used in the manufacturing of semiconductors.

Speed controllers for a-c motors

One of the most maintenance-free motors in industrial use is the three-phase squirrel-cage induction motor. It have no brushes or slip rings. On the other hand, it is somewhat difficult to control the speed of an a-c motor, particularly if wide range and smooth variability are required.

Other than pole-changing methods that provide only a few discrete operating speeds, there are two primary methods of varying the speed of an a-c motor. Both use a motor-driving voltage. Either a constant volt-second variable frequency or a variable voltage constant-frequency drive can be used.

The cost of the variable-frequency approach is somewhat higher than that of the variable-voltage approach.

constant-frequency approach.

Due to the complex nature of a motor load, the problem of speed control can only be attached from the system standpoint—controller plus motor load. Each approach has some advantages and disadvantages.

Variable frequency—complex, but . . .

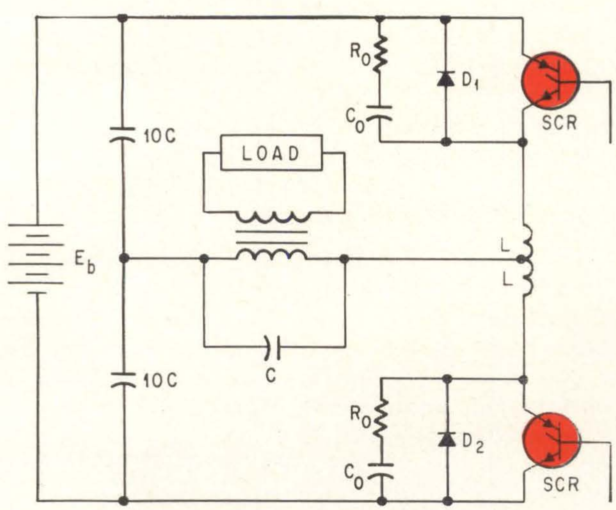
The constant-frequency approach is simpler than the variable-frequency. It is seldom more than a sophisticated three-phase controller with tachometer feedback for improved torque at low speed. The variable-frequency approach requires, in addition to a frequency changer (rectifier and inverter), some way to vary voltage with frequency to keep the volt-seconds delivered to the motor constant. But once this is done, the controller has some desirable features:

- Relatively high efficiency at low speed.
- Independence of power-line frequency, except in the rectifier filter.
- Ability to operate from a d-c voltage source.
- Ability to operate at speeds above 3,600 revolutions per minute.
- Capability of multiple operation in synchronism.

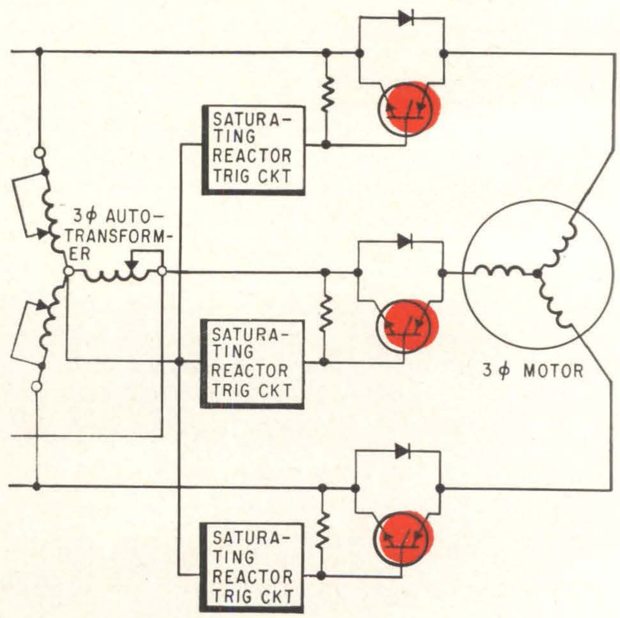
Constant frequency—simple, but . . .

The variable-voltage, constant-frequency approach is simple, but slip losses can be high at slow speeds. Also, this approach requires large machines with more cooling than the variable-frequency method.

The variable-voltage, constant-frequency approach is shown on page 85. Triggering is achieved magnetically, using saturating reactors (transform-



Bringing more light to the subject, a prototype high-frequency (10kc) inverter is for use in a fluorescent lighting system. This new device uses high-speed scr's to deliver 15,000 watts to the fluorescent lamp tepee. Turn-off time of the scr's (both in color), determined by the resonant frequency of C and L, is about 10 to 12 microseconds.



ers). The trigger circuits must be designed so that the scr's are always fired at 120-degree phase intervals to insure a balanced voltage to the load. If this is not done, the load sees a d-c voltage component, which tends to brake the motor because of eddy-current effect. In other words, the reset-voltage amplitudes delivered to each of the three saturating reactors must be identical. On the right is an industrial speed control of the variable-voltage type, using saturating reactor triggering.

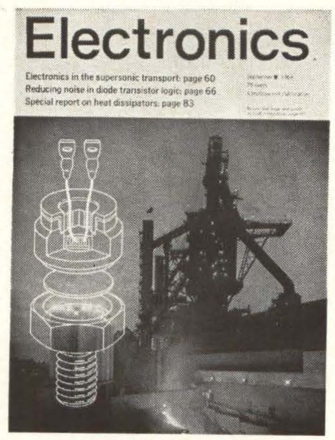
Another approach eliminates the saturating reactors in the trigger circuit, at right, p. 84. Here a pilot scr is used to trigger the load-carrying scr. After the pilot scr is triggered, it maintains trigger current for the remainder of the half-cycle, a condition that is required when the load is inductive, as in the case of an a-c motor.

High-frequency fluorescent lighting

Because of new, higher-speed scr's with improved dynamic characteristics, scr inverters can operate in the 10- to 20-kilocycle region. These can now be used to power large blocks of fluorescent lamps at high frequency in office buildings or drafting rooms, wherever large numbers of flourescent lamps are used. Operation in this frequency range results in a big increase in lamp and ballast efficiency. At the same time, ballast size is considerably reduced and lamp life is greatly extended. One such prototype system (photo, p. 84) is a 10-Kc inverter that delivers 1.5 kilowatts to a bank of flourescent tubes.

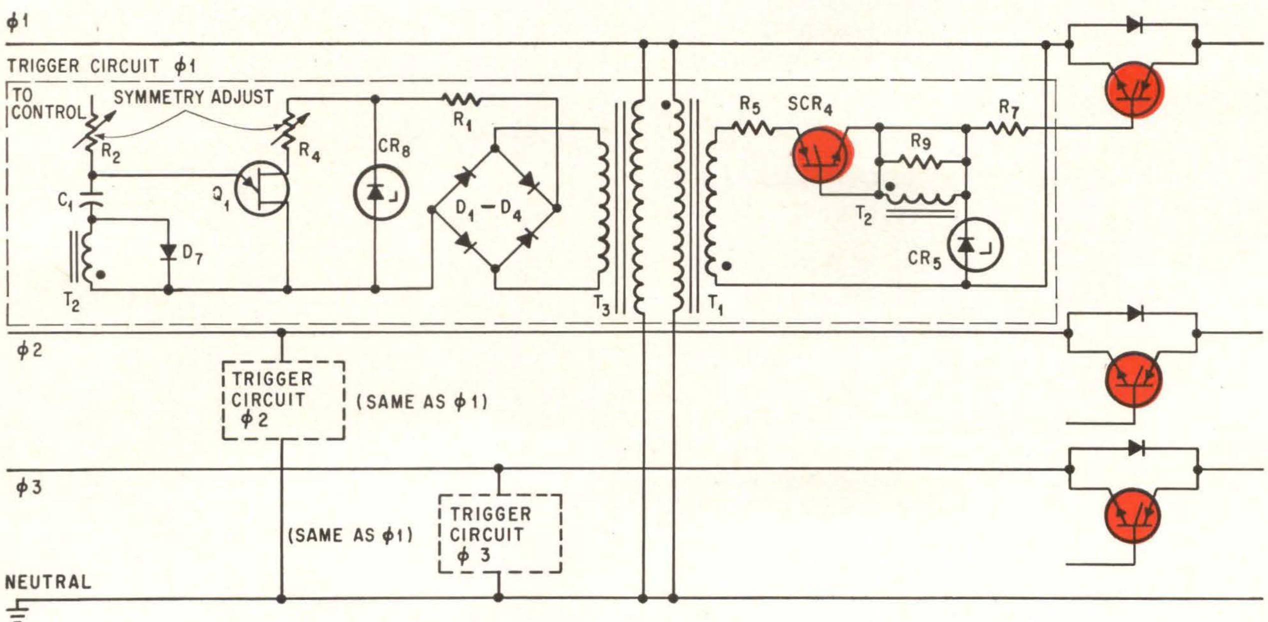
The power circuit of the inverter (bottom left, p. 84) provides sine-wave output voltage with good regulation. With the exception of scr turn-off time, dynamic stresses on the scr's are not severe. Turn-off time is determined by the resonant frequency of C and L. These in turn are determined to some degree by the desired operating frequency. These high-speed scr's can be turned off in approximately 10 to 12 microseconds within the 10- to 20-Kc region.

The circuit on the left, page 84, operates as follows: When scr_1 is triggered, current flows to the load from the d-c source through inductor L. When capacitor C has been charged to its peak voltage, current rings back through D_1 reverse-biasing the scr and turning it off. As the capacitor voltage reaches zero, scr_2 is triggered and the capacitor charges to a peak voltage of opposite polarity, again ringing back through D_2 and turning off scr_2. The cycle then repeats. Resistor R_0 and capacitor C_0 limit the rate-of-rise of forward voltage across the scr's to the amount they can tolerate without misfiring.



The cover

A silicon controlled rectifier has been superimposed on photographer Arthur d'Arazien's dramatic photograph of a steel mill to symbolize the ever-increasing use of scr's metallurgical controls.



Circuit for speed-controller section for three-phase a-c motor. The approach above uses saturating reactors (transformers) for triggering the scr's (color). At the left is another approach that eliminates the saturating reactors, replacing them with a pilot scr (color) to trigger the load-carrying scr (color).

Advanced technology

A comeback for wireless power?

An old idea and a new technology give promise of a new and prosperous life for the microwave industry

By George V. Novotny
Advanced Technology Editor

Transmitting power without wires, cooking steaks from the inside out, powering a helicopter from the ground, and controlling tornadoes are novel applications that might not have occurred to a microwave engineer in 1940. Today, some of these are already in commercial hardware form, others will be here soon, and still more may be generations away—but all share a common basic technology.

Microwave power engineering—sometimes called electronic power, or superpower—is a new technology concerned with the generation, transmission and application of energy rather than the transmission of information, as in radar or communications microwave.

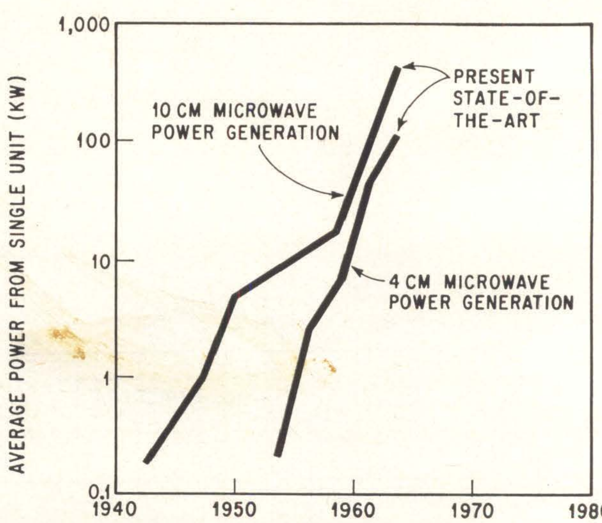
The idea of using electromagnetic radiation as power rather than as an information carrier is not new—Nikola Tesla experimented with it, unsuccessfully, at Colorado Springs in 1889—but only recently, with knowledge gained from the design of very high power radar systems, have engineers viewed this idea as a practical possibility.

A number of radically new developments will be needed, but already the work in microwave power has led to some startling advances in the whole microwave field. The designers' change of attitude from communications to power has been responsible. These days there is a good deal of discussion and speculation,[1] a moderate amount of research, and a modest resurgence of government interest and funding. In fact, as some observers see it, microwave power may mean a new and prosperous life for the microwave industry.

Three classes of applications

Three principal areas of interest are gradually emerging for microwave power. The first of these—the most intriguing and most immediate—is the transmission of small and moderate amounts of power, in the form of a free beam focused through the atmosphere or space, to hovering vehicles such as helicopters, blimps or satellites. The Air Force has recently called for bids on a feasibility contract showing that a hovering helicopter model, entirely powered from the ground by microwave beam, can be built; similar studies involving satellites have been undertaken by the National Aeronautics and Space Administration. W. C. Brown, head of the Superpower section of Raytheon's Spencer Laboratory in Burlington, Mass., says such a hovering vehicle is well within the present state of the art.

A second group of applications involves the transmission of large amounts of microwave power through waveguide. While this application seems remote it is nonetheless a challenge. In theory, the waveguide scheme could have great power-carrying capacity, and numerous advantages over overhead high-voltage transmission lines; among them, efficiency, safety, and invulnerability.



Progress in microwave power generation levels in a single unit, plotted for the two main frequencies of interest for microwave power applications.

The third group of applications uses microwave power directly, without intermediate rectification to d-c current. These involve various applications of microwave heating, such as cooking and food processing[2] [Electronics, Sept. 7, p. 111], food sterilization, and industrial melting of substances such as sulphur and tars. Some more unusual and distant nonheating applications are the destruction of swarming insects, control of tornadoes, and electronic countermeasures—all involving huge amounts of radiated microwave power.

Common hardware

No matter what the final application, microwave power engineering involves a limited number of necessary components. For the time being, such components are being developed as an extension of existing microwave hardware, but with emphasis on high power output and efficiency in continuous-wave operation. These include power generators, antennas, rectifiers and waveguide techniques.

Microwave power generators

There are several principal contenders for the function of producing large quantities of microwave power. They range from the traditional klystron tube to the somewhat revolutionary electromagnetic amplifying lens. Present power levels are in the hundreds-of-kilowatts range, and the rate at which power levels have been increasing is shown on page 86 for the frequencies of interest in power applications.

High-power klystrons

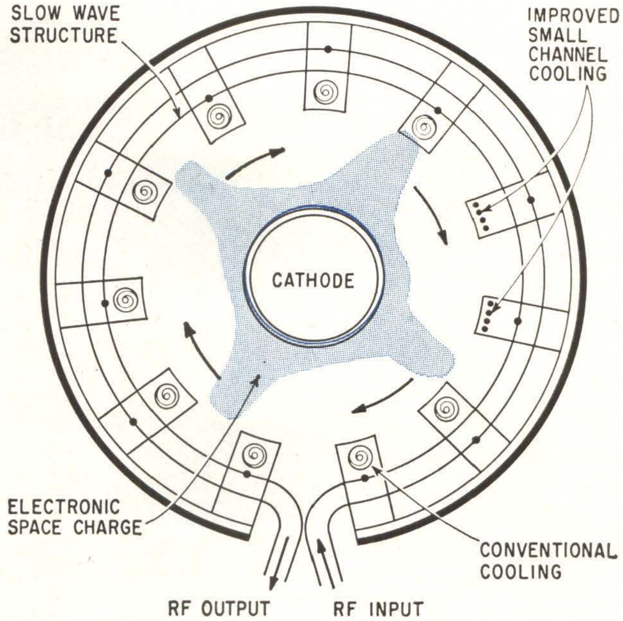
Development of the klystron tube toward higher power levels has recently led to the generation of over 200 kilowatts, continuous-wave, by a single tube at X-band frequencies, with 60% efficiency. The Eitel-McCullough, Inc. X 3030 tube has more than twice the power capability of other existing X-band devices. It uses an extended-interaction principle, which involves the lengthening of the resonant cavities to a length of several electron ballistic wavelengths.[3]

Other Eimac work in this area has been focused on a two-cavity extended-interaction klystron, the X 3028, which yielded 65% conversion efficiency in continuous-wave S-band operation (2,890 Mc) at kilowatt power levels.[4]

Superpower Amplitron

The largest microwave power generator developed to date is Raytheon's superpower Amplitron.[5] This tube uses a nonthermionic cold (water-cooled) platinum cathode, and has achieved continuous-wave operation at 400 kilowatts and 3,000 megacycles with 70% efficiency. As shown above right, the Amplitron has a continuous cathode, surrounded by a slow-wave structure and a magnetic field whose direction is normal to the plane of the figure.

The slow-wave structure carries the r-f wave and acts as a collecting surface for the electrons, which



Schematic of the Amplitron interaction region shows space-charge spokes rotating about center cathode.

are emitted from the cathode and subsequently impinge on the anode. A d-c potential is placed between the cathode and anode. As the potential is raised, electrons emitted from the cathode rotate in concentric orbits, ultimately reaching the anode. During the transit, the electrons become synchronous with the phase velocity of the r-f wave on the network. Interaction occurs, causing the electrons to coalesce into spokes of space charge, which then induce currents in the slow-wave structure. The phasing is such that reinforcement occurs in the direction of the output, while cancellation occurs toward the input.

The entire interaction mechanism is controlled by the r-f power introduced at the input terminals of the Amplitron, so that the output frequency is identical to the driving frequency.

While the Amplitron is suitable for immediate applications, such as the microwave-beam powering of hovering vehicles, its power level is not likely to be substantially increased. One reason is the window problem—the necessity for building large dielectric windows in the tube structure that can pass the microwave power without substantial loss or heat dissipation and yet act as hermetic seals for the interior vacuum. A second reason is that the relatively small size of the electron interaction area presents an upper limit to the amount of power that can be handled in the interaction region.

Electromagnetic amplifying lens

A possible candidate for the generation of power levels two or three orders of magnitude above the Amplitron's 400 kilowatts is the electromagnetic amplifying lens.[6, 7] This concept, shown in the diagram on page 88, uses a large number of waveguides symmetrically arranged with respect to the free space wave excitation, and thus excited with equal amplitude and phase; however, in the transition region between the input face and the electronic interaction region, adjacent waveguides are dimensioned to have different phase velocities. Thus, the energy from adjacent waveguides arrives at the input to the interaction region 180° out of phase.

In the interaction region, a slow-wave transverse interaction takes place between the electron stream and the r-f wave, producing a net gain. As shown in the figure below, the use of half-width waveguides establishes electric fields in the interaction region at the edges of the waveguides that face the cathode. A rotating space charge interacts with these electric fields. The half-width waveguides form resonant cavities just as vanes do in a conventional magnetron.

Although high-power tests have not been run on the electromagnetic amplifying lens, prototype measurements and calculations indicate that power levels of the order of several magawatts can be expected, with conversion efficiencies near 70%.

Microwave power rectifiers

The development of devices that rectify microwave power efficiently into direct-current power has lagged considerably behind generator development, perhaps because high-power rectifiers are not intrinsic to traditional microwave work.

Although there are a number of experimental and potential devices, the highest power level achieved so far with any efficiency is of the order of one kilowatt—several hundred times below generator output power levels. However, for hovering-vehicle applications, where over-all system efficiency tends to be low, a one-kilowatt rectifier may be all that is needed by the time the several hundred kilowatts of radiated power have undergone losses and attenuation in the transmission chain. Substantial rectifier developments will, however, be necessary to make high-power and utility applications practical.

Silicon point-contact diode

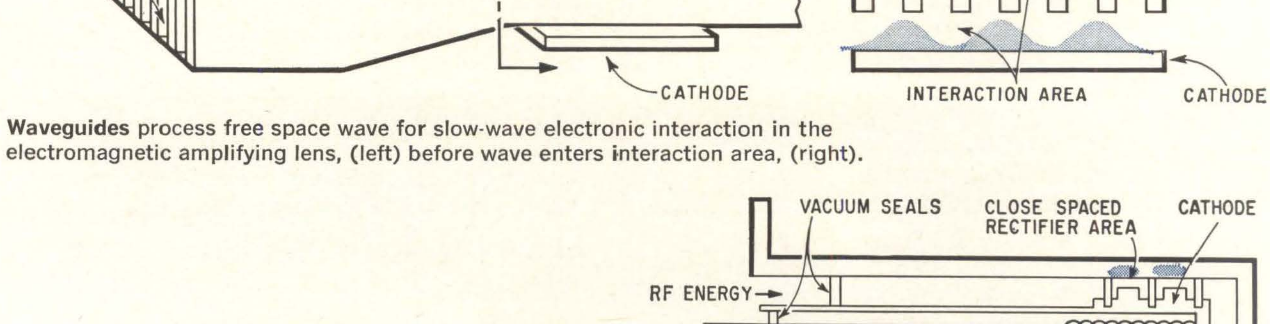
Initial development work by Prof. R. H. George and E. M. Sabbagh of Purdue University, Lafayette, Indiana, has shown that simple silicon point-contact diodes are suitable for microwave rectification. These diodes, operated in bridge configurations, have achieved efficiencies up to about 70% in the 2,440 megacycle band.

However, semiconductor point-contact diodes are intrinsically small and low-power, capable of handling no more than 50 milliwatts each, and only 10 to 20 milliwatts per diode for maximum efficiency.[8] They have been combined in large arrays, consisting of as many as 680, and their size and weight give them a favorable watts/pound figure.

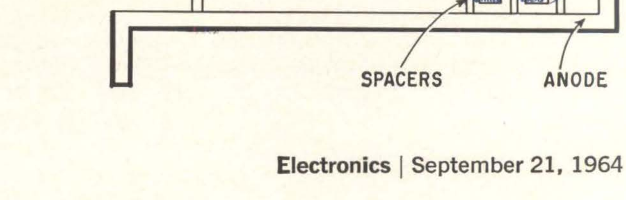
Point-contact diodes have found a very promising use in the Rectenna, a nondirectional rectifying microwave antenna, which is described later.

Close-spaced vacuum diode

The largest presently available microwave rectifier component is the close-spaced thermionic diode, shown schematically below. It is a diode vacuum tube in which the cathode-anode spacing (cylindrical configuration) is of the order of 0.010 to 0.005 inches. This device was first developed by W. H. Hayt of Purdue University, and further developed and built by W. C. Brown of Raytheon. Operating at plate voltages of the order of 1,000 volts, the tube makes use of the kinetic energy of the skin-effect loss electrons in the microwave sig-



Waveguides process free space wave for slow-wave electronic interaction in the electromagnetic amplifying lens, (left) before wave enters interaction area, (right).



Close-spaced thermionic diode by the Raytheon Co. Power-handling capacity can be increased somewhat by extending anode-cathode rectifying area.

nal to heat the thermionic cathode. It has developed power levels up to 900 watts, continuous-wave, at 55% efficiency, and has an operating Q factor of about 15.

A low-impedance device, this type of diode can be used to operate a light load such as a motor, and has been so used in W. C. Brown's demonstrations of microwave-beam power transmission.[9]

Other microwave rectifiers

Other rectifier schemes that have been studied in a preliminary way include the reverse operation of microwave tubes such as the magnetron. The most promising of these is the injected-beam crossed-field device, called the planotron or the Microfier, and developed by Raytheon. It has achieved 160 watts with an efficiency of 42%.

Preliminary work on klystrons operated as rectifiers has been done by W. H. Hayt at Purdue University and by S. P. Yu Electron Tube division of Litton Industries, Inc. According to Yu's computer simulation of the electrostatically focused klystron, the efficiency of these devices is expected to be about 54%, with a power/weight ratio of 150 watts/lb. The klystron scheme is illustrated in the diagram below.

Multipactor diode

Another potential candidate is the multipactor diode rectifier (for multiple electron impact). In a multipactor discharge, a thin electron cloud, supplied by secondary emission from the diode's two electrodes, is driven back and forth across a gap, in synchronism with an r-f field applied across the gap. The maximum electron density is determined by the secondary emission coefficients, which must be carefully designed.

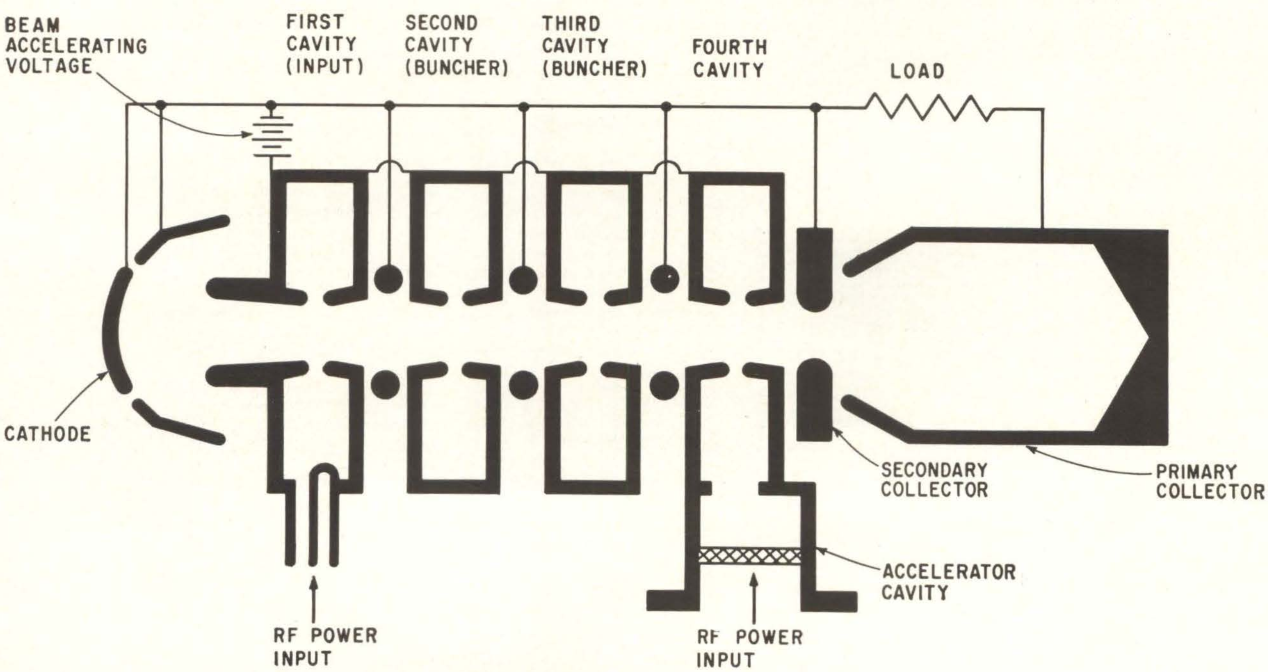
The full-wave multipactor rectifier, shown on p. 90, uses a reentrant microwave cavity with the electric fields concentrated at the center of the cavity where the secondary emitting electrodes are located. These electrons are perforated to allow some of the electrons to escape through the holes to electron collectors that constitute the negative d-c terminal. The walls of the cavity that supply the electrons form the positive d-c terminal.

Studies of the multipactor have been performed by P. P. Keenan of the Scientific Research Laboratory at Lockheed-California in Burbank. Calculated efficiencies range up to 59%, and 80% to 90% in polyphase operation.[10]

Studies have also been performed on the magnetron used as a rectifier, by W. H. Hayt of Purdue. The device delivered 25 watts at 22% efficiency. Another device is Raytheon's cyclotron rectifier, similar in operation to the classical research cyclotron machine (magnetic field causes input electrons to circulate, an electric field extracts a net unidirectional drift), developing 6 watts at 12% efficiency. These and the other crossed-field devices share the disadvantage of having to carry a heavy external magnet, which adversely affects their watts/pound ratio.

Microwave power antennas

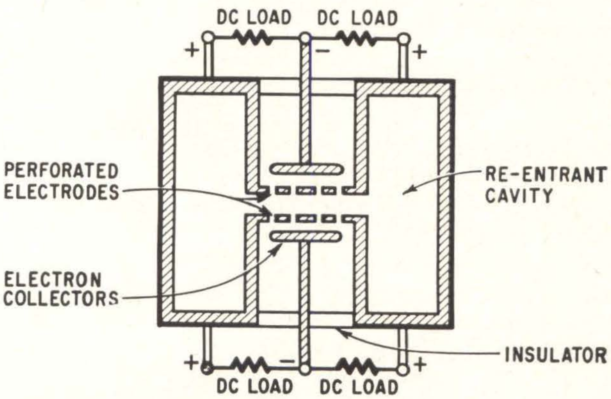
Microwave power can be radiated by beam with fairly conventional antennas, but the beam must be narrowly collimated to minimize loss by stray radiation. Horns, parabolic dishes and large, flat, multiplate antennas are all practical, depending on application. Their heavy weight, need for precise positioning and shaping is a disadvantage in schemes that involve power transmission between spaceships, for example, but are acceptable for



Electrostatically focused klystron rectifier has the advantage that no external magnet is needed as in the magnetically focused case. Tube is by Litton Industries, Inc.

transmission from the ground.

Free beam attenuation in the earth's atmosphere is neglible for wavelengths up to about 1.2 cm (K-band), providing the weather is good; in heavy rain even 3-cm wavelengths (X-band) are heavily attenuated, while 10-cm wavelengths (S-band) are not affected by the weather.



Rectifier cavity of the full-wave multipactor. Secondary electron emission is used to produce electron beam.

For the receiving antenna, the horn was until recently the best choice, and was used in the Raytheon experiments. However, in space applications a directional antenna of several hundred feet diameter would have been necessary; this was a major drawback until the invention of the Rectenna.

The Rectenna

This new concept, developed by R. H. George of Purdue,[8] together with W. C. Brown of Raytheon, combines the semiconductor point-contact diodes with an antenna, to obtain an almost nondirectional antenna that receives microwave power and delivers direct current to the output terminals.

The Rectenna is made up of a large number of small dipoles, each of which has its own small diode rectifier network. The networks are connected to d-c busses, which are combined in series-parallel.

Such an antenna could be made to any desired size and shape, and fabricated as a thin flexible sheet of plastic, to be unfurled from a satellite. Because it is not highly directional, there is no need for a rigid structure or accurate orientation; it also eliminates the need for any subsequent rectifier.

Tests conducted at Raytheon on a prototype Rectenna showed a conversion efficiency of 63.5% at 2,440 megacycles.

Waveguide power transmission

Although still far from realization, transmission of large amounts of power by buried, uninsulated waveguide is a distinct possibility. In theory, such waveguide could be extremely efficient.

According to a study by E. C. Okress of American Standard Research Laboratories,[11] an oversized circular waveguide 1.008 meters in diameter, transmitting power at 10 Gc in a high-order circular electric mode, notably the TE_{01} mode, can transmit 2,000 megawatts continuously. The capacity is equivalent to 18 parallel overhead lines, operating on three-phase, 132-Kv power. The negligible skin depth at this frequency, 6.6×10^{-5} cm, would call for only a thin copper coating inside the pipe.

Unfortunately, waveguide transmission must be maintained in a high-order mode while eliminating all other possible modes by continuous mode filtering. No work has been done yet in this field except at communication power levels.[12]

Only in recent years has emphasis been placed on studying microwave power in terms of systems rather than components. W. C. Brown of Raytheon was the first to demonstrate a system that remotely powered an electric motor; right now, Prof. D. Dunn at Stanford Electronic Laboratory is starting a project for evaluating microwave power systems.

Other microwave applications

Microwave ovens and food processors have been on the market for some years, but are only now becoming commercial possibilities. Among some other proposed uses is microwave melting in industry—the melting of underground deposits for the mining and transportation of sulphur and tar (presently, sulphur is shipped in freighters in the highly dangerous liquid form; with suitable microwave equipment it could be shipped in solid form and melted out for unloading.) Another is the use of huge amounts of microwave power to control insect swarming. This would be accomplished with frequencies whose wavelengths are of the order of the average insect's length. Still another application would check the progress of tornadoes—this application is based on a recent theory that tornadoes are a plasma phenomenon, having large electron-plasma bodies inside their funnels, about 100 feet thick and 50 feet in diameter, 900 feet above the ground. Beaming an intense microwave generator at this plasma concentration might be enough to disrupt the tornado entirely.

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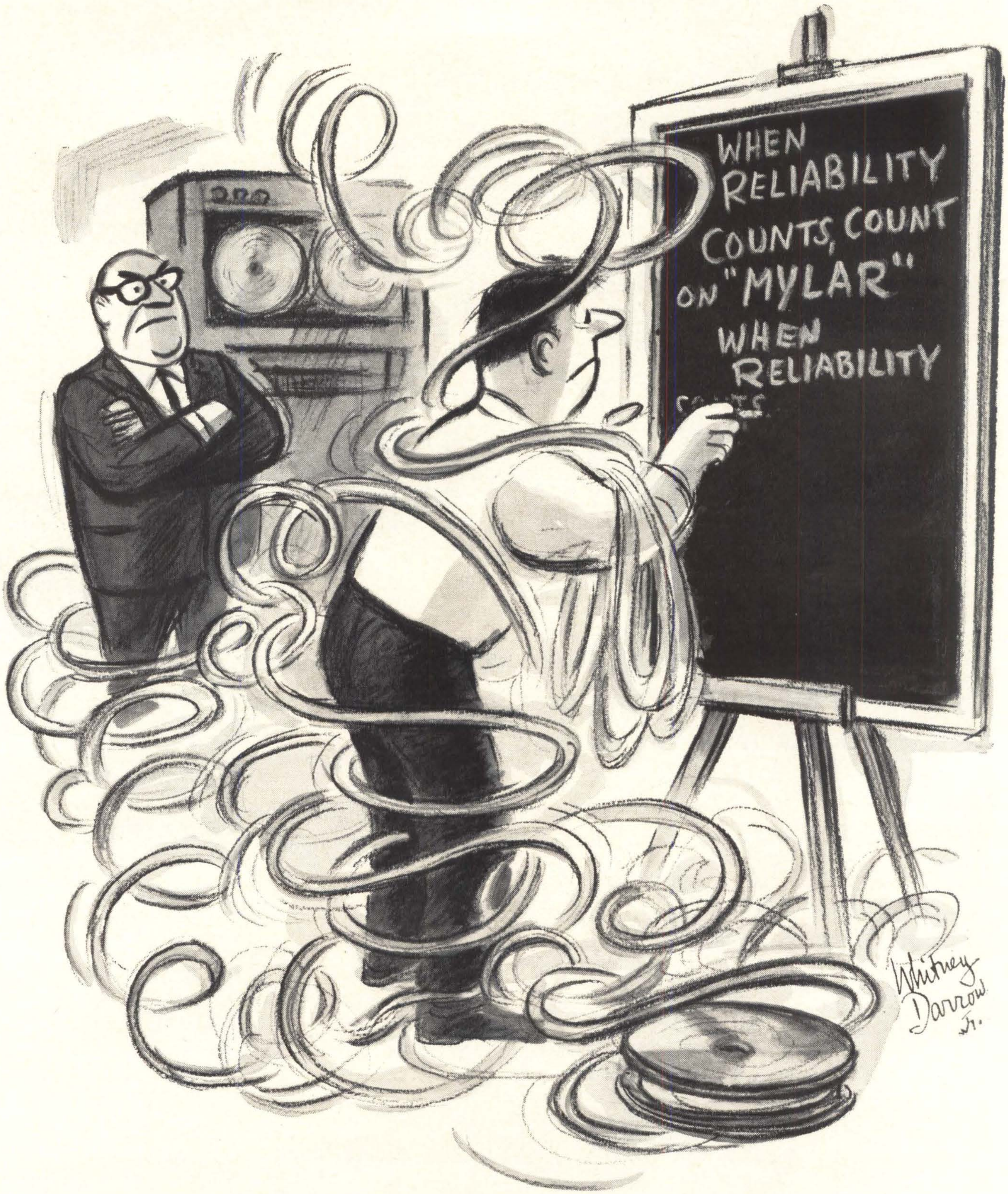

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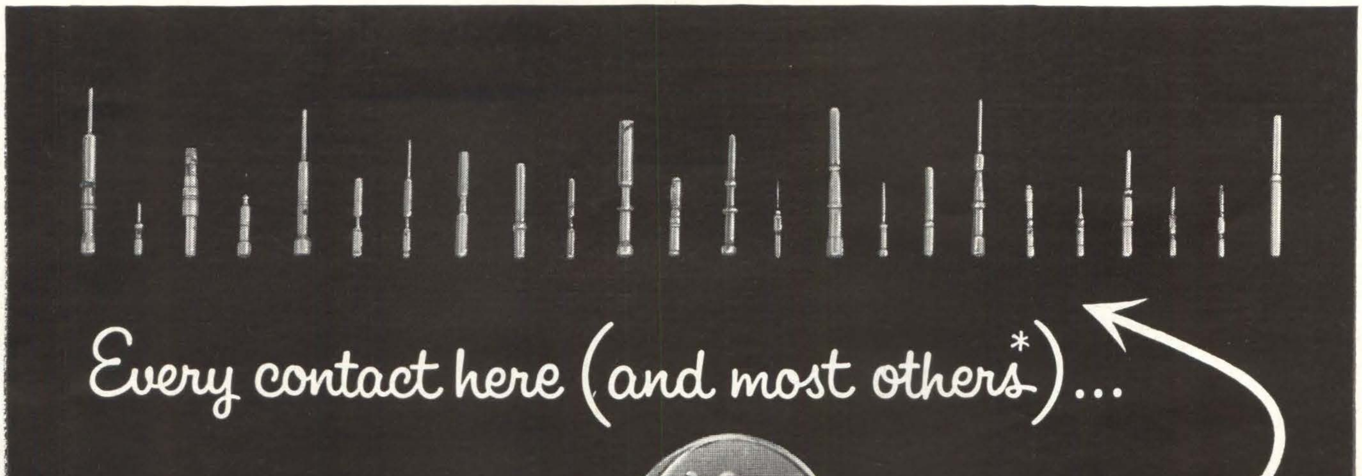

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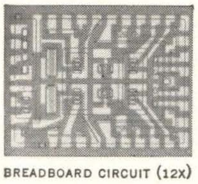

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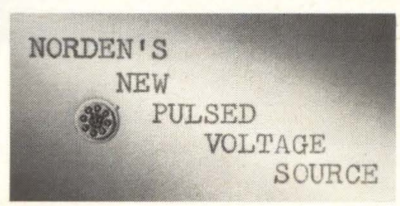

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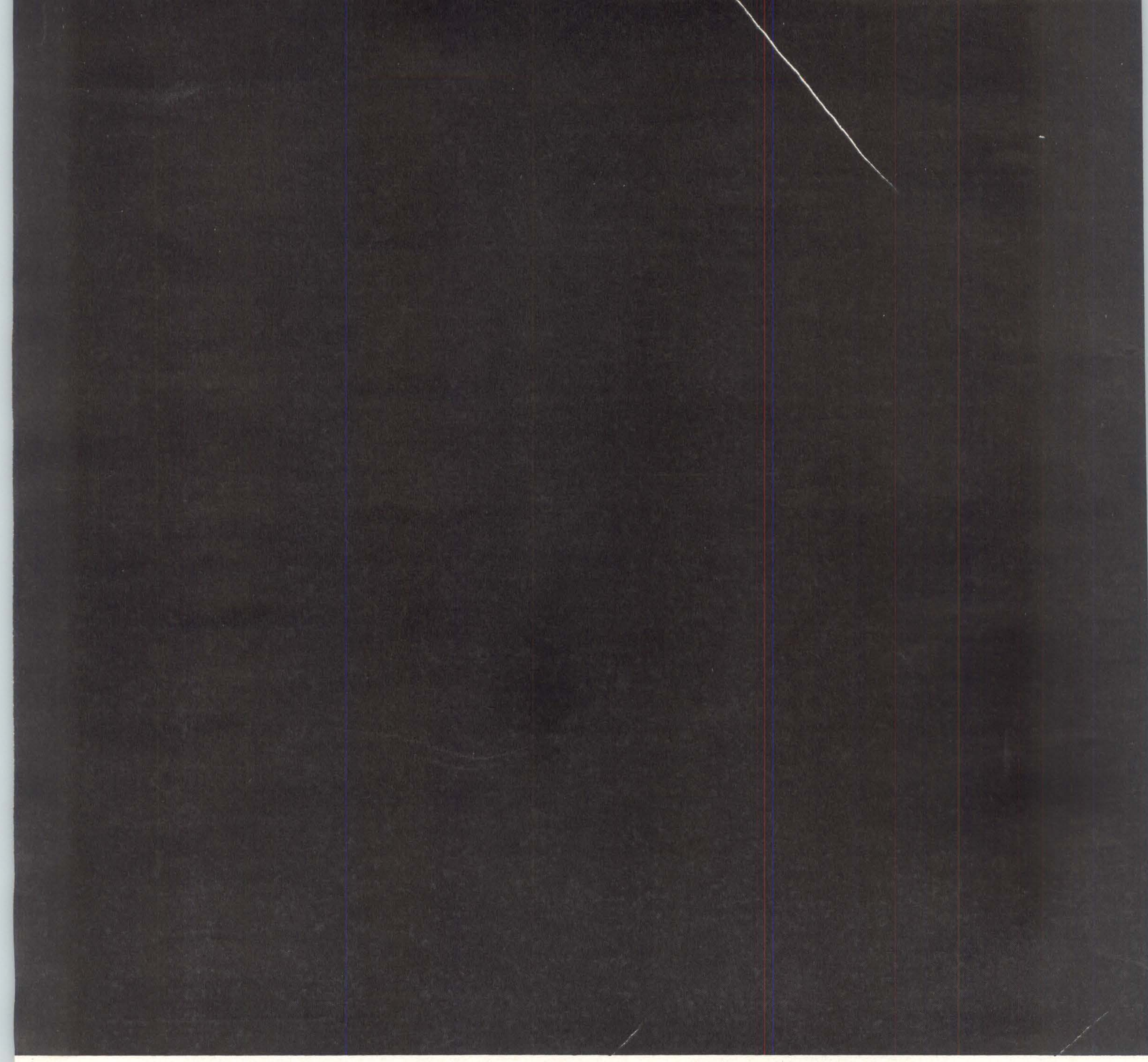
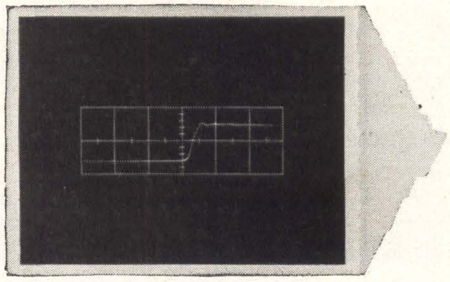
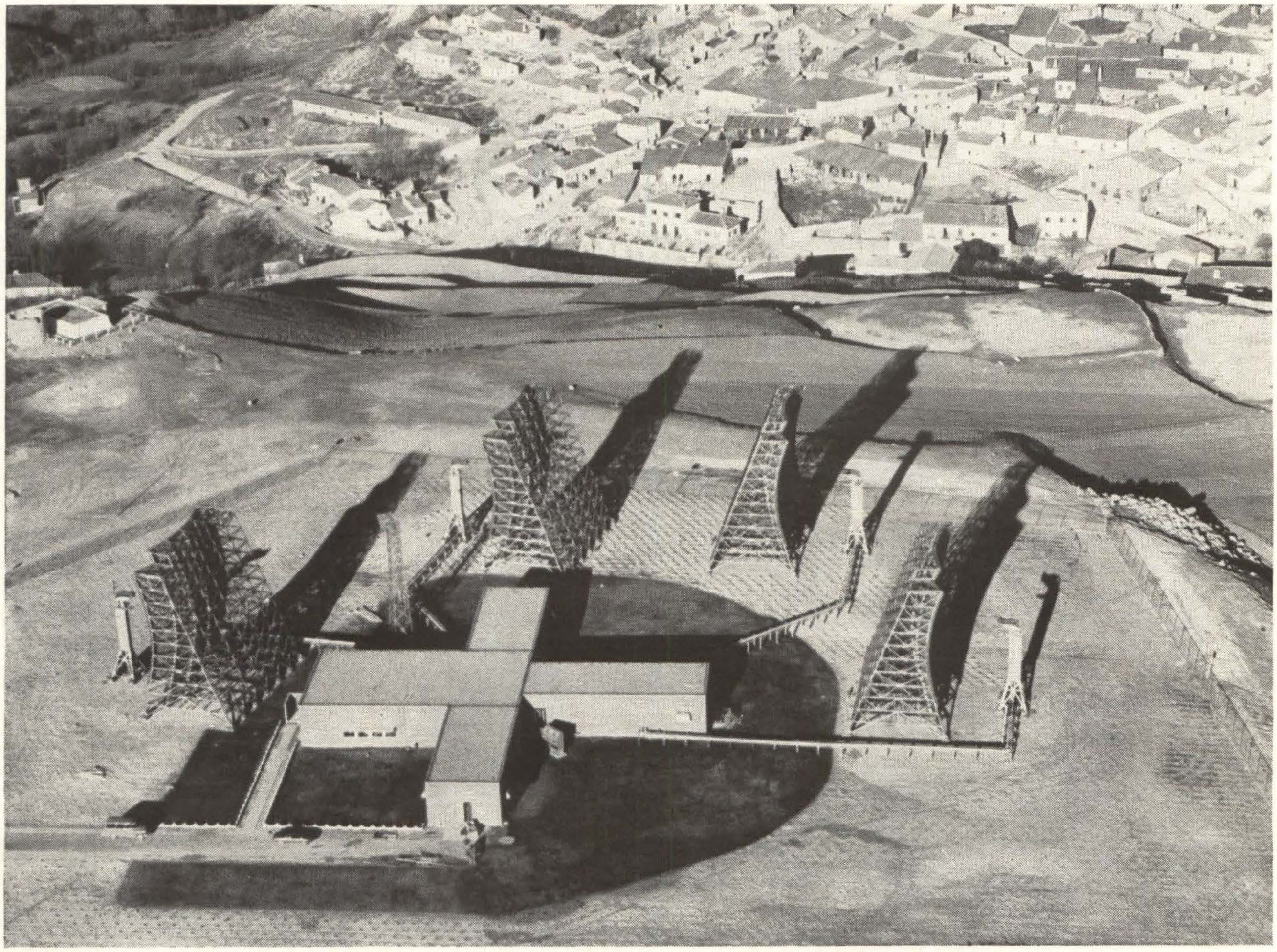






This troposcatter antenna array in Spain provides multichannel voice service for Air Force operations in Europe. Extra bandwidth is available for digital capabilities.

Military electronics

Soft Talk from the Pentagon

This project, part of the switch to digital communications, will permit classified data to be beamed anywhere on earth

By Tom Maguire
Regional Editor

Five major defense communications systems are being built or rebuilt as digital networks. The shift from analog, ordered two years ago by the Defense Department, is now in the various stages of equipment design and procurement.

One network involves the worldwide collection of weather data. The other four are also primarily air-ground systems, concerned with the secure transmission of messages—many of them highly classified and in code—over thousands of miles.

Digital communications offer at least three big advantages over analog: They are faster, more accurate and less vulnerable to interception.

I. Soft Talk.

When a high-ranking government official is airborne thousands of miles from Washington, his usefulness is severely limited. All his communications with the ground must be unclassified.

This handicap may be remedied in a little over a year. That's when Project 484L, commonly called Soft Talk, is expected to be in operation. Soft Talk will permit any government official, flying over any part of the world, to discuss classified information safely with Washington. He will simply dial the Defense Department, or any other agency, and talk.

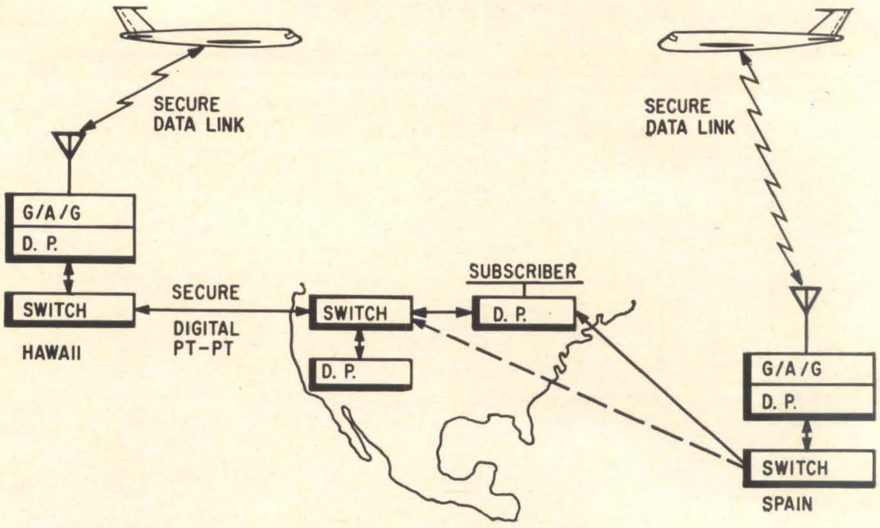
Part of the Soft Talk program is the installation, starting next September, of kilowatt multiplex transmitters operating at ultrahigh frequencies. Their range will be 150 miles for four channels in full duplex operation. Ultimately, a network of uhf ground stations will be built around the world for receiving these transmissions.

Digital communication is relatively easy to garble by introducing interpositions or inversions at the transmitter and by rearranging the digital stream at the receiver. Such immediate encoding and decoding, for both data and voice, are feasible only with digital systems.

At present the Air Force is using high-frequency radio systems on jet aircraft of its Special Air Missions fleet at Andrews Air Force Base near Washington. These are being upgraded by the addition of transceivers and automatic tuning devices for high-ranking officials.

Ground system. A system is also being designed to link Washington with key military centers. This network, designated Project 493L, but commonly known as Vocom (for voice communication), will be compatible with Soft Talk aboard the jets. It will be part of the National Military Command System now being developed (Electronics, March 22, 1963, p. 28).

Switching will be accomplished with computers—another advantage of using digital data. Digits are the language of the computers that process the information; therefore there's no delay for translation when digital data is used.



Idealized digital system knits air and ground communications stations together with data processors and switching centers.

The Radio Corp. of America, the prime contractor for Vocom, is building prototype hardware while continuing research and development on the program. Equipment made by the Philco Corp. is being installed in one plane of the Special Air Missions fleet, using modulator-demodulator devices produced by the Collins Radio Co.

Binary typing. Like VOCOM, little is said about 483L, the project to provide a secure air-ground system for teleprinter transmission of binary data. The network may involve simply a coded radioteleprinter, but details on the type of data and the users are classified.

II. Weather reports in 3-D

Flying at 30,000 feet are several obsolete B-47 bombers carrying ultramodern devices for making continuous weather observations. The devices comprise the AN/AMQ-19 meteorological apparatus, measuring temperature, pressure and relative humidity along the flight path.

The weather communications system is the farthest along of any of the new digital systems. It provides the Air Force Weather Service with information about upper-air atmospheric conditions around the world. It is expected to be particularly useful in determining the characteristics of air masses over large bodies of water and near hostile land areas where ground observations are not available.

Because weather is caused by the interaction of three-dimensional air masses, the new system uses a novel three-dimensional approach for better vertical soundings. Radiosondes—miniature weather stations equipped with tiny radio transmitters—are dropped every half-hour from the B-47s. The vertical and horizontal information is then digitized and stored temporarily on magnetic tape. As soon as the plane comes close enough to a ground station, the stored data is released in a multiplexed digital stream, as a high-frequency single-sideband radio signal.

On the ground. At the ground station, a data analysis central (AN/GMH-4) decodes, error-checks and translates the observations before feeding them at 640 or 1,040 words a minute through a buffer storage unit onto the slower-speed (60 to 100 wpm) teletypewriter line (diagram). The masses of data are finally combined with others in computers to aid forecasters in making short- and long-term weather predictions.

The weather apparatus is being installed by the Friez Instrument division of the Bendix Corp. under contract with the Air Force's Electronic Systems division and Aeronautical Systems division. The Air Force Communications Service provides ground stations and existing equipment needed to pass data to the Air Force Weather Service. The Aeronautical Systems division is responsible for modifying B-47s, and the Electronic Systems division takes care of new ground-station equipment.

The nine stations set up to receive data from the flying weather observers are at Andrews Air Force Base, Washington; McClellan Air Force Base, Calif.; Hickam Field, Honolulu; Anderson Field, Guam; Elmendorf Air Force Base, Alaska; Fuchu Air Station near Tokyo; Lajes Air Base in the Azores; the Croughton base in England; and Wheelus Air Base, Libya. Full-scale system tests began late in August from McClellan, with a plane gathering data from 1,100 miles out over the Pacific Ocean. A message of 6,000 characters, equivalent to 1,000 words, can now be sent in 80 seconds. When keyed out at 20 words a minute it takes 50 minutes. The huge distances involved in worldwide communications point up another advantage of digital methods: greater accuracy over longer ranges. Analog methods, such as simple voice telephony, require frequent amplification to keep the signal above the level of ever-present noise. But residual noise is amplified along with the signal. Finally, signal and noise become hopelessly mixed.

Digital methods are like on-off Morse Code signaling—either an impulse is there or it isn't. Even when a code pulse is nearly buried in noise, it can be regenerated by a repeater and started off again, strong and noise-free. This can be repeated as many times as desired.

III. The brain center

Technical proposals for a multimillion-dollar improvement are now being evaluated at the Air Force's Electronic Systems division (ESD) at Hanscom Field, Mass. Most major communications contractors have submitted bids.

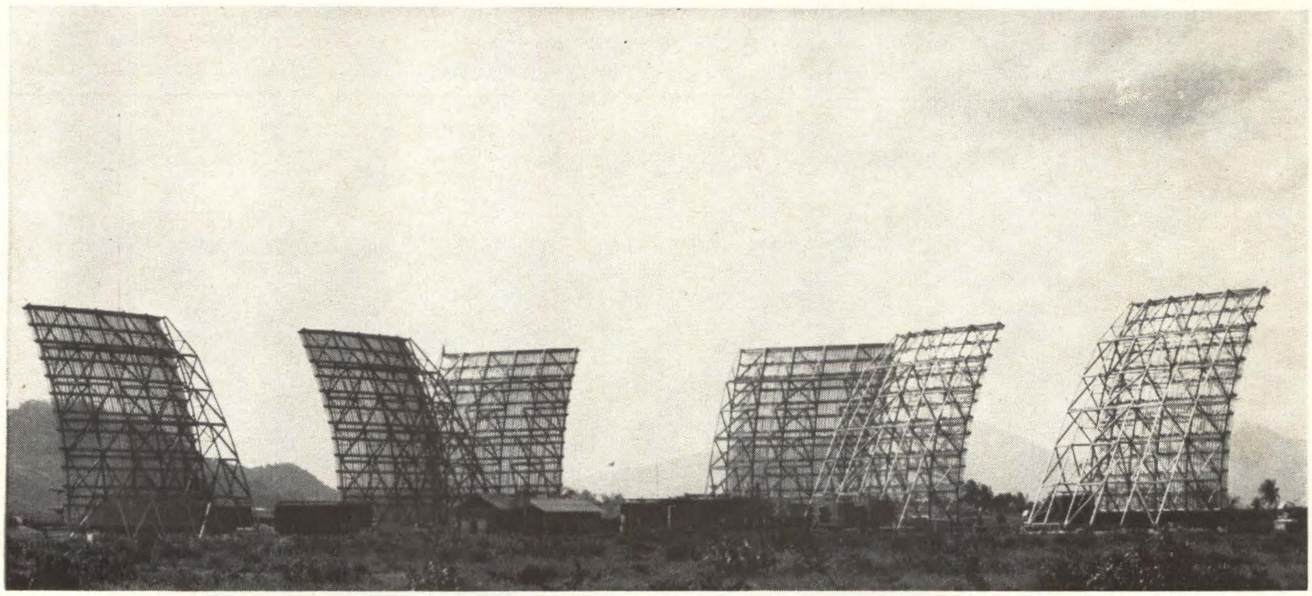
Present thinking is in the direction of augmenting existing uhf with more sophisticated equipment employing single-sideband modulation. The technique is complex but well known, and should provide satisfactory transmission at much narrower bandwith than at present. From another viewpoint, many more communications channels can be fitted into the band now occupied by simpler equipment.

The project officer at ESD, Lt. Col. W. E. Bird, says the equipment will be the most advanced off-the-shelf gear available. The only research involved will be toward selecting the right equipment. To do this, studies are planned on atmospheric disturbances, maximum transmission distances for a given power, receiver sensitivity and antenna gain requirements. In his office at Hanscom Field, Col. Donald W. Roberts presides over the $100-million-a-year business of planning, developing and acquiring a worldwide complex of communications systems to fill the needs of the Air Force and the Defense Communications Agency (Electronics, Apr. 19, 1963, p. 22). His office is the focal point for the switch to digital communications.

The military, Roberts explains, needs digital techniques for reliability, flexibility, speed and security. Aircraft engaged in surveillance and tactical support, for example, make stringent demands on data-transmission speeds. Such a system must handle data at 600 to 38,000 bits a second from computer to computer, and at 75 to 600 bits a second between computers and access-and-display devices. The move to digital will have its greatest impact on Air Force operations in the 1970s, Roberts predicts.

Triservice systems. At ESD, Roberts is deputy for communications systems management. He receives engineering advice from ITT Communication Systems, Inc., a subsidiary of the International Telephone and Telegraph Corp. The Mitre Corp., a nonprofit firm near Boston, also provides technical support in specific areas.

More than half of the tasks within Roberts' organization are assigned by the Defense Communications Agency in the evolution of the Defense Communications System. This system is a tri-service, complex, automatically switched that basically comprises two different worldwide networks. One is for voice (Autovon), the other an automatic digital network (Autodin).



At Nha Trang, South Vietnam, antennas face north, south and west. Tropo system has voice channels only, but will probably be modified to provide digital capability.

Europe: newest battleground for U.S. computer companies

GE and RCA, girding to battle IBM for the European market, form alliances with Italian, French and German companies

By Peggy Jackson

Staff Writer

Enticed by Europe's prosperity and her mushrooming computer market, two major United States companies established beachheads there this summer and seem to be girding to challenge the dominance of a third American concern, the International Business Machines Corp., on the continent.

In July the General Electric Co. invested $43 million in the French Compagnie des Machines Bull, acquiring 51% interest in its computer sales company and 49% of its manufacturing and research units.

At the end of August, GE branched out into Italy with the acquisition of the data-processing operations of Ing. C. Olivetti & Co.

This month the Radio Corp. of America confirmed that it is planning a joint computer venture in Europe with Siemens & Halske A. G. of West Germany.

I. The view from IBM

If these incursions evoked any concern at IBM, it wasn't evident to the world outside the company's World Trade Corp. offices in Manhattan. Most observers agreed that IBM, whose share of the European computer market has been estimated at from 50% to 90%, has little cause to worry.

A representative of one American company that is not involved in European mergers said, "It's going to be a long time before anybody gets IBM sales down." GE's move in France, he added, should not affect IBM's sales there to "any significant extent."

But Europe seems to have computer-market prospects outside of IBM's present grasp. One international marketing man estimated that the European computer market is less than 60% developed—not counting replacements and trading-up.

Any serious impact on IBM would be at least a couple of years away. The industry figures that it takes about five years to build a computer business abroad. "If you can go in with a local sales force and local manufacturing facilities," said a spokesman for one company's international division, "you can cut two to three years off that time."

II. From Britain's standpoint

If RCA's negotiations with Siemens & Halske take the course expected, the result would leave Britain the only country in Europe with a major computer industry independent of U. S. capital. But Britain's three top computer makers—International Computers and Tabulators, Ltd., Electric-Leo Computers, Ltd., and Elliott-Automation,

Chief negotiators in setting up Olivetti-General Electric were Olivetti's Bruno Visentini, GE's Louis T. Rader and Olivetti's Aurelio Peccei.

Ltd.—would probably be hard-pressed in competition with the three American giants on the continent.

Elliott, a maker of automation equipment, electronic equipment, and office and vending machines, has 38 wholly owned subsidiaries abroad. It earned \$4.24 million in 1962, the last year for which figures are available.

International Computer's international agreements include one with RCA for the exchange of patents, technical information and such. The British company's profit in 1963 slipped to \$3.36 million from \$3.64 million the year before.

III. GE's fine hand in Italy

Although Italy's "economic miracle" has begun to fade, her computer market is expected to double in the next four years. That's too little time for a foreign company to start from a stationary position; GE needs a local organization if it is to bid for a share of that market.

Olivetti provided it with Italian manufacturing and research facilities, a line of three basic computers (the Elea 9003, 6001 and 4001) with peripheral equipment, and—perhaps most important—a sales and servicing organization operating from 18 branch offices throughout Italy.

Under the agreement, GE will own 60% and Olivetti 40% of a new subsidiary, Olivetti-General Electric, with headquarters in Milan. GE will pour an unspecified amount of cash into the new venture, which will specialize in data-processing operations. Until GE names a permanent manager of the new company, Ottorino Beltrami, former director of Olivetti's electronics divisions, is acting manager of Olivetti-General Electric.

The GE-Olivetti marriage was brought to its final stages by Aurelio Peccei, Bruno Visentini and Roberto Olivetti of Olivetti's Executive Committee and by Louis T. Rader, vice president and general manager of GE's Industrial Electronics division. The Olivetti transaction was probably Rader's biggest accomplishment since returning to GE in July from the Sperry Rand Corp., where he had been president of the Univac division since 1962.

Battle lines. Until the GE-Olivetti

transaction, Italy's computer market seemed destined to fall to IBM by default. Of 688 computers installed in Italy by the end of 1963, IBM had supplied 465. Olivetti ranked second with 104 and the Sperry Rand Corp. third with 78.

GE is expected to tighten the Olivetti product line. An early step probably will be the abandonment of the 9003, Olivetti's oldest (five years) and largest model. It is comparable to the IBM 7070. GE may also drop the medium-size 6001, which was designed primarily for scientific work, then modified for commercial use. But another medium-size model, the 4001, will extend the range of GE's computer line on the lower end of the price scale. The 4001, a relatively low-cost data processor, was introduced last year.

Some of Olivetti's peripheral equipment—such as a high-speed printer, magnetic character readers and data-transmission gear—will also strengthen GE's marketing position. One big advantage is that the equipment is adapted to European standards.

Mounting debt. Olivetti could not hope to compete with the giant American computer companies. For one thing, its technology was weak; compared with the third generation of U. S. computers, Olivetti's limited line was only slightly advanced from its first computer, introduced in 1959. Another drawback was the company's failure to develop an adequate backup of computer programs.

Olivetti's plunge into the computer business in 1959 was engineered by Adriano Olivetti, the son of Camillo Olivetti, the company's founder.

When Adriano bought control of the faltering Underwood Corp. in 1959 and tried to bolster the American company, Olivetti's long-term debt began to climb. From $21.3 million in March, 1958, it soared to $66.6 million in December, 1963.

New stockholders. Last spring the Olivetti family sold almost half of its stock in the company. The buyers brought in Bruno Visentini, former vice president of the government holding company IRI and a long-time adviser to the Olivetti family; Aurelio Peccei, formerly a top executive of Fiat, S. p. A., the automobile manufacturer; Silvio

Borri of Istituto Mobiliare Italiano, the government-controlled credit institute; and Roberto Olivetti. This four-man executive committee pushed through the deal with General Electric.

Olivetti is staying in the electronics business. A group of its engineers is working on, among other things, a small desk-size computer. The company also plans to continue producing electronic accounting and billing machines, an automatic collector of production data, and numerical-control equipment for machine tools.

In fact, it is reported that Olivetti recently concluded an agreement with Britain's Electrical and Musical Industries, Ltd., for sales and service of the machine-tool control equipment throughout much of Europe.

The company's sales last year totaled $422.7 million. Of this, computers accounted for only about 5%.

IV. West German venture

With assets exceeding $1.2 billion, Siemens & Halske is one of Europe's largest and most respected industrial concerns. Its marketing operations are strong throughout the noncommunist world, and its research is considered one of the most advanced. Its sales last year totaled $1.46 billion, putting the company in ninth place among all companies outside the United States.

Observers believe that a joint effort by RCA and Siemens & Halske could result in Europe's biggest computer company.

The German company now offers three computers. The best seller is the 2002, a medium-size computer introduced in 1960 that is roughly comparable with the RCA 501 that went into production in 1960. It is used in science and industry. About 40 have been delivered so far.

The 3003, which falls somewhere between RCA's 301 and 501, is also capable of processing both scientific and industrial data. Only three or four have been delivered. Deliveries are also just beginning on the 303, an industrial process-control computer.

RCA has declined to tell any details of its transactions with Siemens & Halske other than that discussions of the proposed agreement with the German concern "are

Olivetti Electronics division employees will work for Olivetti-General Electric.

still in the early stages."

V. American computers in Paris

When all pending transactions are completed, RCA's German venture could find itself competing with RCA computers in Europe. Machines Bull, the French company with the GE money, manufactures the RCA 301 among other computers.

RCA's interest in pushing its older 501 computer in Europe is clear. A company official disclosed recently that the computer had paid for all of its development costs; any sales abroad would be "gravy."

At about the time of GE's deal with Machines Bull, RCA announced that it was modifying its business arrangement with the French concern. RCA hastened to add, however, that Machines Bull would retain patent licenses to manufacture the RCA 301 and other computers, and that RCA would continue to supply "technical aid and know-how on the RCA 301 and its future enhancements." But the technical-aid provision is being modified, RCA said, although the company wouldn't give details.

Microelectronics

Multichip circuits get off the ground

They'll be used exclusively in a microelectronic system for an advanced Orbiting Geophysical Observatory

By Jerome Eimbinder
Solid State Editor

As space contracts go, the one recently awarded the General Instrument Corp. is far from spectacular—the National Aeronautics and Space Administration is buying only one microelectronic data processor for about $100,000. That's chicken feed in these days of multimillion dollar contracts for space systems. Yet, officials of the company are jubilant. Jack Herre, the vice president who handles government relations for General Instrument rates the contract among the most important in the company's history. And he may be right.

Flying start. For some time now, General Instrument has been championing a multichip approach to integrated circuitry. With its award, NASA has approved the first use of multichip construction methods in a satellite system. The completely microelectronic data processing system, using multichip circuitry exclusively, will go aloft in an advanced Orbiting Geophysical Observatory (OGO) research satellite. Thus, it will be the first time that multichip circuits have been used in space vehicles.

"We'll have an opportunity," says Herre, "to demonstrate, in space, the capabilities of a microelectronic system composed entirely of multichip circuits."

Last week, the first phase of the program was completed with the construction of a feasibility model of the system.

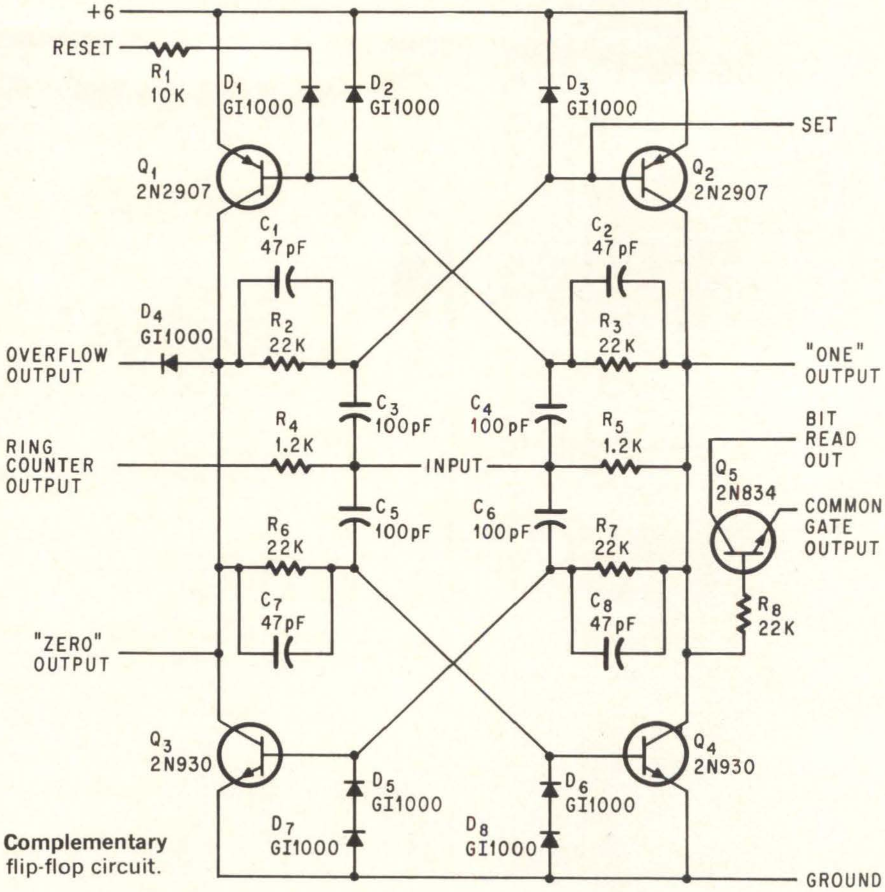
Monolithic or multichip? There has been spirited, if inconclusive, debate in microelectronics circles on monolithic versus multichip construction. In a monolithic circuit, the active and passive components share the same substrate in what is essentially a two-dimensional unit. By a series of manufacturing steps, the monolithic circuit is produced on a single substrate.

By contrast, multichip construction involves making a number of identical components on the same wafer, dicing them apart into microelements and then combining them, with other separately made components, to form circuits.

General Instrument says the multichip approach runs rings around the monolithic technique when a relatively small number of microcircuits are needed quickly. The system being built for the space agency will use about 150 microcircuits. The company will deliver it in five months to the Goddard Space Flight Center, Greenbelt, Md.

The satellites. NASA plans to orbit a total of six of the geophysical observatory satellites. The first OGO was launched from Cape Kennedy on Sept. 4. It was boosted into an oval orbit, ranging from 177 to 93,313 miles above the earth, by an Atlas Agena rocket. The launch was excellent but the satellite developed trouble when two booms failed to deploy. This meant the satellite couldn't travel without spinning. None of the 20 experiments carried by OGO were turned on until Sept. 7. Then, despite the spin, 14 were turned on and successfully transmitted data.

The over-all aim of the OGO program, said George Ludwig, project scientist for NASA, is "to find out as much as we can about the environment near earth and to obtain a better idea of earth-sun relations." Such knowledge, Ludwig explained, is vital to Project Apollo because manned flights to the moon now face the hazard of potentially dangerous solar flares. OGO will be collecting information about these bursts of gas and flame for the astronauts.

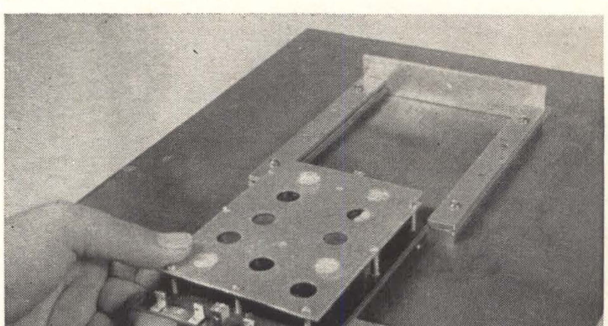


Complementary flip-flop circuit.

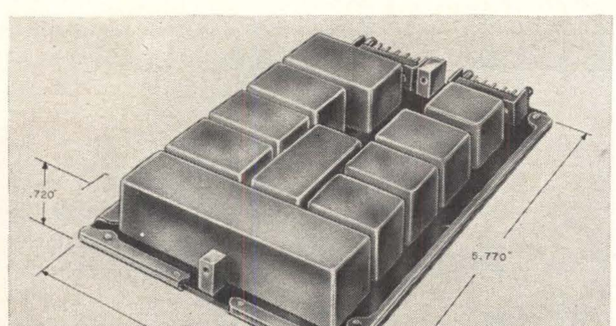
The reasons. Officials of General Instrument refer to the contract as a victory. One spokesman emphasized that General Instrument did win out over a number of advocates of the monolithic technique.

When asked why, he advanced several reasons: the high tooling-up cost for monolithic circuitry, the length of time required for that tooling up, and the fact that in a monolithic circuit the common substrate material has to be a compromise. What may be the ideal substrate material for a particular transistor may not be the best material for a particular capacitor. This problem does not exist in multichip-circuit construction which allows the use of the most suitable substrate for each of the individual components.

The power consumption of the microelectronic data processing system is extraordinarily low. It needs between 277 and 370 milliwatts to operate. This is about half



An actual-size mechanical sample, simulating the completed system, being placed into a vibration test fixture.



The system consists of ten modules mounted on a plug-in circuit card.

the power consumed by an ordinary flashlight. The entire data processing unit will occupy about eight cubic inches and will weigh approximately 200 grams.

Building block. A complementary flip-flop microcircuit is the key building block. According to General Instrument, it duplicates the performance of a conventional circuit 140 times its size.

The system will be housed in a total of 10 modules. Seven will contain binary-counter register subsystems; each subsystem will use nine of the complementary flip-flop circuits. The other three modules will consist of a quasi-binary floating-point register subsystem, containing 24 flip-flop circuits, a readout register subsystem with 10 flip-flop circuits, and a control subsystem.

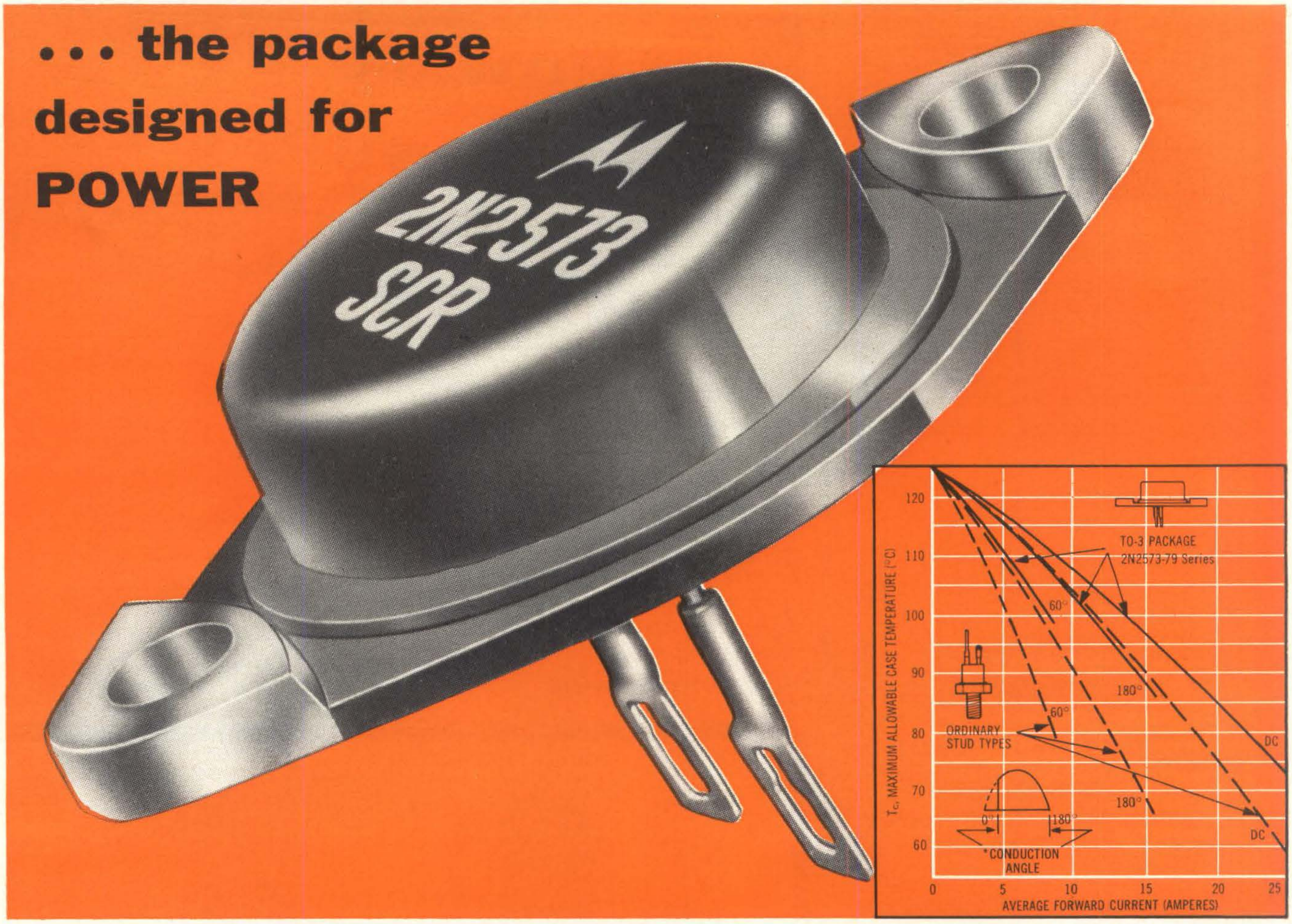
What it does. The processor will collect information on conditions in space from the satellite's 20 sensing devices and feed it, on command, into the central data system. It will be able to handle information from as many as eight of the sensing devices at a time. Data can be accumulated at the rate of one million bits per second, stored on tape, or fed out immediately at a rate of up to 64,000 bits at a time. This output could be speeded up, but the system is limited by the speed of the external equipment to which the information is fed.

In charge. A three-man team, headed by Sol Schwartz, senior project engineer, is directing the system-building program at General Instrument's design and engineering products group facilities in Hicksville, L. I. Schwartz's colleagues are Marc Swirlock, assistant project engineer, and Emery Vezer, mechanical project engineer. Harry Zacharia is consultant.

The recently completed feasibility model (a breadboard model using conventional circuits) closely simulates the actual microelectronic system. It occupies 4,800 cubic inches and weighs 75 pounds.

Only one other microelectronic system has ever been used in space. This is the microelectronic optical computer for attitude determination installed in NASA's Interplanetary Monitoring Probe, launched late last year. The optical computer uses monolithic circuits made by Texas Instruments, Inc.

Circle 107 on reader service card



MOTOROLA'S NEW 25-AMP SILICON CONTROLLED RECTIFIER GIVES YOU FULL POWER AT HIGHER TEMPERATURES

These new Motorola 25-amp silicon controlled rectifiers (types 2N2573-79), electrically equivalent to the 2N681-9 series stud-type SCR's, utilize the natural power operation advantages of the TO-3 package design to give improved performance over stud-mounted devices in areas such as:

- **Higher DC current output — 25 amps @ 71°C**
- **Higher surge current — 260 amps at rated load @ 125°C**
- **Lower thermal resistance — 1.5°C/W**
- **Freedom from failures due to excessive stud torquing**
- **Lower vertical dimension — only .41"**

With the low forward voltage drop (only .7 volts @ 16 amps full cycle average, 180° conduction angle, $T_J = 125°C$) plus the low thermal resistance of the TO-3 package, you can operate at higher current levels for any given case temperature . . . or in applications with lower current requirements, you can reduce the heat sink area required for your equipment.

Find out for yourself how the TO-3 package provides you with highest performance silicon controlled rectifiers at lowest cost for *your* equipment applications!

LOOK AT THESE PERFORMANCE ADVANTAGES

This chart gives key parameter comparisons for Motorola TO-3 package 2N2573-79 type and stud-type 2N681-89 silicon controlled rectifiers.*

	(2N685)	2N2576	
P_{LOSSES} (Av. forward power loss @ max. junction temp. @ I_{avg} above)	(24)	21	Watts
T_C (Max. allow. case temp. @ I_{avg} max. for 180° conduction angle)	(65)	85	°C
I_{surge} (Peak ½-cycle 60 cps surge current @ max. junction temp.)	(150)	260	Amps
I^2t (Max. subcycle surge rating as function of RMS current/time @ max. junct. temp.)	(75)	275	A^2sec

*Data obtained from published specifications

If you would like additional information on Motorola's 2N2573-79 series 25-amp silicon controlled rectifiers, contact your nearest Motorola District Office or Distributor or write Technical Information Center, Motorola Semiconductor Products Inc., Box 955, Phoenix 1, Arizona.

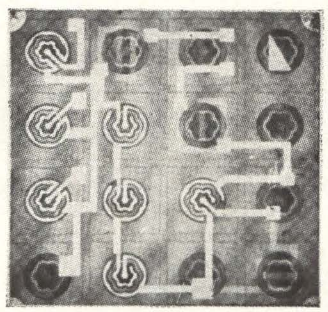
MOTOROLA
Semiconductor Products Inc.
A SUBSIDIARY OF MOTOROLA INC. D13-014
BOX 955 • PHOENIX 1, ARIZONA

A GROWING LIST OF MOTOROLA SILICON CONTROLLED RECTIFIERS ■ High Efficiency Diamond Package types 2N2573-79 & MCR649 ■ 11/16" Stud-mounted types 2N681-89 ■ 7/16" Stud-mounted types MCR846 ■ Low Cost Industrial Press-Fit Package types MCR808 ■ *ALSO — Gate Controlled Switch — Diamond package types MGCS821 series — with pulse turn-on, turn-off gate control.*

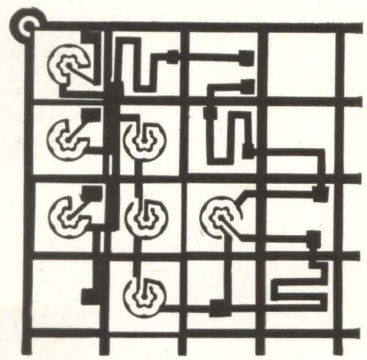
Custom-integrated circuits by design kit

New approach circumvents manufacturer's premium, thus reducing customer costs

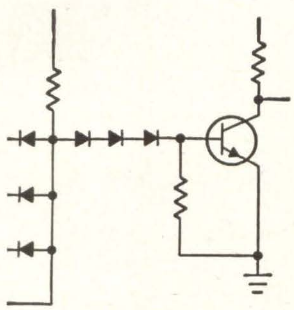
A designer's kit has been announced for the layout of custom-integrated circuits. It permits the design engineer to arrange and define his own schematic in a form compatible with the microcircuit state-of-the-art. Until now, this type of circuit has been designed primarily by the semiconductor manufacturer, and at a premium cost. The kit approach returns the circuit—design function to the customer without price penalties. This is possible through the use of the integrated-circuit technique of diffused active devices, with thin-film passive devices deposited directly upon the silicon dioxide that covers the diffused portion.



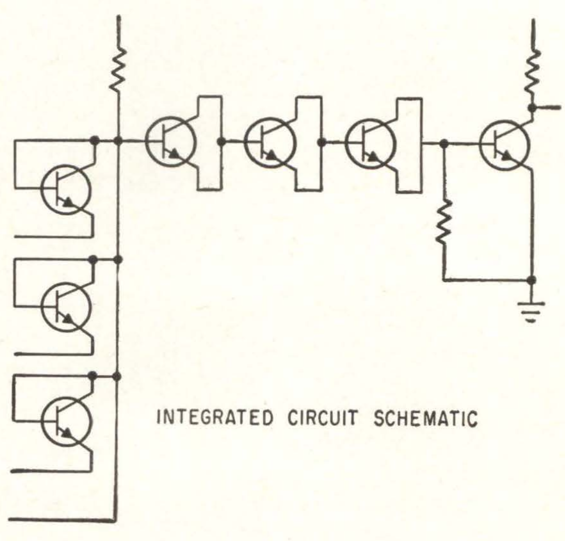
ACTUAL CIRCUIT



ACTUAL LAYOUT



ACTUAL SCHEMATIC



INTEGRATED CIRCUIT SCHEMATIC

This technique, known as the Mosaic monolithic circuit, is said to offer many engineering advantages over the more common all-diffused technique. These include wider resistance range, tighter tolerance and matching on resistors, low parasitic capacitance, improved temperature stability and greater circuit density.

What you get. A customer is offered the option of several active devices in the kit—amplifier and switching transistors or diodes. These basic specifications represent active device geometries that are already tooled and manufactured as "master slices." It should be noted that these device parameters can be adjusted further by such techniques as varying diffusion depths and doping levels; these do not require any additional masking costs.

After active devices are selected, the next step is to choose passive component values within the listed range of capability allowed by size and industry know-how. Thus a circuit can be developed that is ready to be converted directly into microelectronic technology.

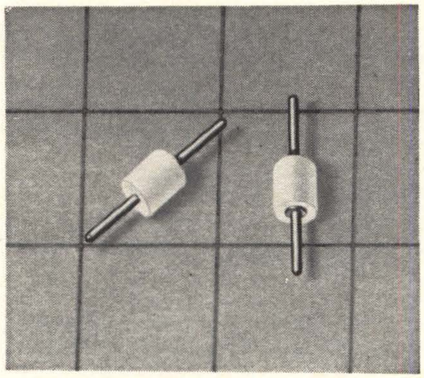
Upon completion of his schematic, the designer is in a position to do an actual layout of a custom-integrated circuit chip. He is provided with a scaled-up address format and separate component and contact pattern representations that can be placed upon the format as desired. Instructions are provided describing cross-over techniques, spacing of components and contact runs, and mechanical size required to achieve desired values of resistance and capacitance.

Upon completion of the custom layout, the customer is invited to forward the circuit to the company for development of a firm engineering proposal and quotation. At such time, the input and output functions will be confirmed, the customer's package preference verified; unusual environments evaluated, and availability and cost figures stated.

Some examples of costs are: custom buffer amplifier, \$55 each for 100 pieces; custom DTL single NAND circuit, \$22 each for small quantities; and diode ring modulator, \$11 each in quantities of 1,000 pieces.

Bendix Semiconductor Division, Bendix Corp., Holmdel., N.J.
Circle **301** reader service card

New Components and Hardware

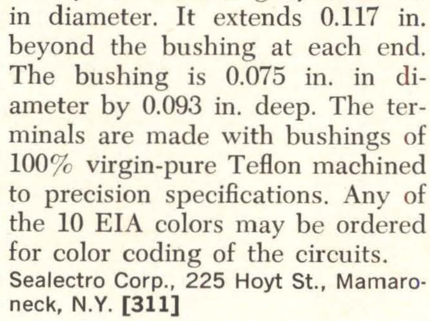


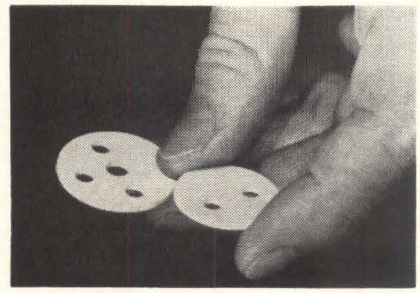
Feed-through terminal in microminiature size

A microminiature feed-through terminal serves as probe and guide for mating chassis to chassis. The FT-MM-100 is bonded in place with an epoxy compound after insertion. The lug is brass with a solder plating and is approximately 0.328 in. long by 0.020 in. in diameter. It extends 0.117 in. beyond the bushing at each end. The bushing is 0.075 in. in diameter by 0.093 in. deep. The terminals are made with bushings of 100% virgin-pure Teflon machined to precision specifications. Any of the 10 EIA colors may be ordered for color coding of the circuits. Sealectro Corp., 225 Hoyt St., Mamaroneck, N.Y. **[311]**

Pellet film resistors with fluted design

Pellet film resistors featuring a fluted design are available in diameters of 0.100 in. and thicknesses of either 0.030 in. or 0.063 in. They are said to be ideal for application in high-frequency equipment in the uhf region. Test results indicate that these pellets have a low standing-wave ratio when used as r-f terminations and fast rise time when used in pulse applications. Actual swr measurements made with a 50-ohm pellet indicate a swr of less than 1.1 at 1,200 Mc. P. R. Mallory & Co. Inc., 3029 E. Washington St., Indianapolis, Ind. **[312]**



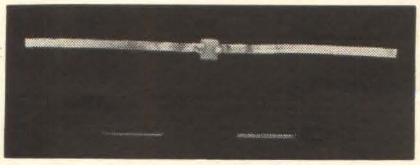


Mounting wafers of boron nitride

Transistor mounting wafers of boron nitride, a material that is an electrical insulator and a heat conductor, have been announced. Designed primarily for power-handling transistors ranging up to 100 w, the wafers provide 90% of the performance of premium materials at about half the cost. While electrically insulating the collector from the chassis under the transistor, the $\frac{1}{16}$-in.-thick wafers remove the heat generated in the transistor and conduct it into the chassis, which serves as a heat sink. No conductive greases are required, as dry boron nitride has a thermal resistance of less than 0.1°C per w. Union Carbide Corp., 270 Park Ave., New York 10017. **[313]**

Ceramic capacitors offer high Q

Fixed ceramic capacitors have been developed in a configuration only $\frac{7}{64}$ in. square and $\pm\frac{1}{16}$ in. thick. Series YUO1 are available in capacitances from 0.5 to 62 pf, for a working voltage of 300 v d-c. A choice of tolerances is available for



each size, from ±0.25 to ±0.50 pf at the low C end of the line to from ±1 to ±10% at the high end. All units have a guaranteed minimum Q of 3,000. Ceramic dielectric layers, fused into a monolithic structure and encapsulated in solid glass, insure complete protection against moisture and other environmental factors. Stability is maintained through extremes of voltage, frequency, temperature and other stresses. Standard leads are silver ribbon, axial, a minimum of 7/8 in. long, 0.050 ± 0.003 in. wide and 0.008 ± 0.002 in. thick. Other types and configuration leads can be furnished on special order.

JFD Electronics Corp., 1462 62nd St., Brooklyn, N.Y. 11219. [314]

Power tetrodes survive severe treatment

Two new power tetrodes of metal-ceramic construction are offered. When cooled by forced air, the 4CX125C and F have a maximum plate dissipation of 125 w. The tubes have a high endurance for extreme environmental conditions of temperature, shock and vibration. Operating at frequencies up to 500 Mc, they can be used in Class C f-m telephony and telegraphy, Class C plate-modulated telephony, and Class AB1, audio or single-sideband amplification. Standing 2½ in. high, the tubes have diameters of approximately

New Components

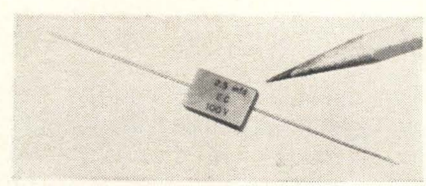
$1\frac{1}{4}$ in. including the radial cooling fins designed for either liquid or forced-air cooling. The base is a special breechblock type with radial contact tabs. In single quantities, the 4CX125C and F are priced at \$43 and \$86.50, respectively.

Raytheon Co., Industrial Components Division, 55 Chapel St., Newton, Mass. 02158. **[315]**

Metal-film resistor saves board space

A molded, precision metal-film resistor, type PE-$\frac{1}{4}$, for printed-board applications, is designed to conserve board area and surpasses MIL-R-10509E characteristic E and C levels. Power rating is $\frac{1}{4}$ w at 100°C and $\frac{1}{8}$ w at 125°C. Voltage rating is 250 v and the resistance ranges from 10 ohms to 0.5 megohm. Dimensions are 0.140 by 0.200 by 0.468 in., and the two leads projecting from one end are 0.025-in.-diameter tinned copper, or gold-plated Dumet, a low-expansion alloy, in either case $\frac{3}{4}$ in. long, the leads can be trimmed to suit the application. Standard tolerance is $\pm1\%$, but tolerances from $\pm0.1\%$ to $\pm5\%$ are available. The unit features low noise and temperature coefficients of ±25 ppm per °C, ±50 ppm per °C, and ±100 ppm per °C. Prices range from \$2 to 45 cents depending on tolerance, temperature coefficient, and quantity.

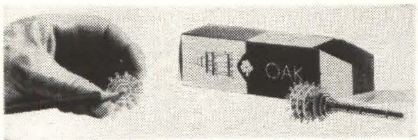
American Components, Inc., 8th Ave. & Harry St., Conshohocken, Pa. **[316]**



Ceramic capacitor rated 100 wvdc

A new subminiature ceramic capacitor offers a 0.1 to 2.5 μf capacitance with a $\pm20\%$ tolerance and maximum capacitance change of

±15% over a temperature range of −55°C to ±125°C. The voltage rating is 100 wvdc with no derating to 125°C. The dissipation factor is less than 2½% at 25°C. The envelope is dipped in epoxy for maximum environmental protection.
Nytronics, Inc., 550 Springfield Ave., Berkeley Heights, N.J. [317]



Distributor switches in subminiature sizes

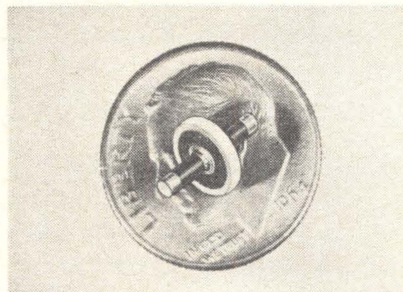
Rotary distributor switches have been developed in subminiature sizes. The line of "A" switches offers eight different types and features silicone glass stators and rotors of Kel-F material. Frames for the switches are 1 in. high, $\frac{15}{16}$ in. wide by $1\frac{3}{16}$ in. over clips. They are equipped with ¼-in.-diameter shafts, 2⅜ in. long, with break-off points at ¾ in., 1⅛ in. and 1⅞ in. from the mounting surface. The switches meet 200-hr. military salt-spray requirements. They are rated 1 amp at 28 v d-c and 0.5 amp at 115 v a-c. Silver-plated brass contacts are double wiping, shorting or nonshorting types.
Oak Mfg. Co., a division of Oak Electro/Netics Corp., Crystal Lake, Ill. [318]

Tiny toggle switch operates up to 85° C

This single-pole change-over toggle switch has a working temperature range of 0° to 85°C. Primary applications are in portable test sets, instrumentation, radar display equipment and as a computer test facility. Two models are available. The TS70, with fine silver contacts, is rated at 1 amp resistive at 50 v d-c or 0.25 amp at 125 v a-c. Initial contact resistance is 10 milliohms. Type TS71 has heavily gold plated

contacts, rated at 100 ma at 1 v d-c, contact resistance 6 milliohms. They are otherwise identical—0.25 in. diameter and 0.5 in. body length, and intended for panel mounting.

Miniature Electronic Components, Ltd., St. Johns, Woking, Surrey, England. [319]



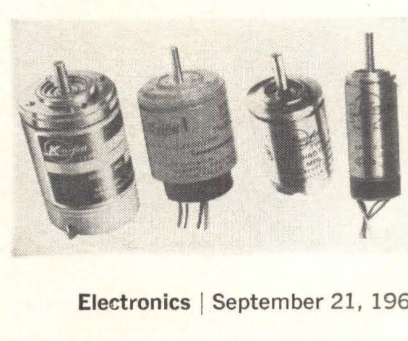
Co-ax T-pad assembly offered in microminiature

A microminiature coaxial T-pad is being offered with an over-all length of 0.425 in. and attenuation values of 3, 6, 10, 15 and 20 db. Units are assembled and shipped from stocks of standard rod and disk resistors fabricated with metal-resistive films deposited on precision substrates of high-alumina ceramic. The resistance tolerances are ±1% and the units operate over a temperature range of —55°C to 200°C with a range of 0 to 100% relative humidity.

Nytronics, Inc., 550 Springfield Ave., Berkeley Heights, N.J. [320]

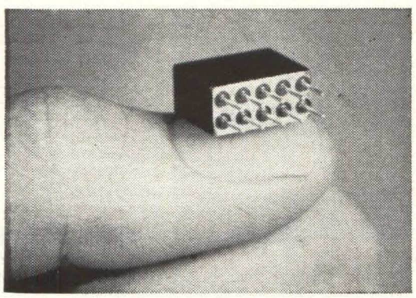
Transolvers combine servo-system functions

A series of transolvers—combinations of transformers and resolvers —range from size 5 (½-in. diam-



eter) to size 11 (1.062-in. diameter). They are used in phase conversion, vector resolution, servo system monitoring, angle summing and other applications in systems that transmit, convert, use or indicate information in electrical form. The transolver can provide sine and cosine outputs simultaneously, contrasted to the single sine function produced by a conventional synchro control transformer. The transolver consists of a three-phase, Y-connected winding and two single-phase windings, either of which may be the fixed or rotating element. By using transolvers judiciously to replace other sets of individual components, systems may be greatly simplified and significant savings in volume and weight can be made.

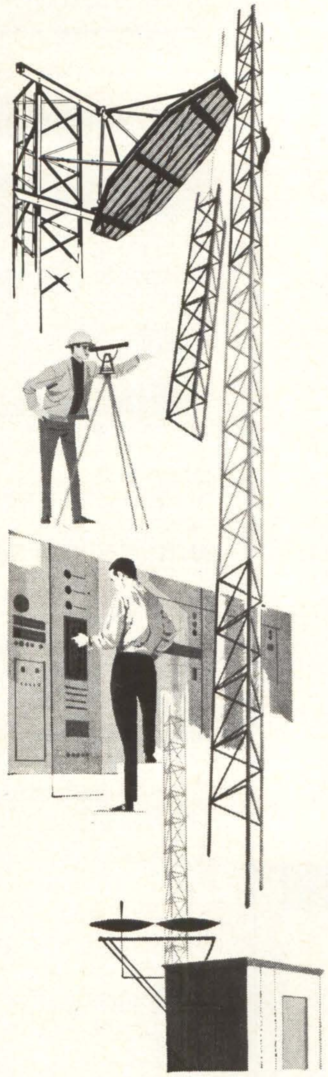
Kearfott Division, General Precision Equipment Corp., 1150 McBride Ave., Little Falls, N.J. 07424. [321]



Latching relay is 1/6 crystal-can size

A one-sixth crystal-can-size dpdt relay has been developed with contacts rated at 1 amp resistive at 28 v d-c. Operated from a short-duration, low-power pulse, the contacts remain in either position without consuming power. Type LJ, a hermetically sealed latching relay, operates in a $-65°$ to $+125°C$ temperature range and is unaffected by extreme aerospace conditions such as high altitude and severe shock and vibration. The relay measures only 0.2 by 0.4 by 0.5 in. It is available with coils for operation at 6, 12, 24 and 48 v d-c. A variety of case and header styles are offered to satisfy all mounting requirements. Type LJ meets or exceeds applicable section of MIL-R-5757D.

Branson Corp., 41 South Jefferson Rd., Whippany, N.J. [322]

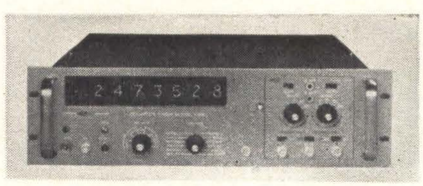


New Instruments

Solid-state servo repeater with digital readout

Solid-state servo repeater, model PPR, indicates the position of remotely located synchros and resolvers with an accuracy of six minutes of arc. Readout angle, in ¾-in. character height, is displayed on an illuminated, in-line module which consumes only 1 in. by 4 in. of panel space. Decimal or BCD (1, 2, 4, 8) code at a 24-v d-c level is simultaneously available from the servo. Useful in performing gyro system measurements, the unit indicates gyro pitch, roll, and yaw angles. It displays the angular positions of any system containing synchros or resolvers. Range of the instrument is 360° continuous; slewing time, 8 sec; price $1500.

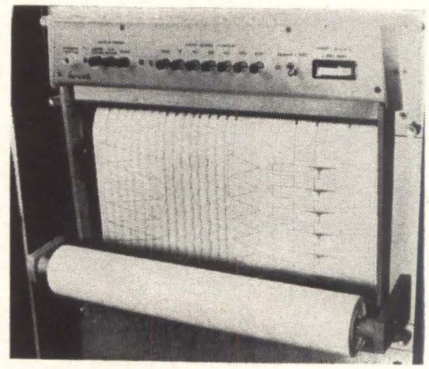
Theta Instrument Corp., Saddle Brook, N.J. 07663. [351]



Counter features front plug-in design

A new counter has been introduced with a versatile front plug-in design. Model 1014 measures frequencies directly to 100 Mc by means of prescaling (non-indicating) decade. The front plug-in feature provides for simple interchange of functional plug-ins that tailor the basic model 1014 to a broad range of specific frequency measuring and timing applications. Associated plug-ins available include universal, dual-measurement, preset, time interval, and frequency extenders covering the full range to 15 Gc. Standard oscillator stability is 3 parts in 10^7 per week. Model 1014 can also be provided with an optional high-stability oscillator that has an aging rate of 1 part in 10^9 per day. Other options include display storage, remote programing, and BCD output. Unit is priced at $2,250.

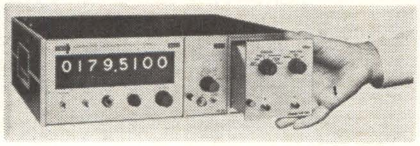
Systron-Donner Corp., 888 Galindo St., Concord, Calif. [352]



Recording systems in modular design

A series of direct-writing recording systems permits a variety of different writing modules to be grouped into a single recorder in any combination desired. Modular grouping in the series 1707, Mark 200 system, allows a variety of data to be recorded simultaneously. Each type of recording is said to be presented in the most readable form possible—extreme resolution for precision measurements, closely spaced presentation for several channels of dynamic or trending information, and well-organized "yes-no" information from relays, actuators, time codes and digital functions. Three independent writing modules, available for insertion into the combination unit, produce data correlated to the same time base. They include a dual-channel 40-mm analog module, a single-channel 80-mm analog module and an 8-channel Multi-marker event-recorder module. Each writing module occupies one-fourth of the space available in the series 1707. Any recorder can be made up of four individual modules. All four modules may be alike, or two or three can be selected in any combination. All writing modules share a common writing-fluid supply system. Cost of the series 1707 system is about $900 per channel.

Brush Instruments division of Clevite Corp., 37th and Perkins, Cleveland 44114. **[353]**



Phase meter plug-in for use with counters

A new phase angle meter plug-in is designed for the Digi-Twin line of electronic counters. The 838-A plug-in provides an accurate means of measuring phase angle and digitally displaying the results directly in degrees. The device has a frequency of 10 cps to 100 kc. It will measure phase angle from 1° to 360°, with automatic decimal point indication. Sensitivity is 0.5 v rms to 4 v rms maximum, without attenuator. The phase meter plug-in is one of 10 modules which can be inserted in the 800 series solid-state counters—said to be the only twin plug-in counters currently on the market. It can be used directly with a frequency range module or to provide all the functions of a frequency-period module. Price of the 838-A is $750.

Computer Measurements Co., 12970 Bradley Ave., San Fernando, Calif. **[354]**

Gaussmeters use cryogenic sleeve

A new vacuum-insulated sleeve for Rawson-Lush rotating-coil gaussmeters makes possible accurate measurements of magnetic fields at liquid helium temperatures. The sleeve is designed for the types 829S, 729S, 820S and 720S gaussmeters (all 50-in. probe lengths). It consists of three concentric tubes: a) a thin-walled outer tube having an o-d of ⅞ in., the main length of which is nonmagnetic stainless steel for minimum heat transfer, but there is an 8-in. length of copper at the tip so it will be truly non-magnetic near the rotating coil; b) an inside tube of 0.450 in. i-d copper, to contain the probe; c) a third tube of aluminum between the other two, to act as a heat radiation shield. A vacuum valve and connection are provided for evacuating the space between the tubes. Only a moderate vacuum is required for operation in liquid helium, since the remaining gas between the tubes will soon freeze out, leaving an almost perfect vacuum. This will keep the gaussmeter tip from further cooling for an indefinite period. Price of the sleeve is $450. Prices for complete cryogenic gaussmeters, with limit of measurement to 100 kg, range from $975 for type 720S (transverse fields, 1% accuracy) to $1,725 for type 829S (axial and transverse fields, 0.1% accuracy).

Rawson Electrical Instrument Co., 110 Potter St., Cambridge 42, Mass. **[355]**

Electrometer features high input impedance

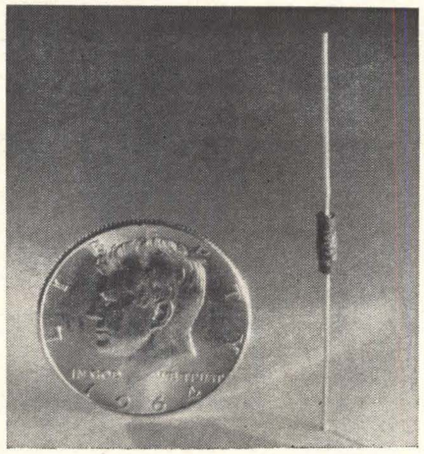
Model 610B electrometer offers 79 ranges for d-c measurements; 11 voltage ranges from 1 mv full scale to 100 v; 28 current ranges from 10^{-14} amp full scale to 0.3 amp; 25 resistance ranges from 100

ohms full scale to 10^{14} ohms; 15 coulomb ranges from 10^{-12} coulomb full scale to 10^{-5} coulomb. The instrument uses solid-state components except for two electrometer tubes and one other vacuum tube. This results in high stability, sensitivity and accuracy. Applications include directly measuring potentials of vacuum-tube plates and grids, pH electrodes, piezoelectric crystals, capacitors, electrochemical cells and gate potentials of field effect transistors. Price is $565.
Keithley Instruments, Inc., 12415 Euclid Ave., Cleveland, O. **[356]**

Test sets measure transistor noise

Three new noise test sets offer an economical, convenient means for making rapid measurements of electrical noise in transistors as an aid to elimination of failure-prone devices prior to installation as well as to achieve optimum signal-to-noise ratio. They are intended for those applications where the full multipoint spectrum analysis of noise is not required, for example in production testing, quality control and incoming inspection functions. Models 510, 511, and 512 have collector-current ranges of 0.1 to 10 ma, 3 to 300 μa, and 10 μa to 1 ma, respectively. Noise voltage and current spectral densities are measured in the models 510 and 511 at 1 kc. In the model 512, broad-band noise figure measurements are made over a frequency range from 10 cps to 15.7 kc. All of these instruments are readily adaptable to high-speed go/no-go test procedures, and may be easily integrated into existing component testing programs. Prices are: model 510, $1095; 511, $1145; 512, $1145.
Quan-Tech Laboratories, 43 S. Jefferson Road, Whippany, N.J. **[357]**

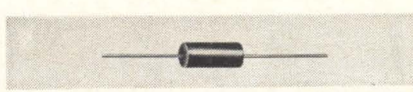
New Semiconductors



Silicon rectifiers in rugged package

Miniature plastic silicon rectifiers have been introduced that meet humidity requirements of MIL Standard 202A, Method 16. Series B silicon rectifiers are said to possess electrical ratings equal to or better than larger epoxy package types. Voltages to 1200 piv, currents to 1.5 amps and high-performance avalanche types are offered. Axial lead, tubular-insulated construction and small size facilitate circuit-board and point-to-point wiring needs in industrial and commercial power supplies. The ruggedness of the package permits reliable operation even with severe humidity and other environmental conditions. Weight is 0.4 gram, body length ⅜ in. and diameter 0.115 in.

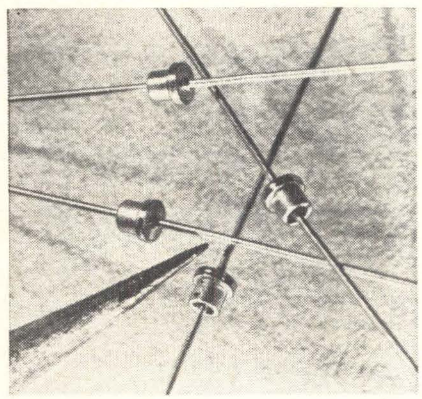
Edal Industries, Inc., 4 Short Beach Rd., East Haven, Conn. [331]



Silicon varactor diodes for shifting frequencies

New silicon abrupt-junction varactor diodes provide the circuit designer with a wide choice of characteristics, including: Qs to 200, low frequencies through microwave frequencies, capacitances from 6.5 to 500 pf, working voltages from 15 to 200 v, power ratings from 0.5 to 2.0 w, and low inductance. The epitaxial varactor diodes are expected to find wide application in communications for shifting frequency and in electronic tuning, harmonic generation and parametric amplification. The products are intended for both commercial and military applications.

Solitron Devices, Inc., 500 Livingston St., Norwood, N.J. [332]



Silicon tunnel diodes feature high stability

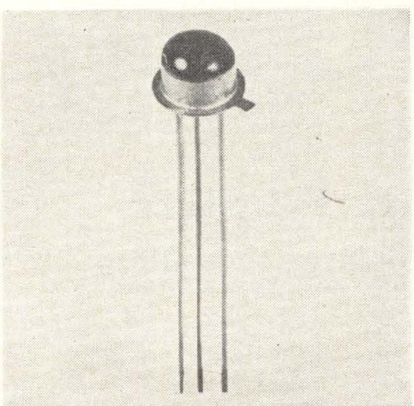
These silicon tunnel diodes consist of JEDEC types 1N4393 through 1N4399, with peak current ratings from 0.10 to 10 ma as well as other types with peak current ratings up to 100 ma. The devices offer extreme stability over a wide temperature range, and feature closely controlled electrical and mechanical tolerances. They are supplied in standard JEDEC TO-17 cases, and have gold-plated weldable leads for maximum installation flexibility. According to the manufacturer, environmental specifications easily meet the requirements of MIL-S-19500 or MIL-STD-750. The tunnel diodes are specifically designed for applications in low-level, high-speed switching circuits where operating temperatures may vary from −65°C to +150°C. They are also said to perform well in vhf-uhf oscillators, level detectors, event counters, and time delay circuits.

Heliotek, a division of Textron Electronics, Inc., 12500 Gladstone Ave., Sylmar, Calif. [333]

Silicon transistors in two power types

Silicon power transistors, both JEDEC series 2N3470 and 2N3429, are designed for amplifier, regulator and switching applications. They provide design advantages to circuits having inductive loads. The 2N3470 series has a rated collector current of 10 amps and is available with collector-emitter voltages through 200 v. The device has a peak power of 2 kw and can produce gains of 1,000 at 2 amps. The 2N3429 series has a rated collector current of 7.5 amps and collector-emitter voltages through 250 v. Its peak power is 1.8 kw. Both transistors are free from secondary breakdown within the complete range of maximum current, maximum voltage ratings. The devices are 100% power tested; thus derating for actual operating conditions is not required. They are guaranteed for the life of the original equipment in which installed.

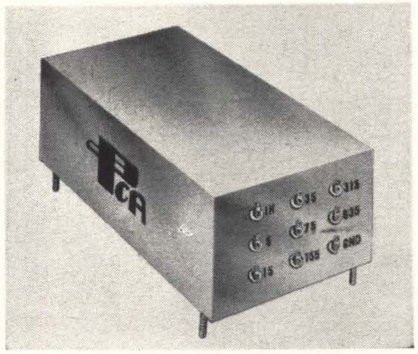
Westinghouse Electric Corp., Semiconductor Division, Youngwood, Pa. [334]



Low-noise transistor designed for uhf tv

This high-frequency, low-noise transistor is an improved npn silicon type, packaged in a modified TO-18 outline. It is designed primarily for uhf television and commercial uhf amplifier applications. Power gain measures 15 db at 200 Mc. Noise factor is 4 db at 60 Mc. Oscillator power is 5 mw at 930 Mc. Maximum power dissipation is 0.5 w at 25° C.

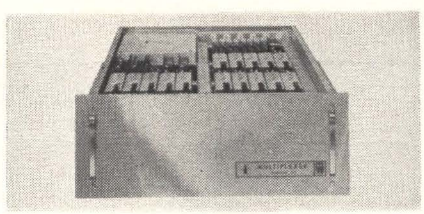
Kmc Semiconductor Corp., Parker Road, R.D. 2, Long Valley, N.J. [335]



Telemetry delay line covers f-m band

A subcarrier delay line featuring a delay bandwidth product of over 50 and a delay time of 635 μsec, is designed to cover the entire f-m telemetry band from 400 cps to 80 kc with only 3 db of attenuation. Taps are provided at 5, 15, 35, 75, 155 and 315 μsec to a tolerance of $\pm 1.5\%$. Impedance is 1,000 ohms. Measuring 15 in. in length, 6 in. high, and 9 in. wide, the unit is mounted by means of four ¼-in. studs projecting from the bottom of a hermetically sealed can. Price is under $2,000 each.

PCA Electronics, Inc., 16799 Schoenborn St., Sepulveda, Calif. [371]



Analog subsystem in miniature package

A miniature analog subsystem has been developed for low-level data acquisition. The new 625 Min M_x incorporates an amplifier, filter and multiplex switch on a single card and costs less than $450 per channel. Features of the system include the following: a precision, low-level differential amplifier with six selectable gain positions, and with an accuracy, linearity and stability of $\pm 0.01\%$; an active filter which rejects the amplifier, wideband noise, and low-level signal source frequencies that may cause errors resulting from distortion; and a multiplex switch that can be operated at d-c to 50 kc (randomly). Thirty-two channels can be packaged in a box measuring 7 in. by 19 in. by 22 in.

Redcor Corp., 7760 Deering Ave., Canoga Park, Calif. 91304. [372]

Tape subsystems for large computers

A line of six computer magnetic tape units has been introduced. All are available in seven and nine-channel models and will operate with the recently announced Compatibles-400 and the new large-scale Compatibles-600 computers. Employing vacuum-grip drives and photocell protective devices, the new tape units are designed to virtually eliminate the inconvenience and expense of broken, scratched and stretched magnetic tape. Nothing but the read-write head touches the oxide side of the tape. Two basic tape-handling mechanisms are used in the six models: a single-capstan, low-inertia drive for tape transfer rates from 7,500 to 80,000 characters per sec; and a multiple-capstan, constant-speed drive (shown above) for the high-

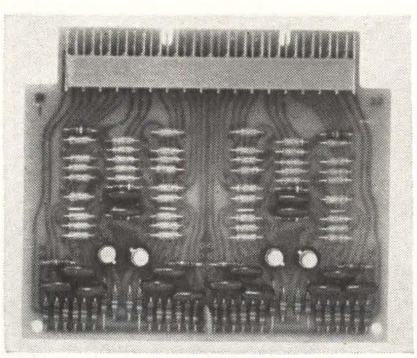
performance range up to 160,000 characters per sec. Prices range from $100,000 for a minimum rational magnetic tape subsystem, through $80,000 for a large multichannel subsystem with monthly rentals from $2,000 to $20,000. Deliveries take eight months.
General Electric Co., Deer Valley Park, Phoenix, Ariz. **[373]**

Pulse generator for diode lasers

New pulse source has been designed especially for use with gallium arsenide diode laser systems. Model DLP-2 has a rated peak output of 300 amps, with a nominal pulse width of 10 nsec and a rise time of 1 nsec. The unit can be internally or externally triggered, or operated in a single-shot manner. With internal triggering, the pulse repetition rate can be continuously varied from 10 to 200 pulses per sec. With external timing, it can be varied continuously from zero to 200 pps. A special feature of the DLP-2 is the fact that it permits room temperature operation of the diode laser. Price of a single unit is $695.
Maser Optics, Inc., 89 Brighton Ave., Boston 34, Mass. **[374]**

Multifunction-register universal flip-flops

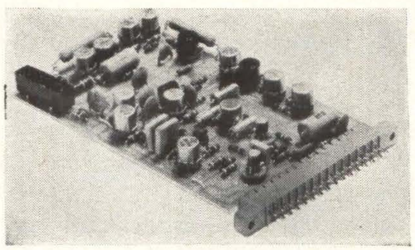
The UF universal flip-flop series of digital logic cards are designed for use in multifunction registers such as add-subtract counters, preset counters, digital programers, time clocks and digital servo controls. They can count in any number base, up and down, and can shift either left or right. Six models are



New Subassemblies

available: UF-1, with frequency range d-c to 300 kc; UF-2, to 2 Mc; UF-1A, to 5 Mc. For asynchronous systems, models UF-3, UF-4 and UF-3A correspond in frequency to the three synchronous models UF-1, UF-2, and UF-1A. Each card contains two independent flip-flops. Each flip-flop has three set gates ORed together and three reset gates ORed together. By wiring at the connector, any three of the four functions—count up, count down, shift left, shift right—may be performed. Two set gates and two reset gates are internally "steered" by diodes from the collectors, and trailing-edge clock-triggering is used. Thus no "race" condition can occur and reliable operation is assured.

Computer Logic Corp., 11800 W. Olympic Blvd., Los Angeles 90064. **[375]**



Operational amplifier is chopper-stabilized

A series of inexpensive, general purpose amplifiers has been announced. Employing solid-state chopper stabilization, the 140 series units are designed for use in automatic production checkout systems where heavy capacitive loading is anticipated. All versions have ± 20 v output range and gain of 10^6. Drift is within 5 μv/°C with input current of only 10^{-11} amp/°C. Full output to above 125 kc and a slewing rate of 12 v per μsec makes the amplifiers useful in high speed digital-to-analog conversion. Maximum load current is 100 ma, and all units are short-circuit proof. Chopper drive is internal, and the amplifiers require only ± 24 v d-c for operation. Price is $125.

Zeltex Inc., 2350 Willow Pass, Concord, Calif. **[376]**

New Microwave

Octave bandwidth directional couplers

Series CSD octave bandwidth directional couplers are available in coupling values of 6, 10, 15 or 20 db. They offer 15 db minimum of directivity over frequency bands of 250 to 1,000 Mc, 750 to 3,000 Mc, or 1,000 to 4,000 Mc. Units are light, small and of rugged encapsulated design with reliable performance over a broad frequency band. Price is $120.
LEL, Inc., 75 Akron St., Copiague, N.Y. [391]

Parametric amplifier designed for L-band

A commercial, nondegenerate type parametric amplifier is announced with a noise figure of 0.9 db without diode cooling. Fixed-tuned to 1,667 Mc for observation of oxygen-hydrogen-line radiation from distant galaxies, the model L-5 increases detection range more than three-fold over techniques now in use, according to the manufacturer. The amplifier is also suited, through modification, for use wherever a low-noise amplifier will aid performance as in telemetry, satellite communication, or radar. Heart of the model L-5 paramp is a silicon varactor diode with very high cut-off frequency. The diode's figure of merit is said to be considerably greater than that of varactors commonly employed in L-band parametric amplifiers. To utilize effectively the low-noise amplification properties of the diode, a pump frequency of approximately 24 Gc is required, resulting in a pump-to-signal frequency of 14:1. Tuned filters are incorporated in the microwave structure to isolate the signal, pump and idler circuits from each other. The L-5 displays a 30 Mc 3 db instantaneous bandwidth at 20 db gain with a single-tuned signal input circuit.
Microwave Physics Corp., 420 Kirby St., Garland, Texas. [392]

Power source for microwave tubes

A hard tube pulse modulator has been developed that is suitable for pulsing triodes, tetrodes and magnetrons. Model MH20 has continuously variable pulse voltage up to 4.5 kv at 5 amps and filament voltage variable to 7 v at 4 amps. Pulse width is continuously variable from 0.25 to 6 μsec and rate from 200 to 4,000 pps. Internal and external synchronization are provided as well as metering, viewing, overload and safety features.
Applied Microwave Laboratory, Inc., 106 Albion St., Wakefield, Mass. [393]

Coax terminations cover d-c to 12.4 Gc

Miniature coaxial fixed terminations —models 4370 M/4370F—cover a broad sweep of d-c to 12.4 Gc and

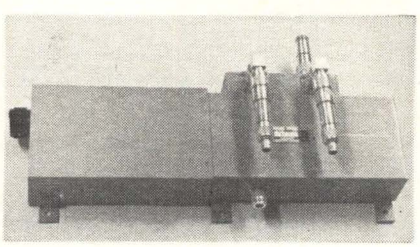
feature NPM connectors that can be mated with 0.141 in. coax line connectors. Critically controlled close tolerances afford improved vswr over a wide range of frequencies: d-c to 8 Gc, 1.10 max; 8 to 12.4 Gc, 1.15 max; and 10 to 12.4 Gc, 1.20 max. The terminations are approximately $\frac{13}{16}$ in., lightweight, with ½-w power rating. Price is $30.

Narda Microwave Corp., Plainview, L.I., **[394]**

Tunnel-diode receiver for X-band applications

An all-solid-state, tunnel-diode receiver has been developed for microwave applications in X-band. It consists of a tunnel-diode amplifier, a mixer-preamplifier and a main i-f amplifier. The main i-f amplifier exhibits approximately 90 db of gain and has a peak holding type of automatic-gain-control network. The charging time constant is 0.05 millisec and the discharging time constant is 150 millisec. The center frequency is 9.7 Gc ±50 Mc with an i-f of 30 Mc. Noise figure is 5.5 db; gain, 125 db; i-f bandwidth, 1 Mc; output impedance, 50 ohms; agc, 40 db; local oscillator power, 2 mw; and maximum power drain, 3 w. The receiver weighs less than 2 lb and has a cubic volume of only 20 in. It is suited for space or aircraft applications where size, weight and reliability are at a premium.

International Microwave Corp., subsidiary of Microwave Associates, Inc., Burlington, Mass. **[395]**



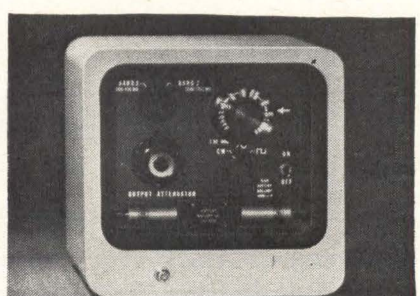
Preselector-mixers span 250 Mc to 10 Gc

Tunable preselector-mixers cover the range 250 Mc to 10 Gc in six units and exhibit a relatively constant bandwidth for a fixed noise figure over the tuning range. They are ready for plug-in to a receiver for rejection of image frequencies and to provide a minimum noise figure for optimum receiver performance. The preselector is normally a two-section filter that is tuned by means of a single control shaft for remote tuning or easy manual adjustment. Additional sections can be provided to improve selectivity. The mixers are stripline devices that incorporate balanced hybrids with matched crystals to achieve the best noise figure and match between the filter and mixer. They can be furnished in single or double-ended types with crystal current monitoring. Noise figure is 8 db at 2 Gc and up to 12 db maximum at 10 Gc. Maximum vswr is 1.5. Price is approximately $1,600.

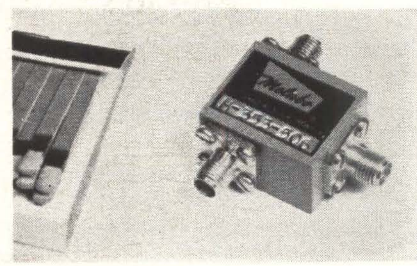
Frequency Engineering Laboratories, Farmingdale, N.J. **[396]**

Signal sources are solid-state

Two signal sources offer new standards of frequency and power stability for testing, aligning and measuring communications and radar systems. The c-w model DG502 and pulse model DG503 are both solid-state sources with an output frequency drift less than ±0.0015% over the entire working temperature range of −7°C to 70°C. Crystal control and high efficiency harmonic generation are the key to this frequency and power stability. Unlike klystron signal sources, output power of these solid-state models does not drop or change transmission modes with age. Also, frequency does not drift widely with small power supply voltage variations. Bulky high-voltage power supplies are not required. Units operate with maximum output power capabilities from 0.1 to 10 mw. Dual band models offer up to 12 fixed frequencies within the two bands—400 to 450 Mc and 1,200 to 1,320 Mc. All models measure 12 in. by 12 in. by 8 in., and weigh 25 lb.



Sanders Associates, Inc., 95 Canal St., Nashua, N.H. **[397]**



Small and light ferrite circulator

A three-port ferrite circulator is available for use in the 4.4 to 5.0-Gc range. Especially useful for space and airborne applications, the model H-353-506 circulator has a minimum isolation of 20 db, maximum insertion loss of 0.3 db, and maximum vswr of 1.2. Designed in a T configuration, the circulator is only $\frac{27}{32}$-in. long, ⅞-in. wide, and ⅝-in. high, excluding the length of its OSM connectors. It weighs 1 oz. The unit also is available with one port terminated for service as an isolator.

Melabs, 3300 Hillview Ave., Stanford Industrial Park, Palo Alto, Calif. **[398]**

Balanced mixers save weight and space

Subminiature balanced mixers are designed to replace previous types weighing over 20 times as much and having over three times the volume. Series CM504 single-ended mixers are available in both S band and C band with a 20% bandwidth. They have typical noise figure of 8 db and a conversion loss of 7 db.

The Tri-Plate mixers are of interest to microwave design engineers where weight and space saving are of vital concern in receivers, and antenna front-end applications. The new mixer weighs less than ½ oz and is 1½ in. in diameter with a body thickness of approximately ⅛ in. Total thickness is less than ½ in. including miniature coax connectors. Semiconductor components are shielded by the ground plane and the leads are clamped between the inner surfaces of the dual center conductors to provide a stable clamped contact on the lead wire right up to the component body for optimum control of inductance. The crystal, chokes, resistors and capacitors are all of the most advanced microminiature type according to the manufacturer. Unit price is $390. In production quantities the unit price is approximately $150.

Sanders Associates, Inc., 95 Canal St., Nashua, N.H. **[399]**

Traveling-wave tube for uhf-tv transmitters

A high-efficiency traveling-wave tube is offered as a video driver amplifier and as an audio output amplifier in uhf-tv transmitters. The VA-651 twt delivers a c-w output of at least 275 w over the frequency range of 450 to 900 Mc, with a minimum efficiency of 21% and a mid-band efficiency of approximately 33%. The tube and integral focusing electromagnet are cooled by forced air, thus simplifying the design of the transmitter. Only a single forced-air supply is required, with the air entering the focus magnet at the cathode end of the tube, discharging through the finned collector. Uhf color tv transmitter phase and amplitude linearity requirements are met by the VA-651.

Varian Associates, 611 Hansen Way, Palo Alto, Calif. **[400]**

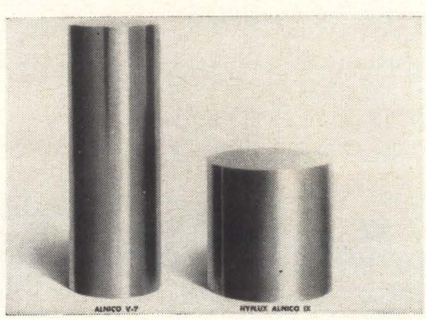
New Materials

Polyurethane resin for component potting

A new polyurethane resin, No. 8788, is said to have unusually low initial viscosity for potting electronic components. Pot life for a half-pound mass is at least 60 minutes at room temperature. The compound is recommended for dip-coating of p-c boards and welded modules to provide maximum protection where a minimum number of coats is desirable. In the cured state, this resin has high electrical and physical properties, plus excellent solvent and abrasion resistance. Its high mechanical resilience protects against extremes in vibrational shock. Properly cured, the compound withstands temperatures up to 250°F without deterioration or loss in electrical properties. At 77°F, the formulation has a Shore A hardness of 80, a tensile strength of 3,000 psi, and elongation of 600% minimum. Mold release time is 2 hours at 180°F, and cure time to Shore A hardness is 6 hours. When degassed, the compound forms void-free castings. Application is by pouring at room temperature, or by dipping or brushing.
The Epoxylite Corp., 1428 N. Tyler Ave., S. El Monte, Calif. **[411]**

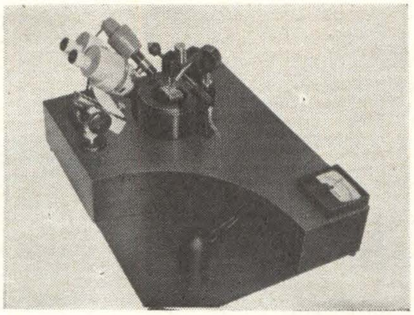
Magnet material offers high energy product

A new permanent magnet material, Hyflux Alnico IX, achieves an energy product of up to 9.5 million and a coercive force of at least 1,400 oersted. The previous energy leader, Alnico V-7, has a typical value of 7.5 million, according to the manufacturer. Alnico IX is a premium magnet material developed for critical applications requiring a minimum of size and weight, a maximum level of energy and extreme resistance to demagnetization. Typical applications include straight field focus devices, ppm twt stacks, high performance holding, repulsion and torque transmitting devices, specialized motors, generators and alternators. Residual induction (typical) of Alnico IX is 10,500 gauss; peak magnetizing force, 3,000 oersted; and permeance coefficient, 7.0 to 7.5.
Indiana General Corp., Valparaiso, Ind. **[412]**



Potting compounds cure at room temperature

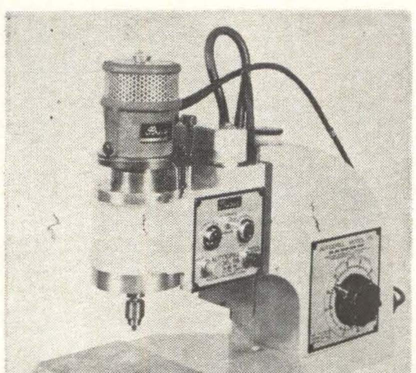
Two new potting compounds for electronic components and assemblies feature a color indicator that guards against errors in mixing the two components. They cure at room temperature, and combine favorable electrical properties with extremely low shrinkage. The transparent Microcast 200 has a shrinkage factor of less than 0.1%, a continuous service temperature of −70°C to +150°C, and a pouring viscosity of 2000 centipoise. Microcast 203, with shrinkage of less than 0.05%, is a more rigid, mineral-filled compound featuring high heat conductivity and continuous service temperature of −55°C to +180°C. Both of the new materials are packaged in a pair of tubes or cans from which equal amounts, either in weight or volume, are extracted prior to application. Proper mixing produces a green color, indicating that the compound is ready for application. The compounds will harden at room temperature within several hours, or heat may be applied to further speed the curing process. Microcast 200, in a 4-oz trial kit, is available for $4.90. The comparable kit price for Microcast 203 is $5.40.
Electro-Science Laboratories, Inc., 1133 Arch St., Philadelphia. **[413]**



Fine-wire bonder for microcircuits

A new thermocompression fine-wire bonder for microcircuits is announced. A grip/snap action that eliminates hand-tweezering of wire pigtails, and one-knob control of both the X-Y position and rotation of the workpiece are two features that permit high production rates. Aluminum or gold wire can be bonded. Model MT measures 20 in. by 24 in. and, including optics, is priced at $2,450.

Axion Corp., New Fairfield, Conn. **[421]**



Compact drill with variable speeds

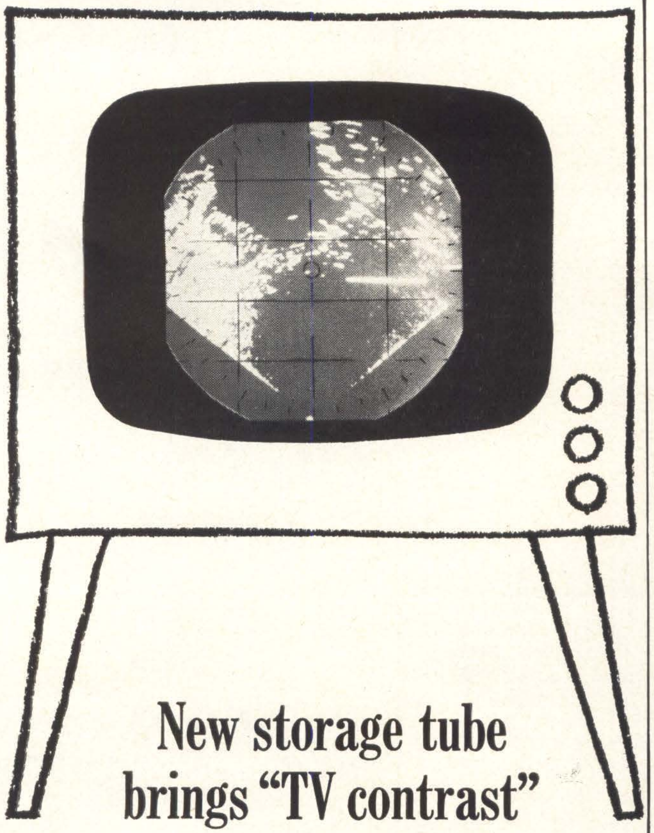
The Autodrill has spindle speeds varying from 10,000 to 45,000 rpm and built-in variable speed control. According to the manufacturer, the ½ hp electric-powered unit is designed for short-run circuit board drilling, for drilling in plastic or non-ferrous metals, and for accurate burr-free drilling in ferrous metals. Model 65 is compact, simple to operate and easy to maintain. It features adjustable controlled infeed from 0 to 120 inches per minute; adjustable rapid traverse, and built-in Vapor Lub cooling unit.

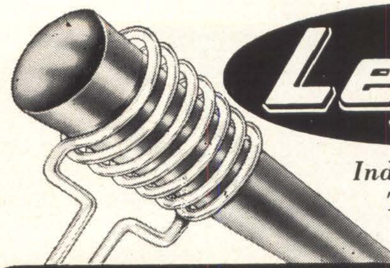
Precise Products Corp., Blue River Road, Racine, Wisc. **[422]**

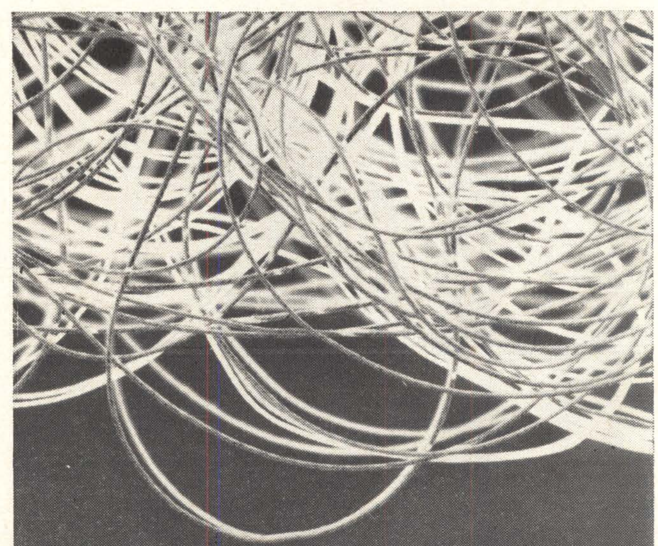
Portable marking kit for metal surfaces

A portable kit is announced for electro/chemical etching metal parts with permanent inspection codes, parts numbers, trade names and marks. The kit may be used anywhere that 110 v, 60 cycle a-c power is available. The Lectroetch process produces a sharply defined mark on any metal surface by controlled electrolysis. The kit includes a low-voltage power unit; also electrolyte fluid, a liquid cleaner, and stencil stock which can be processed with the desired mark by the user. Appliances include choice of several hand pads for use with a ground plate. A bench fixture also is furnished. A mark is produced in several seconds, with the optional choice of clear or dark contrasting marks. The completely self-contained kit meets the need for a tool crib-type of service that allows equipment to be released on requisition. For production marking service, it requires a bench area of only 25 in. deep by 18 in. wide by 15 in. high.

Lectroetch Co., 14925 Elderwood Ave., East Cleveland 12, O. **[423]**






ELIMINATE CONFUSION WITH LTCo
ELECTRONIC LACING TWINES & TAPES

New Literature

Piezoelectric quartz crystals. Lenkurt Electric Co. San Carlos, Calif. Vol. 13, No. 7 of the Demodulator contains an illustrated article on the properties and uses of piezoelectric quartz crystals. Circle **451** on reader service card

Pressure transducer. Crescent-East Electronics Corp., 363 W. Glenside Ave., Glenside, Pa. Catalog CE-52 gives technical data on a transducer designed to perform precise gage, absolute or differential measurements in the low—pressure ranges. **[452]**

Zener and reference diodes. Motorola Semiconductor Products, Inc., P.O. Box 955, Phoenix, Ariz. 85001, is offering a 19-page cross reference and interchangeability guide for zener and reference diodes. **[453]**

Data sorter. Astrodata, Inc., 240 East Palais Rd., Anaheim, Calif., has available a 6-page brochure describing the model 1500 data sorter. **[454]**

Industrial coil catalog. J. W. Miller Co., 5917 S. Main St., Los Angeles. Catalog 64A describes r-f and i-f coils, chokes, filters and transformers. **[455]**

Circuit breakers. Wood Electric Corp., 244 Broad St., Lynn, Mass., has issued a 20-page catalog describing the latest models in thermal and magnetic circuit breakers. **[456]**

Casting resins. Emerson & Cuming, Inc., Canton, Mass. An updated quick-reference chart for notebook or wall mounting describes the line of Stycast encapsulating and potting resins. **[457]**

Delay lines. Andersen Laboratories, 501 New Park Ave., West Hartford, Conn. Electrically variable delay lines are described and illustrated in a two-page bulletin **[458]**

Microminiature amplifiers. Advanced Products, Loral Electronic Systems, a division of the Loral Electronics Corp., 825 Bronx River Ave., Bronx, N.Y. Amplifiers in microminiature i-f, .i-f video, video or standard packages are described in a 4-page catalog. **[459]**

Solid-state amplifiers. Melcor Electronics Corp., 1750 New Highway, Farmingdale, L.I. A two-page data sheet describes a line of solid-state, differential operational amplifiers. **[460]**

Sweep oscillators. PRD Electronics, Inc., 202 Tillary St., Brooklyn, N.Y. 11201, offers a two-page data sheet describing its 720 series of sweep oscillators. **[461]**

Laser systems. Lear Siegler, Inc., Laser Systems Center, 2320 Washtenaw, Ann Arbor, Mich. A brochure covers a line of advanced laser systems that can be furnished for either burst-type or Q-switched operation. **[462]**

Miniature power transformers. Torwico Electronics, Inc., Lakewood, N.J., has available a 36-page catalog on custom-built Tinymax 400-cycle miniature power transformers. **[463]**

RFI gasket material. Technical Wire Products, Inc., 129 Dermody St., Cranford, N.J. Data sheet RF-204 describes Teckfelt, an easily cut material for gasketing complex joints against radio-frequency interference. **[464]**

Pulse generators. Tempo Instrument Inc., East Bethpage Road, Plainview, L.I. A technical data sheet describes low-frequency, high-power, variable-time pulse generators for industrial applications. **[465]**

Microwave filters. Loral Electronic Systems, a division of Loral Electronics Corp., 825 Bronx River Ave., Bronx, N.Y. 10472, has published a 4-page catalog on a line of YIG electronically tunable microwave filters. **[466]**

Tin oxide resistors. Corning Electronics, Raleigh, N.C. A 6-page folder describes nearly every glass tin oxide film resistor made by the company for general-purpose, precision, power and high-reliability applications. **[467]**

Glass regulators. The National Transistor Division of ITT Corp., 500 Broadway, Lawrence, Mass. Data sheet B-123 lists characteristics and specifications for approximately 100 EIA-registered glass silicon voltage regulators. **[468]**

Precision attenuators. Microwave Development Laboratories, Inc., 87 Crescent Rd., Needham Heights, Mass. Preliminary bulletin AP-1 describes in detail a series of fixed precision attenuators covering EIA waveguide sizes WR51 to WR112. **[469]**

Fiber optics displacement detector. Mechanical Technology, Inc., Latham, N.Y. 12110. An 8-page brochure describes the fiber optics technique used in the Fotonic Sensor for observing vibration and displacement at frequencies to 100 kc. **[470]**

Harness tying method. Thomas & Betts Co., 36 Butler St., Elizabeth 1, N.J. High-speed tying, clamping and identification of wire bundles and harnesses through the use of Ty-Rap ties, straps and accessories is the subject of technical bulletin T-75. **[471]**

Microwave spectrum analyzer. Lavoie Laboratories, Inc., Morganville, N.J. has issued an illustrated catalog sheet on the LA-22 solid-state microwave spectrum analyzer. **[472]**

Magnetoresistance multipliers. American Aerospace Controls, Inc., 123 Milbar Blvd., Farmingdale, L.I. A 7-page application note analyzes the drive requirements of new magnetoresistance analog multipliers. **[473]**

New Books

Electronics, basic & industrial

Standard Electronics Questions and Answers. Steve Elonka and Julian L. Bernstein, McGraw-Hill, Inc., New York, 1964 2 vols., 452 pp., $15.95 set

For the intelligent layman, the technician or technologist whose primary field is other than electronics, this two-volume set is an excellent introduction to the subject and a useful reference. The text is written in a question-and-answer fashion, so that each answer, of one or more paragraphs, defines and describes one specific topic, unit, circuit or component.

The questions and answers are well illustrated, where necessary, with formulas, examples and diagrams. They are organized by subject matter under chapter headings in conventional introductory-text style: direct current, alternating current, tubes, amplifiers etc. The question-and-answer method, coupled with a detailed index, makes it very easy to quickly find any subject.

While the first volume deals with basic electronics, covering the essentials of electricity, basic components and most common circuits, the second volume is on industrial applications. Its chapter headings include oscillators, special circuits, transducers and sensors, control systems, closed-circuit and color tv, industrial processes and devices, and test equipment. Under these headings, some very up-to-date topics such as magnetic core memories, other computer components, and digital circuits are qualitatively described.

A certain amount of confusion is caused by the title, which implies that the questions and answers included are in some way standardized or accepted in the industry. This is not the case; the format of the set has been adapted from similar series published in the plant operation, refrigeration and heating fields, where standard examinations for technicians do exist. Similar standardization in the electronics industry has yet to come.

George V. Novotny
Advanced Technology Editor

Space electronics

Inertial Guidance Sensors. J.M. Slater Reinhold Publishing Corp., New York, 1964, 221 pp., $11.

J. M. Slater has written a general primer on inertial guidance sensors. He has chosen to emphasize the fundamental technology of conventional gyroscopes and conventional accelerometers; in these areas, he has written an illuminating basic work.

It is stated that the book is aimed at meeting the needs not only of those who "invent and design sensing instruments, but also of those who incorporate them into systems". This reviewer takes issue with the statement, for though the book clearly serves a useful purpose in introducing the nonspecialist to the subject, it has limited value to those who have been exposed to these well documented fields.

The organization of the book is sound; it is well illustrated with easily understandable and meaningful diagrams.

However, as the reader proceeds into the more modern and more esoteric areas, the treatment grows rather sketchy. Coverage of the various three-axes-of-freedom devices in Chapter IV consists of 30 pages; Chapter V on vibrating-mass gyros has 10 pages, and Chapter VII on particle gyros only seven and a half pages. There is simply not enough detail given on these instruments to deal with them with any degree of perception. What is most regrettable, however, is that a well-selected and even annotated bibliography is missing; a total of only 80 bibliographical items are scattered through the volume. A large and unified bibliography would fulfill one of the most important functions of any introductory work: to guide, point, and to lead the reader to a higher level of understanding.

The subject of inertial guidance sensors is complex and difficult. Nonetheless this treatment is concise, and, for the uninitiated, valuable.

J.T. LaVan
Martin Co.
Baltimore, Md.

Technical Abstracts

Weldable motherboards

New developments in weldable electronic circuit boards. Richard B. Washer, General Electric Co., Utica, N.Y.

The printed-wiring board's popularity has not diminished in the swing to microcircuits. It is still a basic interconnection medium, although the use of microelectronics requires new joining techniques and materials. Instead of the familiar dip soldering, welding joins component leads to conductors on the boards. Also, to pack more circuits onto a given board area, the familiar single-sided boards have given way to double-sided boards and multilayer boards.

One of the newer welding methods is parallel-gap or surface circuit welding, which makes the welds on the top side of the leads. Two electrode tips touch the lead surface, and some of the current passing between the tips is shunted through the conductor, fusing it to the lead.

This technique permits closely spaced, easily inspected welds, but it doesn't work well on copper conductors. To improve weldability, conductors are terminated in tabs of high-resistivity metal or special clad conductors. One such material is a sandwich composed of nickel for the weldable surface, iron to insulate the board from welding heat, and aluminum to provide a good bond to the epoxy board.

A preferred type of board is the laminated multilayer board, with weldable conductors in the exposed layer and copper in the internal layers. Besides providing greater freedom of interconnection design than do single- or double-sided boards, multilayer boards avoid the tight production tolerances that are required to get close spacing on regular boards.

An experimental alternative to plated-through holes for interlayer connections is the step-weld. Holes of progressively different lengths are punched in each layer, forming steps. A weldable ribbon then runs down the steps, interconnecting the conductors on each layer. After welding, the layers are laminated with resin. Resin overflow encapsulates the interlayer connections. Copper, however, cannot be used for the internal layer conductors.

Presented at the National Electronic Packaging and Production Conference, New York, June 9-11.

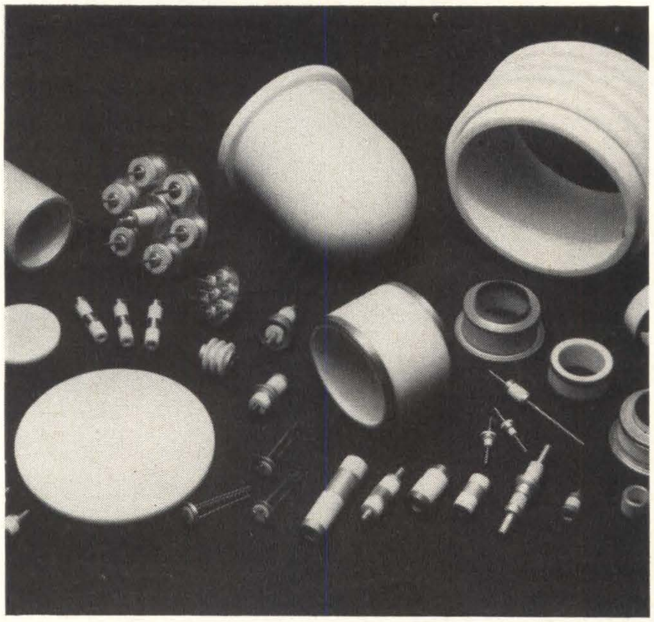
FETs for a-m radios

Designing FETs and MOSTs into a-m radios. Larry Blasser and Earl Cummins, Semiconductor division of Fairchild Camera and Instrument Corp., Mountain View, Calif.

The relative simplicity of the field-effect transistor (FET) and the metal-oxide transistor (MOST), their high input impedance and electrical characteristics that are similar to vacuum tubes, suggest the use of these devices in the radio-frequency stage of a-m radios. FETs and MOSTs are smaller than vacuum tubes and have lower power requirements. In addition, they reduce automatic-gain-control power requirements and obtain better cross-modulation performance than is possible with r-f stages using bipolar-junction transistors.

The Fairchild 2N3277 FET has a p-type channel between the source and drain. With the gate at source potential and an increasing negative voltage applied to the drain, the voltage gradient in the conductive p-channel creates a depletion region that reduces the cross-sectional area of the channel until a pinch-off condition is reached. Then the drain current becomes relatively independent of further increases in source-drain voltage, giving the FET its pentodelike characteristics. A drain voltage of -10 volts and a gate bias of zero volts puts the FET in the pinch-off or pentode region with the following characteristics: input gate capacitance of 2 pf, output drain capacitance of 0.5 pf, drain resistance of 1 meg, drain-to-gate feedback capacitance of 1.2 pf, and transconductance of 150 micromhos.

Performance data of an experimental a-m automobile radio that uses p-channel FETs in the radio-frequency stage and npn silicon planar bipolar transistors in the converter and intermediate-frequency stages is better than in the typical transistor radio. With ex-



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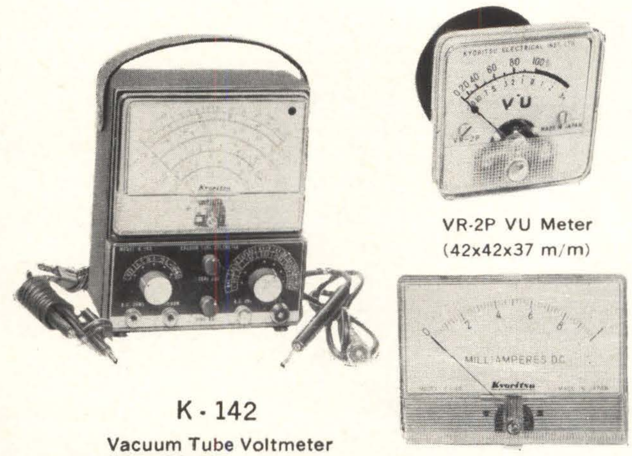

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pected improvements in device characteristics, such as lower feedback capacitance and higher transconductance, it is likely that FETs and MOSTs will be mass-produced for use in car radios and other consumer products, particularly since they are easily incorporated into integrated circuits that are becoming inexpensive enough to be attractive in entertainment applications.

Presented at the Chicago Spring Conference of the IEEE Group on Broadcast and Television Receivers, June 15-16.

New solid-state device

The surface controlled avalanche transistor. William Shockley and W.W. Hooper, Clevite Corp., Semiconductor Division, Palo Alto, Calif.

A new transistor structure has been designed which may make it possible to build transistors capable of amplification at frequencies in the 10-Gc range.

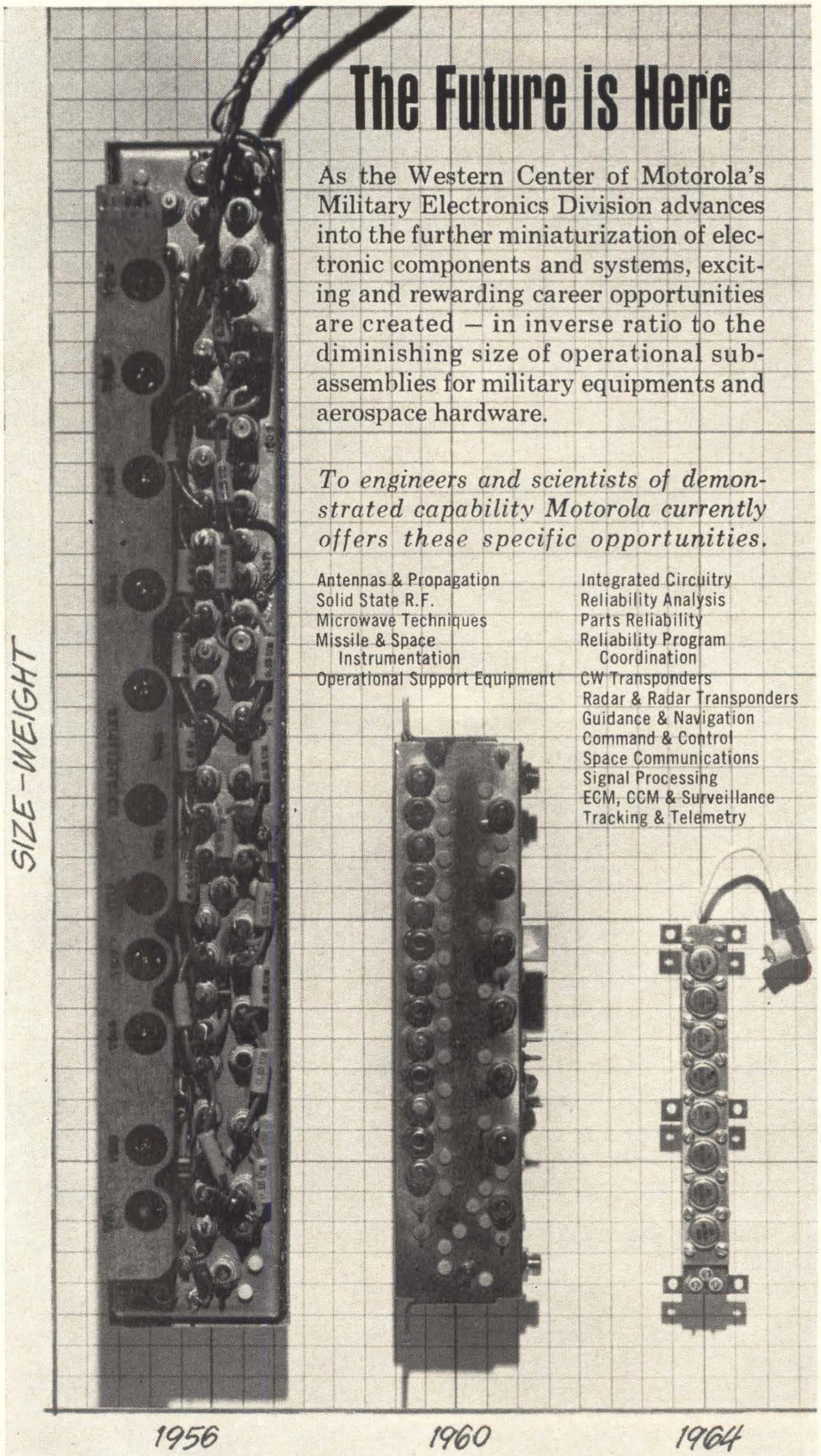
In one form, the new device consists of a silicon $(n^+)p$ junction covered with a thin insulating layer of SiO_2. The three electrodes are the source (an n^+ region), the drain (a p region), and the gate (a metal layer over the oxide and covering the intersection of the junction with the surface).

In the surface-controlled avalanche transistor, amplification results from controlling the avalanche breakdown of a p-n junction. A voltage is applied to an external electrode so that an electric field penetrates the semiconductor surface and extends into the space-charge layer. This field is modified by another field produced by the reverse bias across the p-n junction.

By varying these two fields, the voltage at which avalanche breakdown occurs across the junction may be controlled. In turn, the avalanche breakdown current and, therefore, the power delivered to a load in series with the junction is also controlled.

By using experimental units having low breakdown regions near the surface, it is possible to change the breakdown voltage by a factor of two. Current and power gains greater than 1,000 may be obtained at low frequencies.

Presented at the 1964 Western Electronic Show and Convention (Wescon), IEEE, August 25-28, Los Angeles.



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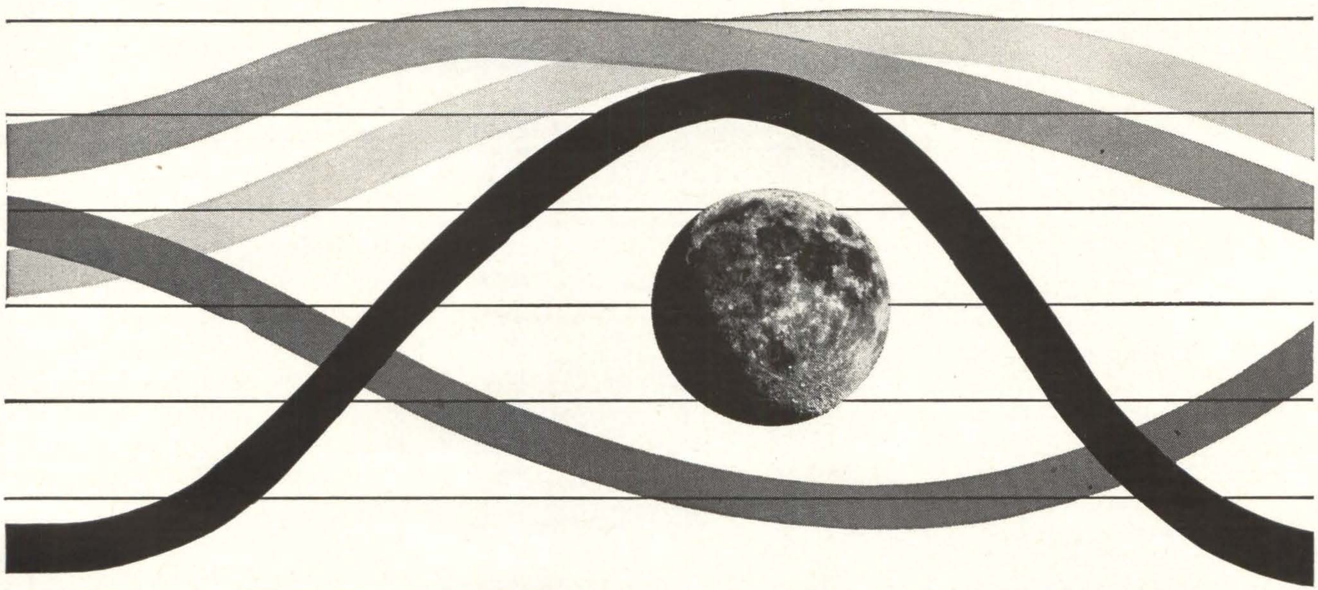

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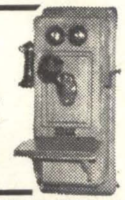

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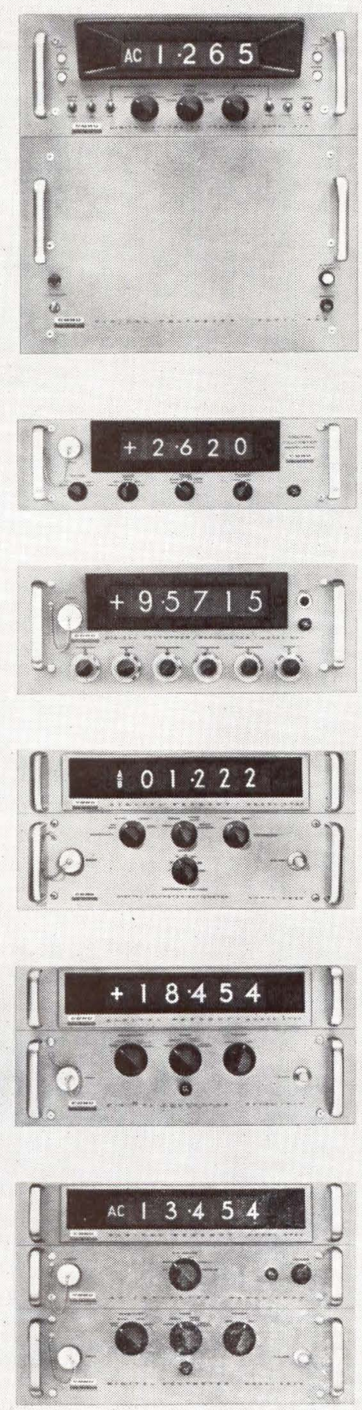

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▪ The maximum collector current (I_C) is selected on the basis of the power dissipation and speed compromise desired.

▪ The input diodes must be reverse biased by a minimum voltage V_R when all inputs are high; therefore, the following conditions must be satisfied:

$$V_{CC} - \frac{\mathbf{V}_{LL}\frac{\mathbf{R}_F}{R_L} + \mathbf{nI}_R\mathbf{R}_F + \mathbf{V}_{BE}}{1 + \frac{\mathbf{R}_F}{R_L}} \geqq V_R \qquad (1)$$

▪ When all inputs are high, the transistor should be on and saturated, or

$$\frac{V_{LL} - \mathbf{V}_{BE}}{\mathbf{R}_L + \mathbf{R}_F} - \frac{\mathbf{V}_{BB} + \mathbf{V}_{BE}}{R_B} \geqq \frac{\mathbf{I}_C}{h_{FE}} \qquad (2)$$

▪ When any one of the inputs is low, the transistor must be in a cutoff mode and its base-emitter junction must be reverse-biased by a minimum voltage V_B (off), or

$$\frac{V_{BB} - \mathbf{I}_{BEV}\mathbf{R}_B - (\mathbf{V}_{CE} + \mathbf{V}_F)\frac{\mathbf{R}_B}{R_F}}{1 + \frac{\mathbf{R}_B}{R_F}} \geqq V_B(\text{off}) \qquad (3)$$

▪ When the transistor is on, the maximum collector current is given by

$$\mathbf{I}_C = \frac{\mathbf{V}_{CC} - V_{CE}}{R_C} + \mathbf{m}\left[\frac{\mathbf{V}_{LL} - (V_{CE} + V_F)}{R_L} + (\mathbf{n}-1)\mathbf{I}_R - \frac{V_{BB} - \mathbf{I}_{BEV}\mathbf{R}_B + (V_{CE} + V_F)}{\mathbf{R}_B + \mathbf{R}_F}\right]$$

Therefore, the maximum fanout m is determined as follows:

$$\mathbf{m} = \frac{\mathbf{I}_C - \frac{\mathbf{V}_{CC} - V_{CE}}{R_C}}{\frac{\mathbf{V}_{LL} - (V_{CE} + V_F)}{R_L} + (\mathbf{n}-1)\mathbf{I}_R - \frac{V_{BB} - \mathbf{I}_{BEV}\mathbf{R}_B + (V_{CE} + V_F)}{\mathbf{R}_B + \mathbf{R}_F}} \qquad (4)$$

The value of the collector resistance R_C in equation 4 is selected as a compromise between fanout and speed, because the fall time of the voltage at the collector is almost directly proportional to the collector resistance, R_C.

The dynamic design of the diode-transistor logic circuit involves the determination of the values for C_F and L_C. The capacitance of C_F is determined by the amount of charge stored in the base region of the transistor, for which it must compensate.[2] The inductance L_C may be obtained by finding the value necessary for a critically damped output for maximum fanout.[3] The following design equations are used:

$$C_F \geqq \frac{\mathbf{Q}_s}{V_{CF}} \qquad (5)$$

$$L_C \geqq \left(\frac{\mathbf{R}_C}{2}\right)^2 \mathbf{mC}_o \qquad (6)$$

where Q_s is the total stored charge of the transistor, V_{CF} is the minimum voltage across C_F consistent with the conditions which establish Q_s,

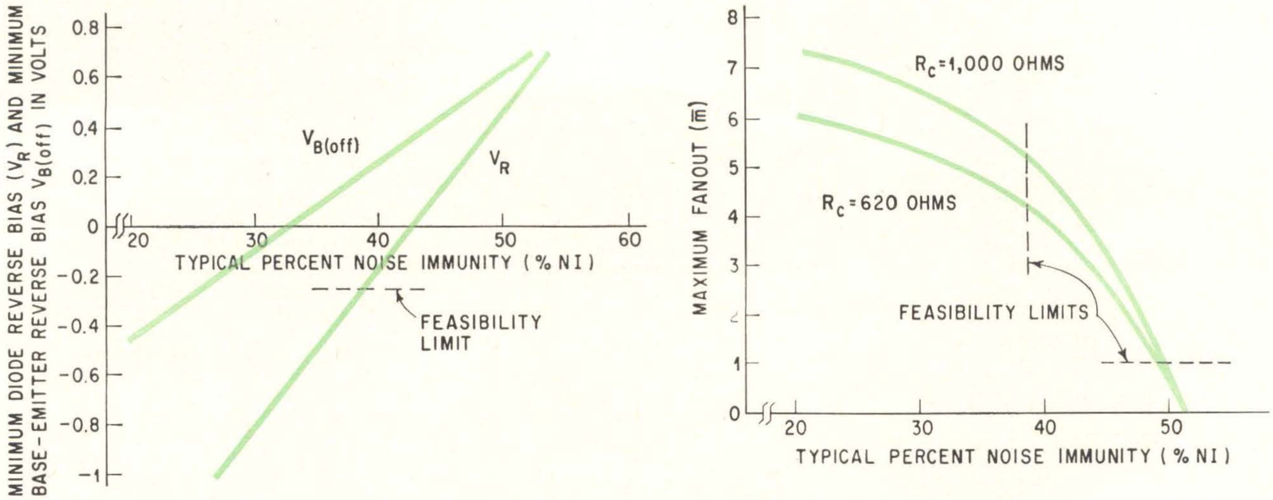
Symbolism of "worst case" equations

All the values in the design equations on this page are either maximums (bold face) or minimums (light face).

A denotes maximum value of quantity A where A is the nominal or typical value.

Definition of symbols

h_{FE}	—Transistor common emitter dc current gain
V_{CE}	—Transistor collector to emitter saturation voltage
V_{BE}	—Transistor base to emitter saturation voltage
I_{BEV}	—Transistor base cutoff current
I_C	—Transistor collector current
I_B	—Transistor base current
$V_{B(off)}$	—Transistor base to emitter cutoff voltage
V_F	—Diode forward voltage drop
I_R	—Diode reverse leakage current
V_R	—Diode reverse bias voltage
V_{CC}	—Collector supply voltage of DTL circuit
V_{BB}	—Base supply voltage of DTL circuit
V_{LL}	—Load or diode gate supply voltage of DTL circuit
R_C	—Collector resistor of DTL circuit
R_B	—Base holdoff resistor of DTL circuit
R_F	—Base forward resistor of DTL circuit
R_L	—Load or diode gate resistor of DTL circuit
C_F	—Speed up capacitor of DTL circuit
L_C	—Collector inductance of DTL circuit
n	—Circuit fan-in of DTL circuit
m	—Circuit fan-out of DTL circuit
C_e	—Emitter capacitance of transistor
C_c	—Collector capacitance of transistor
C_s	—Stray capacitance at base of transistor
Q_s	—Total stored charge of transistor
C_o	—Output capacitance of a fanout including strays
C_i	—Input capacitance at base of transistor
V_{CF}	—Voltage across capacitor C_F
$V_{n(-)}$	—Negative noise voltage at input of DTL circuit required to cause a change in output
$V_{n(+)}$	—Positive noise voltage at input of DTL circuit required to cause a change in output
$\%NI(-)$	—Percent noise immunity of DTL circuit to negative noise voltage
$\%NI(+)$	—Percent noise immunity of DTL circuit to positive noise voltage
$\%NI$	—Percent noise immunity of DTL circuit to any noise voltage, positive or negative
t_d	—Delay time of DTL circuit output
t_r	—Rise time of DTL circuit output
t_s	—Storage time of DTL circuit output
t_f	—Fall time of DTL circuit output
$t_{p(+)}$	—Propagation delay time of positive edge of signal through a pair of DTL circuits
$t_{p(-)}$	—Propagation delay time of negative edge of signal through a pair of DTL circuits



Design example of a diode-transistor logic circuit results in the calculation of the minimum reverse bias for the diode and for the base-emitter (left) and the maximum fanout (right) as a function of noise immunity.

and C_o is the maximum capacitance of a fanout, including strays.

Optimum immunity to noise

Before noise immunity can be set at the optimum value in a switching circuit, the designer must determine what noise-voltage amplitude at the input is required to cause a change in the output. This amplitude is a function of the transient response of the switching circuit, and of the pulse width or duration of the noise voltage.

It is assumed that the noise voltage is of sufficient duration so that effects of the circuit transient response can be neglected, or, in other words that the noise-voltage duration is no less than the longest turn-on or turn-off time of the switching circuit.

If all inputs are high in the circuit on page 66, any negative noise pulse at any input would tend to turn the transistor off from its on condition; however, a positive noise pulse would have no effect. The amplitude of negative noise that can change an output voltage is determined by the reverse bias V_R on the input diodes, the amount of forward bias V_F necessary on an input diode to cause appreciable conduction, and the stored charge Q_s of the "on" transistor. Thus, for the on condition, the negative noise-voltage amplitude required to cause a change in the output is given by

$$V_n(-) = V_R + V_F + \frac{Q_s}{C_F} \tag{7}$$

When any of the inputs is low, the transistor is off; consequently, only a positive noise pulse at a low input would have any effect on the transistor output. The positive pulse would tend to turn the transistor on. The amplitude of the positive noise voltage required to turn the transistor on is determined by the amount of reverse bias $V_{B(off)}$ on the base-emitter junction of the transistor, the forward bias V_{BE} required on the base-emitter junction for appreciable conduction of base current and the amount of charge stored on the input capacitance at the base ($C_e + C_c + C_s$) through the voltage $V_{B(off)} + V_{BE}$. Therefore, for the off condition, the positive noise-voltage amplitude required is given by

$$V_n(+) = V_{B(off)} + V_{BE} + [V_{B(off)} + V_{BE}]\left(\frac{C_e + C_o + C_s}{C_F}\right)$$

or

$$V_n(+) = [V_{B(off)} + V_{BE}]\left(1 + \frac{C_i}{C_F}\right) \tag{8}$$

It is now possible to define a "percent noise immunity" as the ratio of the noise voltages given in equation 7 and 8 to the normal voltage swing of a true input. A normal input swing would be $V_{CC} - V_{CE} \cong V_{CC}$.
Hence, the percent noise immunity may be defined as

$$\%NI(-) = \frac{V_R + V_F + \frac{Q_s}{C_F}}{V_{CC}} \times 100 \tag{9}$$

and

$$\%NI(+) = \frac{[V_{B(off)} + V_{BE}]\left(1 + \frac{C_i}{C_F}\right)}{V_{CC}} \times 100 \tag{10}$$

It is desirable to have equal noise immunity for both on and off conditions, because the percent noise immunity of a switching circuit is no better than the lowest figure, whether it be negative or positive. Therefore, an essential step in optimizing the design for noise immunity is to make %NI (—) = %NI (+). Circuits can be designed for a given %NI with the help of equations 1 and 3. The value of V_R selected for equation 1 determines %NI (—) because the other factors of equation 9 are constants for a given design. Likewise, the

Limit values		**Typical values (25°C)**
$h_{FE}\,(0°C) = 20$	$I_R\,(0°C) = .05\,\mu amp$	$V_{CE} = .25\,V$
$I_{BEV}\,(125°C) = 10\,\mu amp$	$I_R\,(125°C) = 10\,\mu amp$	$V_{BE} = .9\,V$
$V_{BE}\,(0°C) = 1.05\,V$	$V_F\,(125°C) = .7\,V$	$V_F = .65\,V$
$V_{BE}\,(125°C) = .8\,V$	$V_F\,(0°C) = .6\,V$	$Q_s = 15\,pC$
$V_{CE}\,(125°C) = .45\,V$	$n = 15$	$C_i = 5\,pF$
$V_{CE}\,(0°C) = .4\,V$		

Tolerance on all resistors and supply voltages = ±5%

value of $V_{B(off)}$ in equation 3 determines the %NI (+) of equation 10.

Thus, the design can be made not only to obtain %NI (−) = %NI (+), but also to obtain a specific value of %NI.

However, a compromise must be made between %NI and circuit fanout (m). For optimum design, a plot of fanout versus %NI is required. A plot of V_R and $V_{B(off)}$ versus %NI is also necessary to determine over which range of %NI these parameters have practical values.

Design example

In the following diode-transistor logic circuit, a sample calculation of m, V_R and $V_{B(off)}$ is made for a given %NI.

First, a specific transistor and diode are selected. Supply voltages and the current level of the circuit of page 66 are also chosen. After these factors are established, all other constants of the design equations can be found for the given temperature range over which the circuit must operate.

For example, the following design is assumed:

Transistor — 2N2475

Diode — 1N914

Temperature 0° to 125°C

Max. Collector Current I_C = 22 milliamperes

Supply Voltages — V_{CC} = 5 volts

$V_{BB} = V_{LL}$ = 15 volts

Speed — as fast as possible

The other circuit constants are as shown in the table above.

A value for C_F is needed because it appears in equations 9 and 10. At this point, a reasonable value for C_F will be assumed. After the design is completed, this value must be checked to see if it meets the necessary requirements. The sample calculation for one value of %NI is carried out as follows:

$$\text{Let } \%NI(-) = \%NI(+) = 40\%$$
$$\text{and } C_F = 20 \text{ picofarads} \tag{11}$$

Then equation 9 becomes

$$\frac{V_R + .65 + \frac{15pC}{20pf}}{5} \times 100 = 40 \tag{12}$$

or V_R = +0.6 volt

From equation 10:

$$\frac{[V_{B(off)} + .9\left(1 + \frac{5pf}{20pf}\right)}{5} \times 100 = 40 \tag{13}$$

or $V_{B(off)}$ = +0.7 volt

Therefore, equations 1 and 3 on a typical basis at room temperature (25°C) become

$$V_R = .6 = 5 - \frac{15\frac{R_F}{R_L} + .9}{1 + \frac{R_F}{R_L}}\, V_{B(off)}$$

$$= .7 = \frac{15 - (.25 + .65)\frac{R_B}{R_F}}{1 + \frac{R_B}{R_F}}$$

or

$$\frac{R_F}{R_L} = .330 \quad \text{and} \quad \frac{R_B}{R_F} = 8.95 \tag{14}$$

Also

$$\frac{R_B}{R_L} = \left(\frac{R_F}{R_L}\right)\left(\frac{R_B}{R_F}\right) = 2.95 \tag{15}$$

When solved for R_B in the worst case at 0°C, equation 2 becomes

$$R_B \geqq \frac{17.68(R_F + R_L)}{12.57 - 1.10(R_F + R_L)} \tag{16}$$

but

$$R_F + R_L = \left(\frac{R_F}{R_B} + \frac{R_L}{R_B}\right) R_B$$

$$= \left(\frac{1}{8.95} + \frac{1}{2.95}\right) R_B \tag{17}$$

Substitution of this result in equation 16 and

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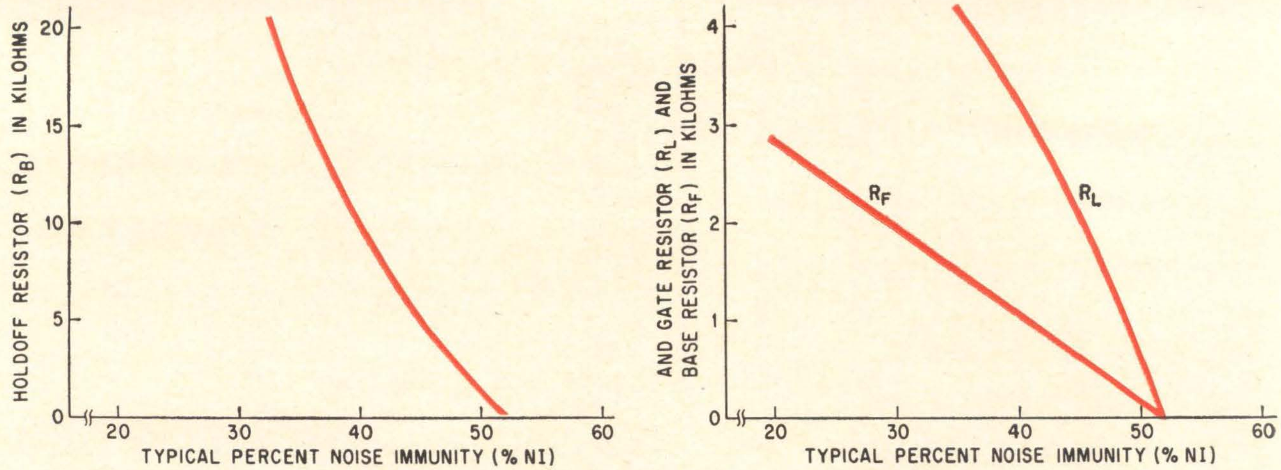


Holdoff—gate and base resistor versus percent noise immunity—permits the selection of exact resistor values for any particular fanout and noise immunity.

solving for R_B yields

R_B = 9.27 kilohms. Equations 14 and 15 yield

$$R_F = \frac{9.27}{8.95} = 1.037 \text{ kilohms}$$

$$R_L = \frac{9.27}{2.95} = 3.14 \text{ kilohms} \tag{18}$$

Because the worst case for V_R and $V_{B(off)}$ occurs at 125°C, equations 1 and 3 for worst-case become

$$V_R = 4.75 - \frac{17.4\dfrac{R_F}{R_L} + .1575R_F + 0.8}{1 + 1.105\dfrac{R_F}{R_L}}$$

or $V_R = -0.16$ volt

$$V_{B(off)} = \frac{14.25 - .0105R_B - 1.272\dfrac{R_B}{R_F}}{1 + 1.105\dfrac{R_B}{R_F}} \tag{19}$$

or $V_{B(off)} = +0.254$ volt

The maximum fanout worst-case conditions occur at 0°C. Hence, equation 4 becomes

$$m = \frac{22 - \dfrac{5.1}{R_C}}{\dfrac{15.53}{R_L} - \dfrac{14.52 - .01R_B}{R_B + R_F}} \tag{20}$$

For R_C = 620 ohms For R_C = 1000 ohms
m = 3.88 m = 4.76

A plot of V_R and $B_{B(off)}$ as a function of %NI for repeated calculations of the above analysis is shown on page 68. At 125°C, the maximum forward bias on the input diodes that can be tolerated without allowing appreciable conduction is 0.25 volt. This is indicated by the dashed line, which shows that a design with %NI less than 38.7% is not feasible.

The maximum fanout m as a function of %NI is shown on page 68. There are two feasibility limits, one at 38.7% (because of the limit on V_R), the other m = 1 (because beyond this point the circuit would have a logical gain of less than one).

Resistor values R_B, R_F, and R_L may also be plotted against % NI, as shown above. These plots permit the selection of exact resistor values for any particular fanout and noise-immunity compromise that may be chosen for the final design.

The final design was selected to obtain a fanout of four. From the graph on page 68 R_C may be 1,000 ohms to provide noise immunity of about 43%, or 620 ohms, for noise immunity of 39.5%. When R_C is 620 ohms, however, fall times are possible about 40% faster than those obtained with a value of 1,000 ohms. Therefore, the best compromise is 620 ohms which, from the design curves, gives the following values:

$$\begin{aligned} m &= 4R_C = 620 \text{ ohms} \\ \%NI &= 39.5 \\ R_B &= 9.8 \text{ kilohms} \cong 10 \textit{ kilohms} \\ R_F &= 1.09 \text{ kilohms} \cong 1.1 \textit{ kilohms} \\ R_L &= 3.25 \text{ kilohms} \cong 3.3 \textit{ kilohms} \end{aligned} \tag{21}$$

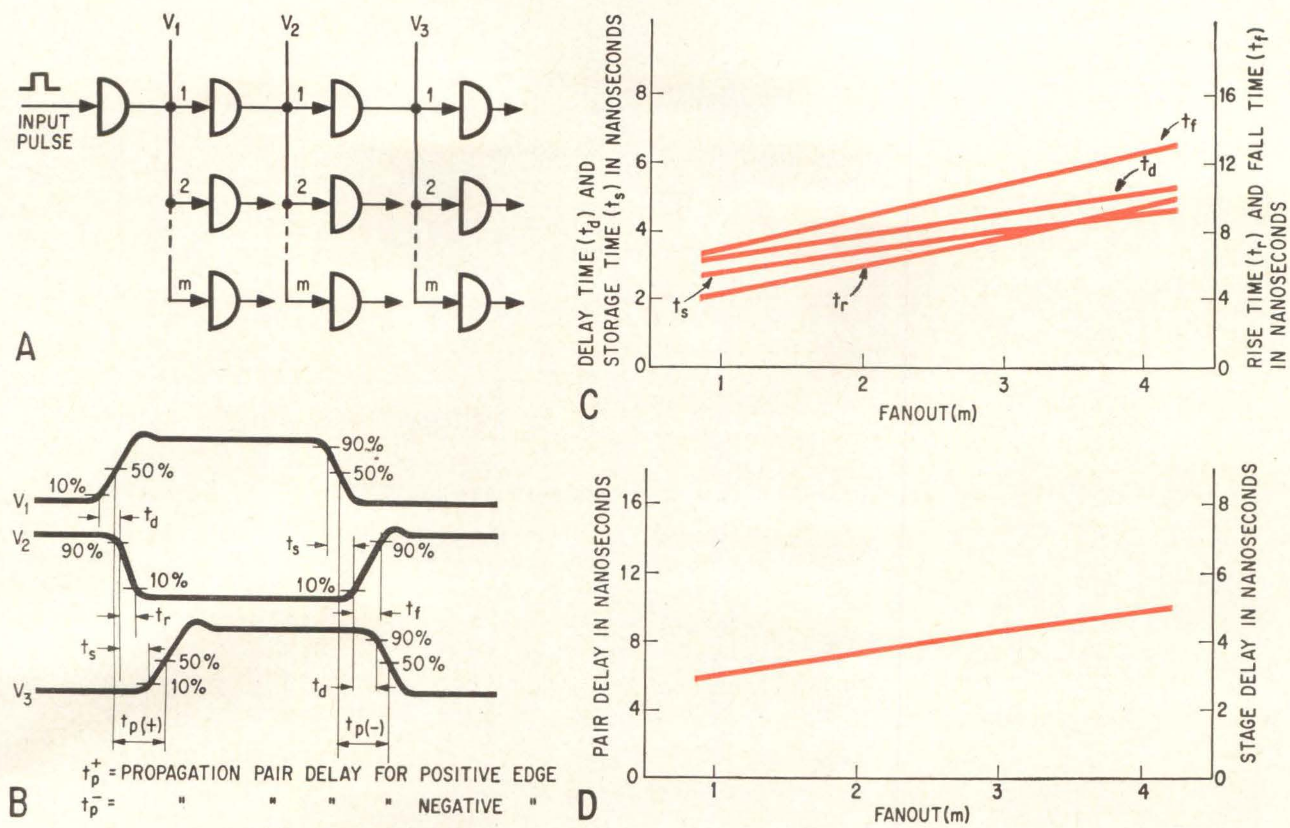
The approximate values are the nearest standard values of 5% resistors. These approximate values for R_B, R_F and R_L should then be substituted back into equations 1 through 4 to verify that all design requirements are satisfied for these values.

To complete the design, it is necessary to check the value of C_F and also to determine the inductance L_C. For the first step, it is noted that maximum stored charge Q_s occurs for the condition of maximum base current I_B and minimum collector current I_C at the highest operating temperature. The minimum collector current occurs when the fanout is only one. Calculation of these values gives

$$I_B = 1.9 \text{ ma} \quad I_C = 9.2 \text{ ma at } 125°\text{C} \tag{22}$$

For the above conditions on the 2N2475 transistor the maximum stored charge becomes

$$Q_s = 40 \text{ picocoulombs at } 125°\text{C} \tag{23}$$



Test circuit determines transient responses (A). Delay, rise and storage fall times and propagation delay per pair of stages were measured in (B). The circuit's transient response is given as a function of fanout (C). The stage delay is actually one-half of a pair delay (D).

From equation 5

$$C_F \geqq \frac{40pC}{2.35V} \geqq 17.0 \text{ picofarads} \quad (24)$$

Hence the selected value, $C_F = 20$ picofarads, is satisfactory. If C_o is assumed to be five picofarads, the value of L_C is obtained from equation 6 as follows:

$$L_C = \left(\frac{1.05 \times 620}{2}\right)^2 (4)(5 \times 10^{-12})$$
$$= 2.1 \text{ microhenries}$$

Therefore, L_C is selected as 2.4 microhenries.

Test results

The first test of the diode-transistor logic circuit was the determination of its transient response. The test setup, shape of waveforms and measured transient response times are shown above. Typical delay, rise, storage and fall times, as well as the propagation delay per pair of stages, were measured. The transient response of the circuit is presented as a function of fanout. A stage delay is actually one-half of a pair delay and, in terms of the switching speeds, may be expressed as

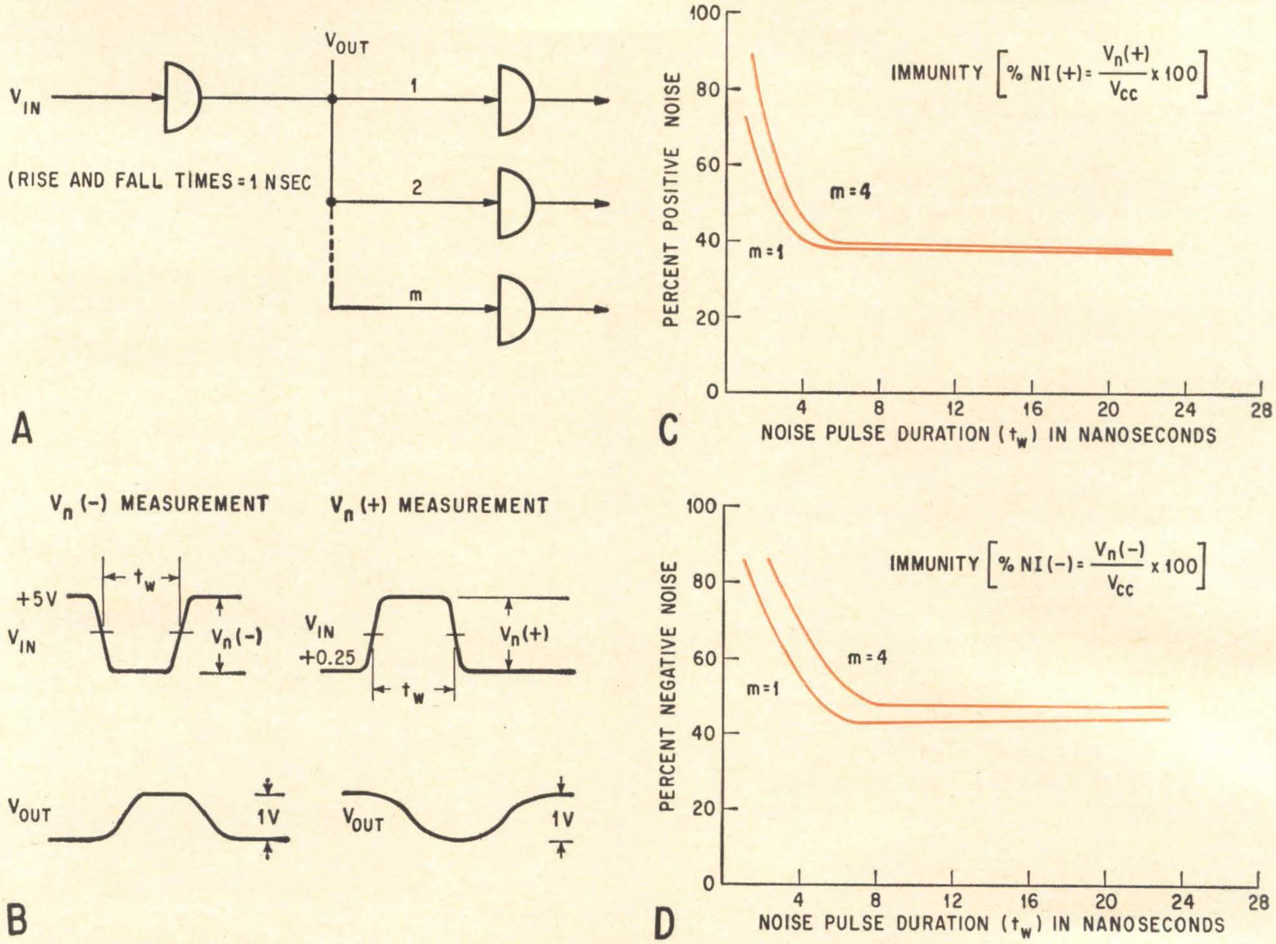
$$\text{Propagation delay per stage} = \frac{t_d + t_s}{2}$$

The inductance L_C in the collector circuits reduced fall times and increased switching speeds and stage delays. When the circuit transient response was checked without any inductance, fall times were about twice as long. Other switching speeds and stage delays were also poorer under these conditions. For a fanout of one, the value of 2.4 microhenries produced about 15% overshoot. For a fanout of four, there was essentially no overshoot.

The test setup for measuring noise immunity is illustrated above. The pulse generator used for simulation of the noise pulse had rise and fall times on one nanosecond. Noise immunity was obtained by measuring the input pulse amplitude required for a one-volt change at the output of the circuit. This measurement was made for pulse widths of 2 to 20 nanoseconds. Both %NI (+) and %NI (—) were obtained for fanouts of one and four.

The curves show that the noise immunity is lowest when the fanout is minimum. This is because the transient response of the circuit is fastest when the fanout is smallest.

The dependence of noise immunity on the noise-voltage duration (p. 72) level off for noise durations greater than 10 nanoseconds. This decrease is due to the fact that the noise duration is now longer



Test setup for measuring noise immunity (A) uses a pulse generator to simulate a noise pulse having rise and fall times of one nanosecond. Pulse widths were varied from 2 to 20 nanoseconds (B). The dependence of noise immunity, positive (C) and negative (D) on the noise-voltage duration, levels off for noise durations greater than 10 nanoseconds.

than the transient response of the circuit, and so a further increase in noise-voltage duration has very little effect on the output.

Before the actual noise immunity is compared with that calculated, it is necessary to point out that the calculations were based on the assumption that the noise duration was at least as long as the transient response of the diode-transistor logic circuit. Therefore, the comparison should be made for a noise duration of about 15 nanoseconds.

At 15 nanoseconds, the lowest noise immunities measured are

$$\%NI_{(on)} = 44\%$$
$$\%NI_{(off)} = 37\%$$

These results are contrasted to the calculated values

$$\%NI_{(on)} \simeq 40\%$$
$$\%NI_{(off)} \simeq 40\%$$

The circuit's noise immunity varies with the operating temperature. This relation is due to the temperature dependence of V_R, V_F, Q_s, $V_{B(off)}$ and V_{BE} which actually determines the noise immunity as given in equations 9 and 10.

Calculations show that, for typical variations of the temperature-dependent parameters, the %NI (+) should change no more than 1% per 50 degrees centigrade, and the %NI (—) should vary less than 1% per 10 degrees centigrade. The larger change of %NI (—) is caused by the significant effects of temperature on Q_s; %NI (+) variation is caused by temperature changes of V_F, V_{BE} and V_{CE}. Therefore, it is evident that %NI (+) decreases whereas %NI (—) increases with rising temperature.

The relatively high noise immunity was made possible by the use of silicon transistors and diodes. This noisy immunity represents an important advantage of silicon devices over germanium types in diode-transistor logic circuits.

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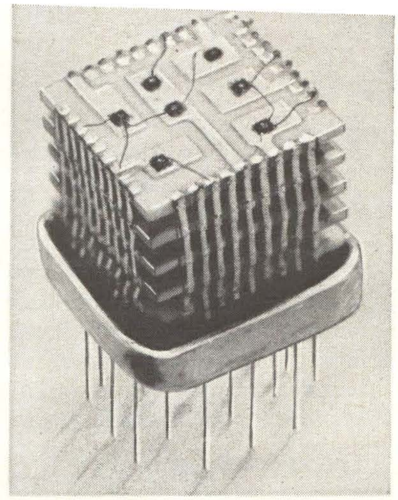
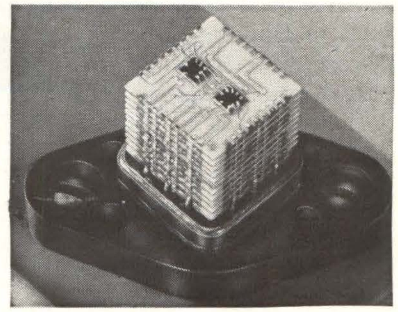




Tape-programed electron-beam machine. Operator peering through binoculars is monitoring the operation. A wired-program machine is used to produce the two micro-modules shown. One module is a binary divider with 20 integrated circuits. The other is a sense amplifier with chip semiconductor devices and deposited thin-film resistors.

Manufacturing

Production-line packaging of solid-state circuits

Programed electron-beam welders assemble new microcircuit module with up to 10 times as many components as before

By D.J. Garibotti and Lee R. Ullery Jr.

Hamilton Standard Division of United Aircraft Corp.

Automated production began last month on a new type of micro-module that can contain up to 10 times as many components as earlier models.

The production line includes an electron-beam welding machine that performs final assembly and hermetic sealing of the modules. The program is financed jointly by the Hamilton Standard division of the United Aircraft Corp. and by the Army Electronics Command. Hamilton Standard provides machines and tooling at its plant in Broad Brook, Conn.; the Army sponsors design equipment and testing.

The units, called microcircuit modules, are an outgrowth of the Army Electronics Command's six-year program[1, 2] to develop three-dimensional packaging. Most of the original micro-module program ended last March.

The new program aims at taking advantage of the compactness achieved by integrated circuits while retaining enough design flexibility to accommodate practically any kind of microcomponent.

The modules being produced are 10-stage binary dividers comprising 20 integrated-circuit chips that are interconnected and hermetically sealed in a 0.1-cubic-inch metal can.

The pilot program calls for the production, in an eight-hour work shift, of a mix of 100 of these and engineering and test modules without the integrated circuits. The manufacturing equipment can turn out 200 modules in one work shift.

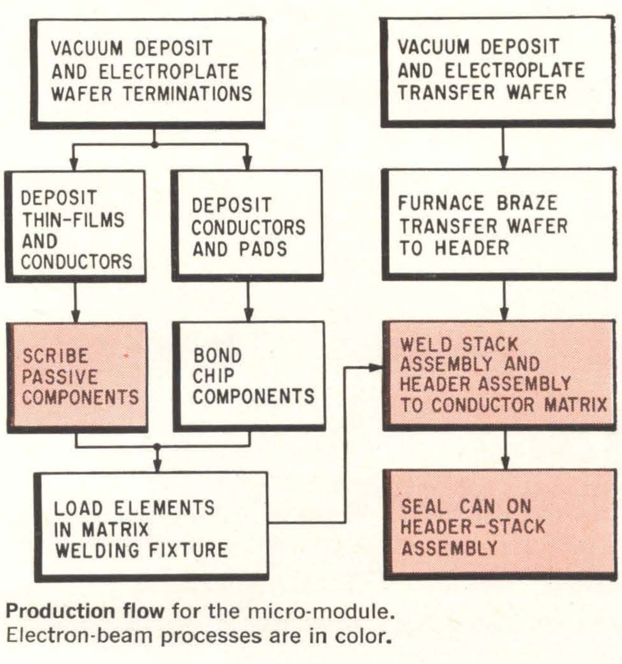
During preliminary work over the past three years, prototypes of a variety of assemblies were made, including linear and digital systems. These have used discrete semiconductor devices, thin-film passive components fabricated by electron-beam techniques, integrated circuits, and hybrid approaches to microminiaturization.

The microcircuit module

The dimensional standardization of the original micro-module—a cube about 0.4 inches on a side—is retained in the new microcircuit module. But for interconnection, the old module depends on riser wires soldered into 12 notches around the periphery of each wafer. The new module has an upnotched wafer that accommodates 36 welded connections. The number of components that can be placed in the module is increased at least an order of magnitude, particularly if the wafers carry integrated circuits. This provides a significant increase in design flexibility.

Because the higher packing density is not achieved at the expense of standardization of form factors, computer techniques can be used to design circuits and determine the arrangement of parts in the module. Most production steps, tools and test equipment are standardized, allowing a new module to be designed and put into production in about two weeks.

Even on the pilot line, manual operations are confined to loading the production fixtures and attaching semiconductor-device chips to the wafers. Welding is fully automated. The electron-beam welding machine, loaded and programed, can make 76,000 welds in four hours.



Production flow for the micro-module. Electron-beam processes are in color.

Production costs, therefore, promise to be low. Small-lot circuit production is expected to compete in cost with packaged, mass-produced integrated circuits. Hamilton Standard plans to manufacture modules for sale.

The target assembly cost for the pilot plant is \$4 for a 10-wafer module, plus the cost of the semiconductor devices. Costs of passive components should also be low for military equipment. Thin-film capacitors with values in the 1,000-picofarad range are deposited on ceramic wafers. Thin-film area resistances with a total value of 500,000 ohms can be deposited and fabricated, at tolerances of 1%, into ten 50,000-ohm resistors.

When electron-beam welding is used, the circuits are sealed in a vacuum. Individual packages for the components would be superfluous. This saves the cost of having components prepackaged, and allows shorter lead lengths for better high-frequency performance.

Other production and performance advantages are built into the microcircuit module. No fluxes or encapsulants are necessary; contaminants are minimized, and stresses associated with potting are avoided. The inorganic materials used make the structure compatible with 200°C operation, while the ruggedness of a welded structure accommodates other environmental extremes. Continuous thermal paths link the wafers with the outside world through the stack stabilizers and conductor matrix. The can is also an interference shield.

Producing a binary divider

Because a 10-stage binary divider contains 20 uncased integrated-circuit chips, it provides a rigorous test of the compatibility of the microcircuit module concept and solid-state technology. The circuit is also an ideal choice for comparison with equivalent circuits assembled by other techniques, because this circuit is widely used in equipment for such functions as timing events, generating binary numbers and counting pulses.

The production sequence followed for the elements of the dividers is illustrated in the flow diagram at the left and described in the following paragraphs.

Making the wafers

After they are cleaned, the wafer blanks are loaded on edge in "cross-arm" jigs that fit, like seats, into a "ferris wheel" fixtures. As the wheel rotates, each jig also rotates around its own axis. Loaded between each blank is a spacer mask that defines the areas on which edge terminations are to be deposited. Combs, resembling the conductor matrices, mask the edges of the blanks. The wheel holds 13 jigs carrying a total of about 1,400 blanks.

The wheel fits into the 21-inch chamber of a vacuum-deposition system. As the wheel revolves, all the wafers are exposed to an equal flux of the materials vaporized in the chamber. A 100-angstrom-thick layer of chromium is first deposited to provide a tenacious bond to the substrate; then 1,000 angstroms of gold are deposited.

The jigs are then reloaded with the flat surfaces of the wafers exposed. The edge terminations are masked, and aluminum is deposited over the surface.

The aluminum serves as a current carrier during a subsequent electroplating operation. It is anodized to prevent plating except on the edge terminations. Relatively thick (0.001 to 0.002 inch) nickel is plated onto the terminations so that the copper conductors can be welded to them. The aluminum is etched off with sodium hydroxide.

The gold-on-chromium conductors and pads needed for bonding the semiconductor chips are then deposited.

A copper plating used to be employed. This produced reliable welds in most cases. However, when the wafers were heated during chip-bonding, a thin film of oxide was formed. The oxide tended to degrade the weld even when bonding was done under a curtain of forming gas.

Nickel is not oxidized after 10 minutes at 450°C, a time and temperature adequate for bonding. Copper can be used if it is overplated with nickel, gold or both, but nickel plate obviates the extra steps and satisfies electrical design requirements.

An alternative to depositing conductors through a mask is making an area deposit of chromium and gold, then etching the pattern. A promising method of reducing the cost entailed in masking or etching is to use a programed electron-beam to remove unwanted portions of an area-deposited film. The techniques are similar to scribing (p. 78). Wafers can be made and stored in quantity and patterned as needed, simply by punching a control tape.

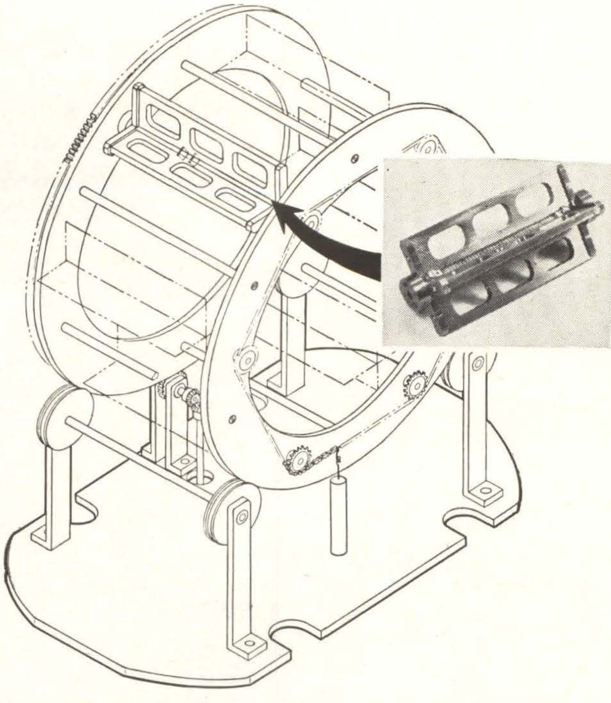
Bonding the chips

The integrated-circuit chips are bonded to the pads by the gold-silicon eutectic method. The wafers are heated to 400 to 425°C on a hot post, then the chip is transferred to the pad with a vacuum probe and vibrated to promote wetting.

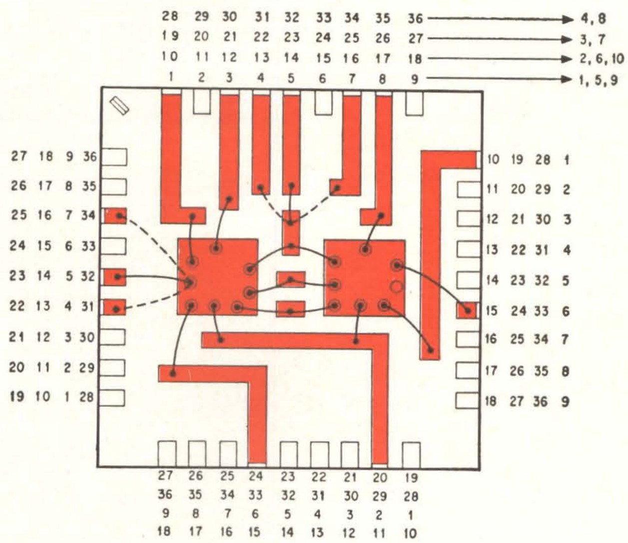
Next, commercial thermocompression-bonding machines (made by the Kulicke & Soffa Manufacturing Co.) bond gold lead wires to the terminations on the chip and the conductors on the wafer. Wafer temperature is 300°C and wire diameter is two mils. A nail-head bond is used at the chip, and a wedge bond at the conductor.

Similar techniques bond the chip components. For example, a sense amplifier has been made, using six chip transistors and a diode on one wafer and 18 thin-film resistors on three other wafers.

It was found during process development that a relatively thick layer of gold must be deposited over the chromium for satisfactory bonds of the chips and the leads. Thin fold films are porous, and diffusion between a thin gold film and chromium apparently lowers the gold's oxidation resistance. The difficulty can be overcome by using gold solder preforms for bonding. But it is simpler, in practice, to increase the gold thickness.



Ferris-wheel fixture deposits edge terminations on wafers. Photo shows loaded cross-arm.



Layout for wafers with two integrated circuits bonded to deposited gold (color). While wafers are stacked, they are rotated 90° as indicated by termination numbers.

Semiconductor chips can also be welded to the wafer by an electron beam. This has been done successfully, but is not yet qualified by the military as a production method.

Layout of chip connections

The illustration (above) of a morphological layout for interconnecting Micrologic circuit chips, Fairchild type 905, also shows how the chips are connected on the wafers used in the binary divider. All the chips are wired identically, except for B+, ground, input and output. As it is placed in the stack, each wafer is rotated 90° with respect to the preceding wafer.

After it is deposited on the transfer wafer, the conductor pattern is brazed to the header. Headers are purchased from vendors.

The brazing technique is the same as furnace-alloying of junction transistors. The header and wafer are positioned in a stainless-steel boat that holds 11 assemblies. Eight alloy spheres, 80% gold and 20% tin, are positioned over the eight interior pinholes. The pins are brazed to the wafer in nitrogen at a temperature of 325° to 340°C. No flux is needed.

Hydrogen atmosphere was used initially, but this reduced the oxide on the Kovar in the glass-to-metal seals, lowering the yield to around 80%. Present yield is 95% to 97%.

Enter the electron beam

All the elements of the module are now ready for electron-beam welding. A brief review of beam welding and a description of the beam controls is therefore in order at this point.

Although electron-beam welding is 10 years old, most applications have been concerned with exotic materials or relatively large workpieces. The Hamilton Standard welder used in the module program can weld pieces three inches thick. But beam-welding is particularly attractive for microelectronics fabrication. This program, in fact, marks the transition of beam-welding from laboratory and prototype work to the mass production of electronic circuit assemblies.

Because the beams are controlled electronically, the operation can be automated easily with resolution, speed and precision that are inherently greater than in mechanical equipment. Beam diameters of 0.001 inch are maintained regularly, and diameters in the micron range are feasible.

Beam-power densities of 10^6 to 10^{10} watts per square centimeter and accelerating voltages to 150 kilovolts are produced. With proper operating parameters, this energy is converted from kinetic to thermal within a closely controlled amount of material. The electrons slow down almost instantly when they strike a solid.

Beams are formed by boiling electrons off a heated filament cathode. The beam, controlled by a grid that is slightly negative with respect to the cathode, is accelerated by a grounded anode and focused by coils that form a magnetic lens. It is deflected to the target point by deflection coils for the X and Y axes.

Each of these components provides a parameter that the control system can modulate. The beam

Microcircuit module packaging system

Each module is an assembly of up to 10 wafers interconnected by a copper conductor matrix and mounted on a 20-pin header. Over-all dimensions of the module are 0.390 by 0.390 inch square and 0.4 to 0.8 inch high. The system includes the following elements.

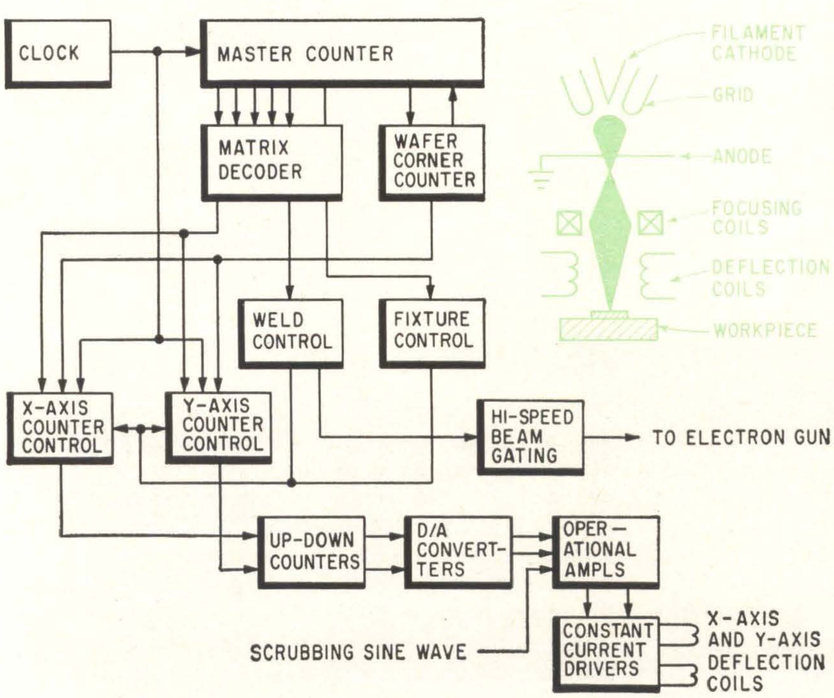
Microwafer—the basic building block, 0.310 inch square. It is 0.010 inch thick if made of beryllia or alumina, and 0.020 inch thick if made of glass. On each edge are nine edge terminations on 0.025-inch centers. Terminations are vacuum-deposited gold on top of chromium, with a heavy nickel overlay for welding.

Microelement wafer—a microwafer carrying one or more components or a simple network. The network can consist, for example, of several thin-film resistors deposited directly on the wafer.

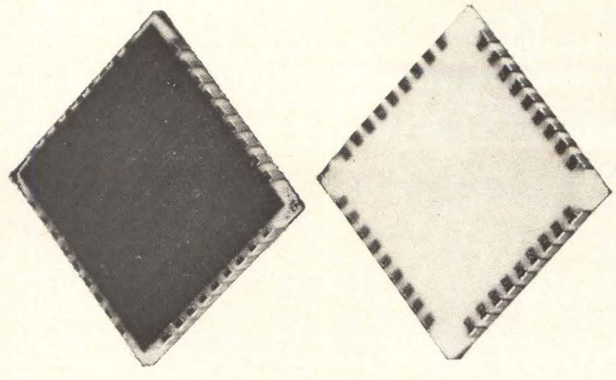
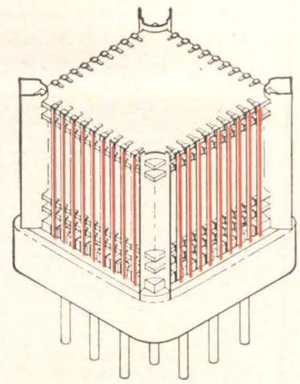
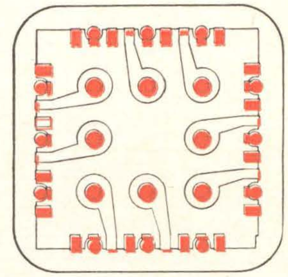
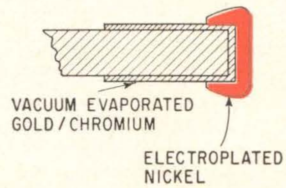
Microcircuit wafer—a microwafer carrying one or more circuit functions, such as a flip-flop or gate. Integrated-circuit chips may be bonded to deposited conductors.

Microwafer stack—an assembly of up to 10 wafers interconnected by a conductor matrix welded to appropriate wafer-edge terminations. The matrix consists of nine ribbons, each 0.010 inch wide, photoetched from 0.002-inch copper foil.

Stack stabilizer—a comb-like part made of a beryllium-



Repetitive welding, to connect the conductor matrix to the wafer terminations, is controlled by programer. Beam (insert) is deflected to hit weld points and is gated on and off by setting instructions into console.

Resistive microelement and a microwafer. Sketches are an assembled stack, a transfer wafer and the edge termination. Welded and brazed connections are in color.

copper alloy. It aligns the wafers in the stack, provides a constrained fit between stack and can, and a thermal path between the wafers and the can.

Transfer wafer—translates the 0.025-inch grid pattern of the matrix to the 0.075 grid pattern of the 20-pin header. The wafer accepts 12 pins in edge notches and eight pins in holes that are connected to edge terminations by vacuum-deposited conductors.

Transfer wafer-header subassembly—serves as the plug-in base for the module. The transfer wafer is brazed to the header. The stack is welded to the wafer. Then the can is welded to the header to complete the package.

can be scanned, pulsed, moved from point to point, gated on or off, oscillated and varied in intensity depending on the nature of the work. The beam can be used for welding, cutting, scribing, heating, or analyzing materials by x-ray techniques.

Typical parameters for the matrix welding are: accelerating voltage, 90 kilovolts; beam current, 0.36 milliamperes; weld time, 6 milliseconds; scrubbing deflection, 1.1-kilocycle sine wave.

Scrubbing is a technique for oscillating the beam, to make the weld spot larger than 0.001 inch and thereby improve the strength of the weld.

Automating the welding machine

Welding a matrix, such as that used in the modules, is a repetitive operation. Therefore, an elaborate control system is not required to automate the welder. A "wired" or semifixed programmer was developed during the past year as part of the pilot production effort.

The control used with the stack-welding system can be set to weld at any combination of the 90 weld points available in a conductor matrix. Also, by changing magnification—that is, by changing the distance from the deflection coils (diagram above) to the workpiece—matrices ranging in size from 0.75 to 0.1 inch square can be scanned by the beam.

In the microcircuit modules, the weld points are on a 0.025-inch grid. The control is basically a multiphase clock set to control the beam so it moves, stops, scrubs and is gated on and off. This can be done at increments of 0.001 inch. So in the present application the clock creates one of these events at every 25th pulse, at the grid points set into the console.

The subsystems in the control direct the clock signals to the proper beam—control or transfer-mechanism control. They also keep track of beam and fixture actions so the beam will move from one weld point to the next in the proper sequence.

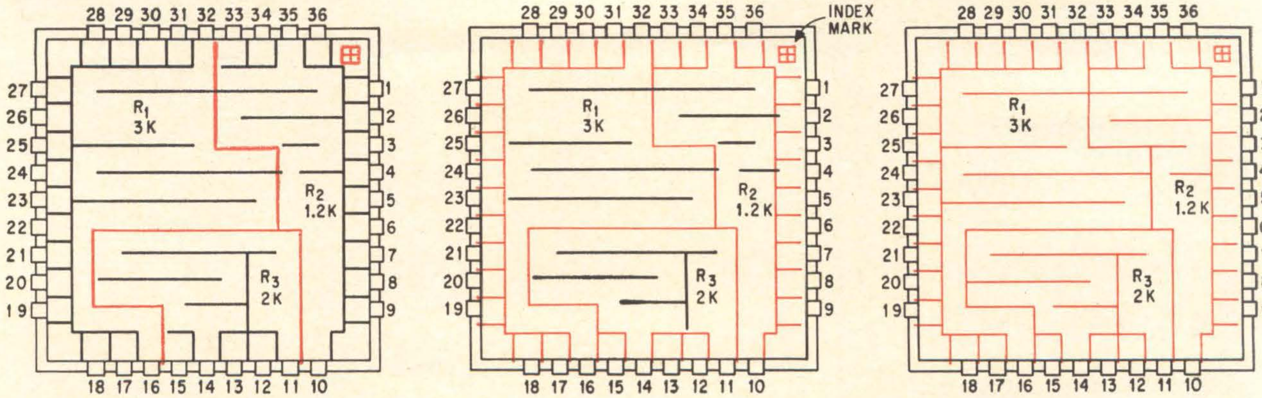
Another control, which is programmed by punched paper tape, was developed during earlier work sponsored in part by the Air Force. This control provides greater flexibility for prototype or small-lot production. The machine can thus be used for all the various electron-beam processing applications mentioned earlier.

This control permits the beam to scan any point over an area of one inch square. For precision, however, the scan is restricted to about 0.2 inch square. The programmer also feeds directions to an X-Y

The authors

D.J. Garibotti, a senior scientist at Hamilton Standard, directs a group studying ways to use electron beams to process semiconductor crystals as well the microcircuit module applications. He received a doctorate in physical metallurgy at Case Institute of Technology in 1955.

Lee R. Ullery Jr. has helped to develop dozens of optoelectronic devices and pieces of equipment, as well as ways to make and use them. His seven patents include rights on infrared detectors and electroluminescent-photoconductor image memory devices. At Hamilton Standard he directs advanced development in the electronics department.



Steps in scribing thin-film microelement resistors are shown cumulatively in color. Areas for three resistors are separated at left. R_1 will run between terminations 16 and 32, R_2 between 10 and 35, and R_3 between 11 and 14. Next, unused terminations are isolated (center). Finally, meander paths are scribed to bring resistors to within 1% of desired value.

positioning table (a General Electric Co. Mark Century) in the vacuum chamber. When the table is loaded with wafer dispensers and other transfer mechanisms, also under program control, a variety of work can be done without breaking the vacuum. This work might be resistor scribing, random welding over a large circuit-board.

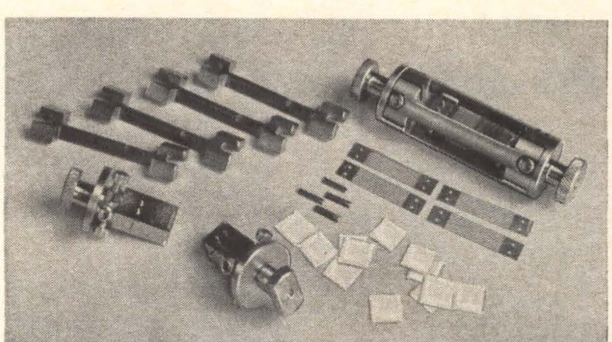
Beam actions are almost instantaneous. The limiting speed is imposed by the control system. The system takes about 25 milliseconds to execute each instruction on the tape. Positional accuracy of the beam and worktable is 0.001 inch.

Welding the matrix

Before the matrix welds are made, the stack of 10 wafers for the binary divider must be positioned so the beam can "see" the matrix.

This is done by loading the microcircuit wafers into a cartridge-type jig. The stack stabilizers act as spacers in the jig. When the wafers are positioned, the copper matrices are clamped in place by means of tabs at their ends. Special tools for handling prevent contamination from contact with the hands. The tools grip the wafer corners.

The jigs are loaded into a transfer mechanism, which fits into the electron-beam machine's vacuum chamber and is controlled by the programmer so that it presents all four sides of the stack to the beam in succession, moving a new stack into position when the preceding stack is welded.



Cartridge Fixture used to load stack assembly. Cartridge parts are at left, stack parts at right below and assembled fixture.

A hold-down device holds the matrix ribbons firmly against the wafer edge terminations while each row of welds is made.

After all the stacks are welded, the fixtures are unloaded and the excess ribbon is trimmed off.

The transfer wafer-header assembly is welded to the stack assembly using the same fixtures. One end plate of the cartridge is replaced by a jig that accepts the plug-in base. The beam is programmed to weld the ribbons to the terminations on the transfer wafer.

Environmental and electrical tests have demonstrated that such electron-beam welding is exceptionally reliable.[3] Pull strengths are well above 200 grams and weld resistances is about 1.5 milliohms. Environmental extremes do not significantly degrade these values.

Sealing the package

The can and header are hermetically sealed by a program that causes the beam to follow the can-header interface.

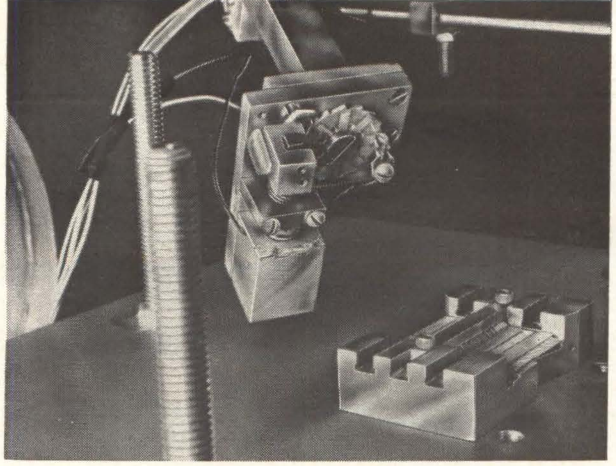
The stack assemblies and cleaned cans are loaded, 200 at a time, into a transfer mechanism that fits the assemblies into nickel cans and presents the interface to the beam.

The fixture is loaded in a dry box containing nitrogen with a dew point of $-100°$C., it is then baked out at least two hours in a vacuum at 250°C.

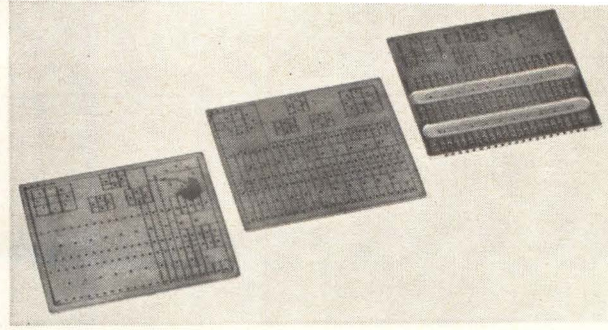
It takes less than one-half minute to seal each package; welding time is 1.6 seconds. Sealing is verified by a helium leak tester made by the Vacuum Electronics Corp. Leak rates are lower than 10^{-8} standard cubic centimeters per second.

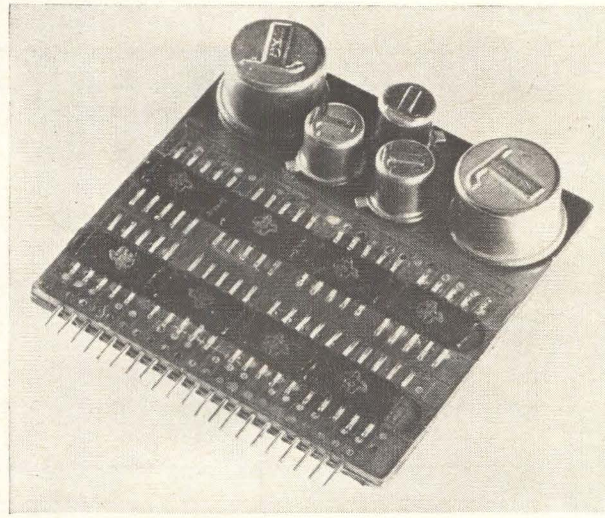
Electron beams can seal metal enclosures at 300 inches a minute. The method is already competitive in cost with other weld-sealing methods and is cheaper for relay-can sealing.[4] At least five relay manufacturers are now using beam welders.

Also, unlike the braze-type seals often used for microcircuit packaging, electron-beam welding does not heat other parts of the package. Brazes, which seal some flatpacks, melt at only a few degrees



Multilayer ceramic circuit-board represents another marriage of electron-beam and thin-film techniques. Designed for 300°C service, it was developed under an Air Force contract. The metallized substrates (top right) are scribed to define interconnections between layers. Layers are stacked with mica insulation between them. Molten silver solder is sucked into the feed-through holes by vacuum casting. The leads of the flatpacks (right) inserted in the grooves are welded using the fluorescent paint technique. The welding fixture is shown above with the photodiode sensor over it. The layers can also carry deposited and scribed thin-film components.





lower than the chip-bonding materials, presenting a difficult process-control problem.

Thin-film passive components

Microelement wafers are now made with the tape-programmed machine. After edge terminations are deposited on the wafers, an area film of resistive material such as chromium or capacitive material such as siilcon monoxide with aluminum electrodes is deposited, plus a protective coating.

For making a resistor—capacitor techniques are similar—the electron beam is set to scribe a pattern of lines on the wafer surface. Scribing is a subtractive process in which the beam vaporized a path through the material.

First, the unused edge terminations are isolated by scribing around them. Then the film is divided into the desired number of resistive areas. Finally, a meander path is scribed in each area to bring the resistor to within 1% of the desired value by increasing the effective length of the resistive film. As the beam scribes the meander (illustration above), resistance is monitored by a bridge circuit and beam power is cut off when the desired value is reached.

It takes about a second to position the wafer on the worktable, and 50 miliseconds to scribe each line—a total of about three or four seconds per wafer, depending on the number of resistors.

Besides maintaining 1% tolerances, this method grealy simplifies vacuum deposition. Masks and tight control of the deposition process are unnecessary. Nor must changes, which normally occur in film value after deposition, be accounted for.

The beam technique allows a tolerance of 10% on sheet resistance. The wafers can be stored and well stablized before scribing.

Punching a control tape is much simpler than preparing masks or changing a photoetching setup.

Welding random patterns

The tape-programmed machine also comes in handy for selective welding and for welding over a large area such as a circuit board, because table and beam motions can be combined.

The welds can either be programmed to a grid pattern or made randomly.

When exact positions of the weld points are unknown, a difficult technique can be used. The desired weld points, or reference points, are covered with a spot of fluorescent paint. The table and beam deflection are programed to scan the workpiece with a "soft" beam whose intensity is too low for welding or cutting. The paint spots fluoresce when the beam hits them. The fluorescence is detected by a photodiode whose output is used as a signal to increase beam energy to welding intensity. The spot is scrubbed to make the weld.

Acknowledgment

Significant contributions to the developments described in this article were made by Weldon Lane of the Army Electronics Command during the development of the microcircuit module; Eugene H. Miller of the Manufacturing Technology division, Air Force Materials Laboratory, in the development of the tape-programed methods; and Paul G. Anderson of Hamilton Standard, who was responsible for the design of program controls.

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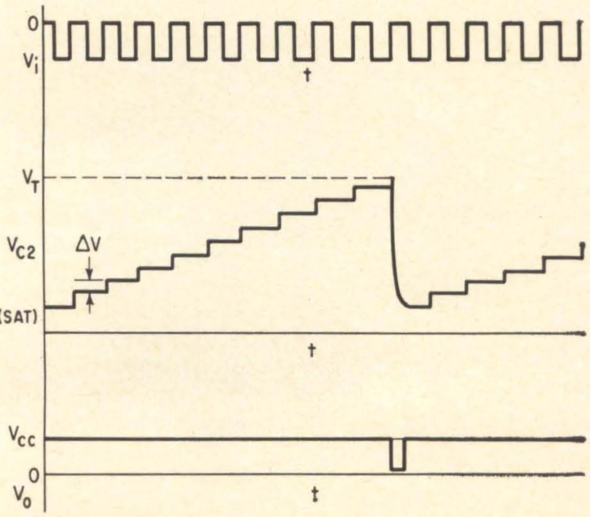
Circuit design

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.



Voltage waveforms

Staircase generator triggers a unijunction transistor

By Joseph J. Panico

General Instrument Corp., Westwood, Mass.

This versatile circuit can be used as a pulse counter, delay circuit or linear staircase generator. It uses a unijunction transistor Q_2 and two conventional n-p-n transistors, Q_1 and Q_3. Transistor Q_3 provides inversion for the unijunction transistor's output signal so that the proper phase relationship is maintained between the circuit's input and output.

Without a trigger voltage, the bias voltage at the emitter of Q_2 is too low to activate the unijunction transistor. The trigger voltage V_T which is required for Q_2 to conduct, is given by

$$V_T = V_{CC}\,\eta' + V_{DE} \qquad (1)$$

where V_{CC} is supply voltage (10 volts), η' is modified intrinsic standoff ratio for Q_2, and V_{DE} is forward voltage drop across the Q_1 emitter-to-base junction.

The intrinsic standoff ratio η of a unijunction transistor is a parameter that is determined by the characteristics of the bar from which the device is made. Basically, it represents the voltage-dividing action that occurs within the device. The modified intrinsic standoff ratio for Q_2 in the circuit shown takes into account the presence of R_2 and $(R_3 + R_4)$. However, since the resistance of the unijunction is much greater than R_2 and $(R_3 + R_4)$, $\eta' \approx \eta$.

A variable resistance is used for R_3 to allow compensation for the variation in intrinsic standoff ratio from one transistor to another. This adjustment permits sufficient signal strength across R_5 when the unijunction transistor Q_2 conducts, so that Q_3 is triggered.

Staircase generator stage

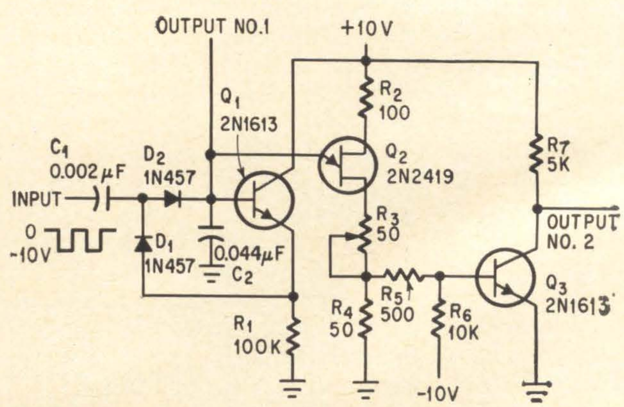
When a negative input pulse V_i is applied, D_1 conducts and C_1 charges through D_1 and Q_1; Q_1 conducts throughout the entire input cycle. When the pulse is removed, D_1 turns off and D_2 conducts. A transfer of charge from C_1 to C_2 through D_2 occurs. The increment ΔV that is added to the voltage across C_2 for each charge transfer is given by

$$\Delta V = C_1\,(V_i - 2V_D)/(C_1 + C_2) \qquad (2)$$

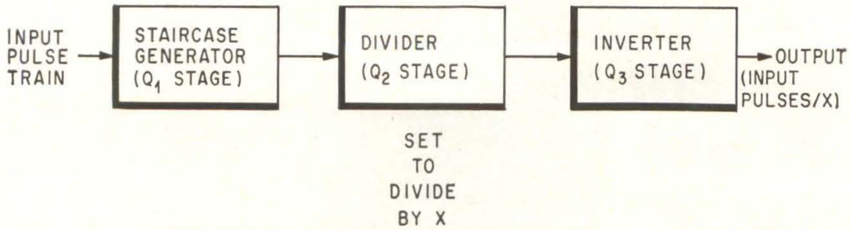
where V_i = input pulse (−10 volts)

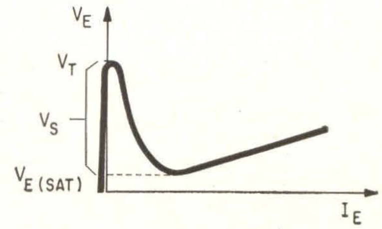
V_D = voltage drop across D_2 or D_1

The above relation is derived as follows: The voltage that is transferred from C_1 to C_2 during each positive portion of the input waveform is a function of the difference in voltage across the capacitors and the ratio of the capacitance values of the capacitors. Let V_{C2} be the voltage across C_2 at any time. After the negative input pulse, the voltage across C_1 is $V_i + V_{C2}$ (neglecting the voltage drops across the diodes), since Q_1 is, in effect, a unity-gain amplifier. Therefore the voltage trans-



Continuous train of input pulses provides a voltage across C_2 that increases incrementally until Q_2 conducts.





Circuit divides the number of input pulses by a preselected divisor (left). Voltage-current characteristic for unijunction transistor (right).

ferred, ΔV, is approximately

$$\Delta V = (V_i + V_{C2} - V_{C2})\,[C_1/(C_1 + C_2)]$$

or

$$\Delta V = V_i\,[C_1/(C_1 + C_2)] \qquad (3)$$

The charging of C_2 is continued until the voltage across C_2 is sufficient to turn on Q_2. Then C_2 discharges until the voltage across it can no longer sustain conduction and Q_2 turns off. At this point the voltage at the emitter of Q_2 is $V_{E(SAT)}$. Therefore the maximum voltage swing V_S at the emitter is the difference between $V_{E(SAT)}$ and the trigger voltage V_T applied to Q_2 or:

$$V_S = V_T - V_{E\,(SAT)} \qquad (4)$$

From (1) and (4) and considering $\eta' = \eta$:

$$V_S = V_{CC}\,\eta + V_{DE} - V_{E\,(SAT)} \qquad (5)$$

Pulse counting

The number of pulses that can be applied to the input before a pulse is generated by Q_2 depends on several factors. One is V_S, which may be obtained from equation 5. Another factor is the value of ΔV, which can be determined from

$$\Delta V = V_S/x \qquad (6)$$

where x is the number of input steps required to obtain one output pulse.

Assuming that the input pulse voltage level is known, the capacitance ratio of C_2 and C_1 can be found by equating equations 3 and 6 for ΔV. The resulting expression is

$$C_2/C_1 = [x(V_i - 2V_{DE})] - [V_T - V_{E\,(SAT)}]/[V_T - V_{E\,(SAT)}] \qquad (7)$$

The choice of the proper capacitor for C_2 is more critical than for C_1. The value chosen for C_2 determines the amount of charge that leaks off during the input cycle and also affects the recovery time of Q_2. Capacitor C_2 must be made large enough to maintain its voltage over the input cycle, yet small enough to avoid counting errors because of incomplete recovery when recycling occurs. Capacitor C_1 should be large enough so that its charge is not limited by the rise time of the charging current.

In a typical application of the circuit, a staircase voltage was needed for the horizontal sweep of an alphanumeric display system. The required voltage rise per step, ΔV, was 0.4 volts ($\pm$10%). The input signal was a 20-kilocycle (period of 50 microseconds), 10-volt square wave.

Resistor R_2 was chosen as 100 ohms—a sufficient value for temperature compensation. Therefore, the sum of R_3 and R_4 should also be 100 ohms. A 50-ohm variable resistor was selected for R_3 to adjust for the standoff ratio variation between transistors, and a 50-ohm fixed resistor was used for R_4. A 10-volt supply was used and a 2N2419A was considered for Q_2. The value of $V_{E(SAT)}$ and V_{BE} for a 2N2419A are typically 3 volts and 0.7 volts respectively. The circuit was designed so that 10 steps would trigger Q_2. The remaining circuit specifications are determined as follows:

from (6): $V_S = x\,\Delta V = 10(.4) = 4$ volts
from (4): $V_T = V_{E\,(SAT)} + V_S = 3 + 4 = 7$ volts
from (1): $\eta = (V_T - V_{DE})/V_{CC} = (7 - 0.7)\,10 = .63$

The 2N2419A was satisfactory for the values calculated above.

The staircase generator

A 2N1613 was selected for Q_1 because of its high current gain and low collect leakage current specification. A 100,000-ohm resistor was used for R_1 to provide high input resistance. The input impedance R_{in} for Q_1 is:

$$R_{IN} = h_{FE}\,R_1 = 30\,(100K) = 3 \text{ megohms} \qquad (8)$$

The relation between C_1 and C_2 is determined from 7:

$$C_2/C_1 = [10\,(10 - 1.2) - (7 - 3)]/(7 - 3) = 21$$

Next, the recovery time constant τ_1, which must be less than 0.1 times the period of the input pulses, is calculated.

$$\tau_1 \leqq 0.1\,T = 0.1\,(50) = 5 \text{ microseconds} \qquad (9)$$

Then C_2 is obtained as follows:

$$C_2 = \tau_1/[R_{E\mu} + (R_3 + R_4)] = 5\times10^{-6}\,(100+100) = 0.025 \text{ microfarads} \qquad (10)$$

where $R_{E\mu} = Q_2$ emitter-to-base dynamic resistance

The charge leak-off time constant τ_2 is determined from:

$$\tau_2 = C_2\,R_{IN} = (0.044 \times 10^{-6})\,(3 \times 10^{-6}) = 0.075 \text{ second} \qquad (11)$$

The total time T_o for one cycle for the Q_2 stage is:

$$T_0 = x\,T_1 = 10\,(50\times10^{-6}) = 0.5 \text{ millisecond} \qquad (12)$$

The ratio τ_2/T_o is $0.075/0.5 \times 10^{-3}$ or 150. Since this ratio is very large, little charge will leak off during the cycle to trigger Q_2.

Now that C_2 has been determined, C_1 can be found.

$C_1 = C_2/21 = 0.025 \times 10^{-6}/21$
$= 0.0012$ microfarads.

The circuit was constructed using the components determined above and performed reliably from 0° to 65°C.

Constant-current source controls sweep rate

By James J. Collins
Kollsman Instrument Corp., Syosset, N.Y.

A constant-current generator stage is used in this circuit to obtain linear sweeps ranging from a few microseconds to one second in duration. The constant-current source portion of the circuit, contained within the dashed-line box, consists of Q_2, R_3, R_4, and R_5.

Transistor Q_2, in the constant-current source stage, and transistors Q_3 and Q_4, which are connected in a Darlington amplifier configuration, conduct at all times during the operation of the circuit.

At first, an input voltage $-E_i$ is applied to the base of the emitter-follower Q_1. This voltage maintains Q_1 in conduction, and places nearly $-E_i$ volts at the upper plate of capacitor C through a path consisting of R_2 and D_1.

When the input signal rises to ground, Q_1 is cut off; diode D_1 becomes back biased and also stops conducting.

Now the only current being supplied to the capacitor is the small positive current from the constant-current source. The voltage across C increases linearly from approximately $-E_i$ volts and approaches $+V_{ce}$, the voltage at the collector of Q_2. This process continues until the input pulse is removed—before or when the voltage at the upper plate of C reaches ground potential.

With the return of the input signal to $-E_i$ volts, Q_1 and D_1 conduct, and the upper plate of the capacitor also goes to $-E_i$ volts.

The voltage across a capacitor is defined by:
$V_C = 1/C \int i dt$
With a constant current flowing, this becomes:
$V_C = (i)(t)/C$

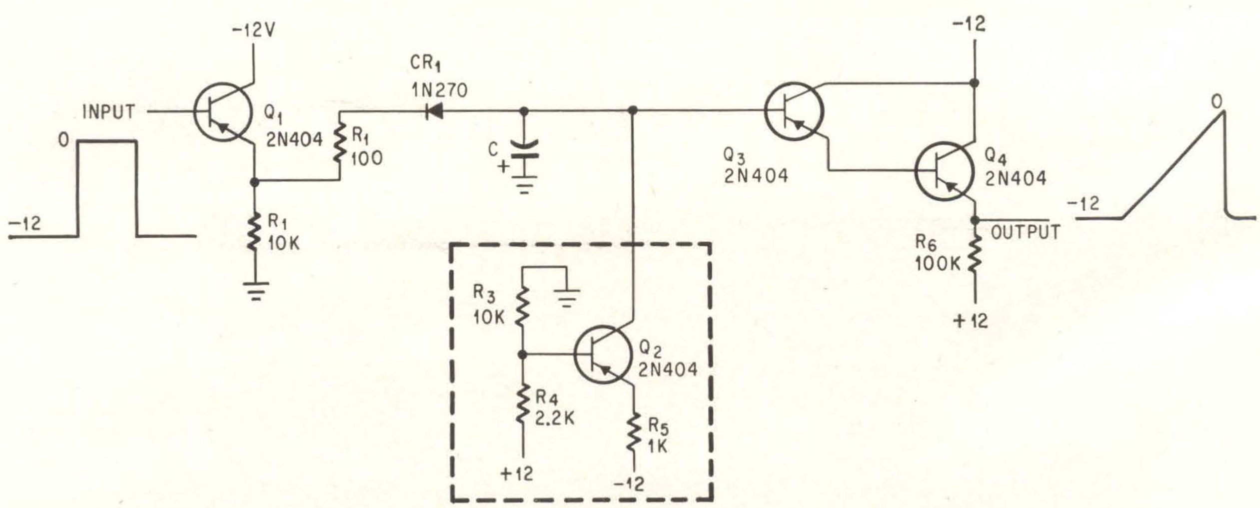
In a typical application, with an input pulse voltage ($-E_i$) of -12 volts, the constant-current source was set at two milliamperes. The total sweep time desired was 100 microseconds, and a full 12-volt sweep was also desired. Therefore:
$C = (2 \times 10^{-3})(10^{-4})/12$
$= 0.016$ microfarad

The retrace time T_R (time for the voltage to revert to nearly $-E_i$) is given by:
$T_R = 3\ RC$
where
$R = (Z_S/\beta_1) + Z_{D1} + R_2$
β_1 = Beta of Q_1
Z_S = Source impedance
Z_{D1} = Forward impedance of D_1

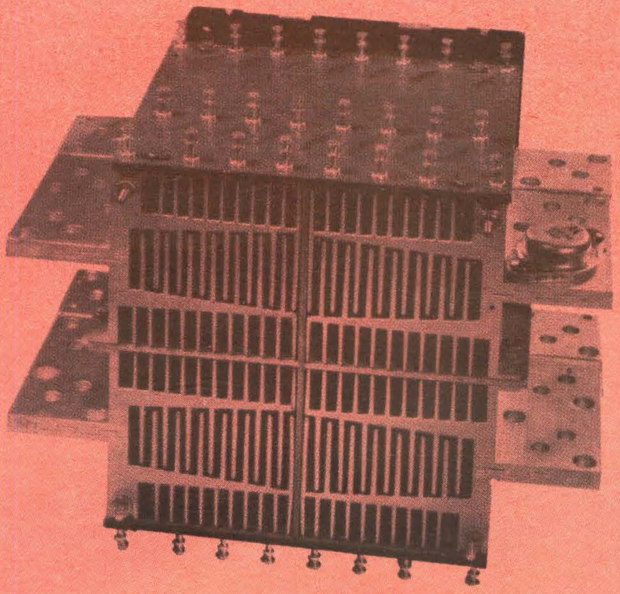
For the example specified above, the retrace time was about four microseconds.

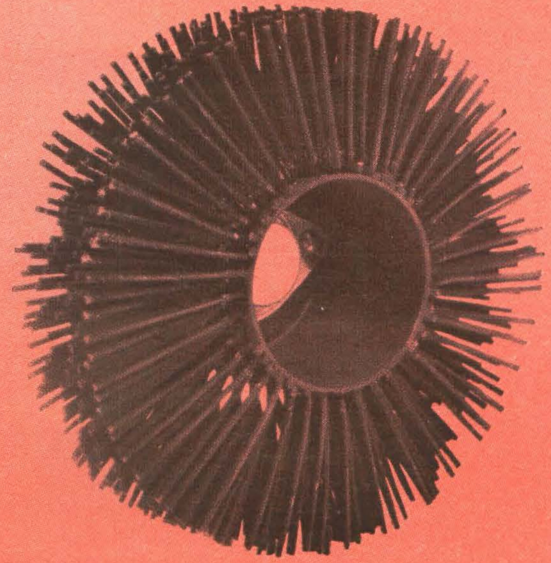
The Darlington connection of Q_3 and Q_4 presents a high input impedance to the sweep circuit and acts as a buffer to the load. For sweep times greater than one second, with good linearity, Q_3 should be replaced with a transistor having high current gain with low base current.

Resistor R_2 was added to the circuit to limit the peak current handled by Q_1 during the discharge of C. Resistor R_2 is 100 ohms.

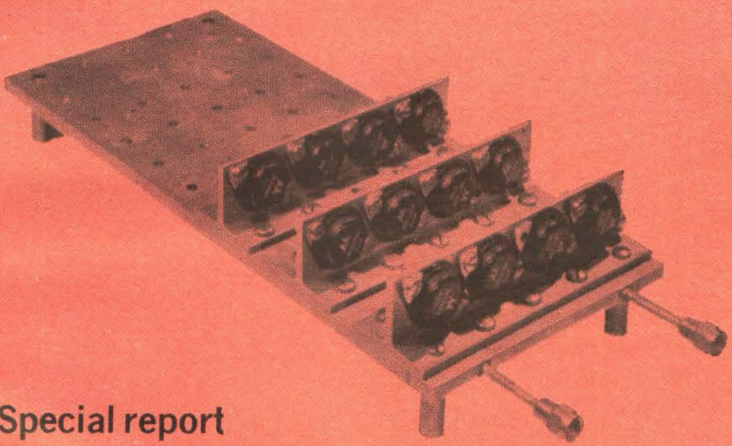


The constant-current generator stage (shown in dashed box) supplies a 2-milliampere current to the capacitor.





Fan-cooled modular heat sink, above
Long-pin dissipator, right
Water-cooled cold plate, below



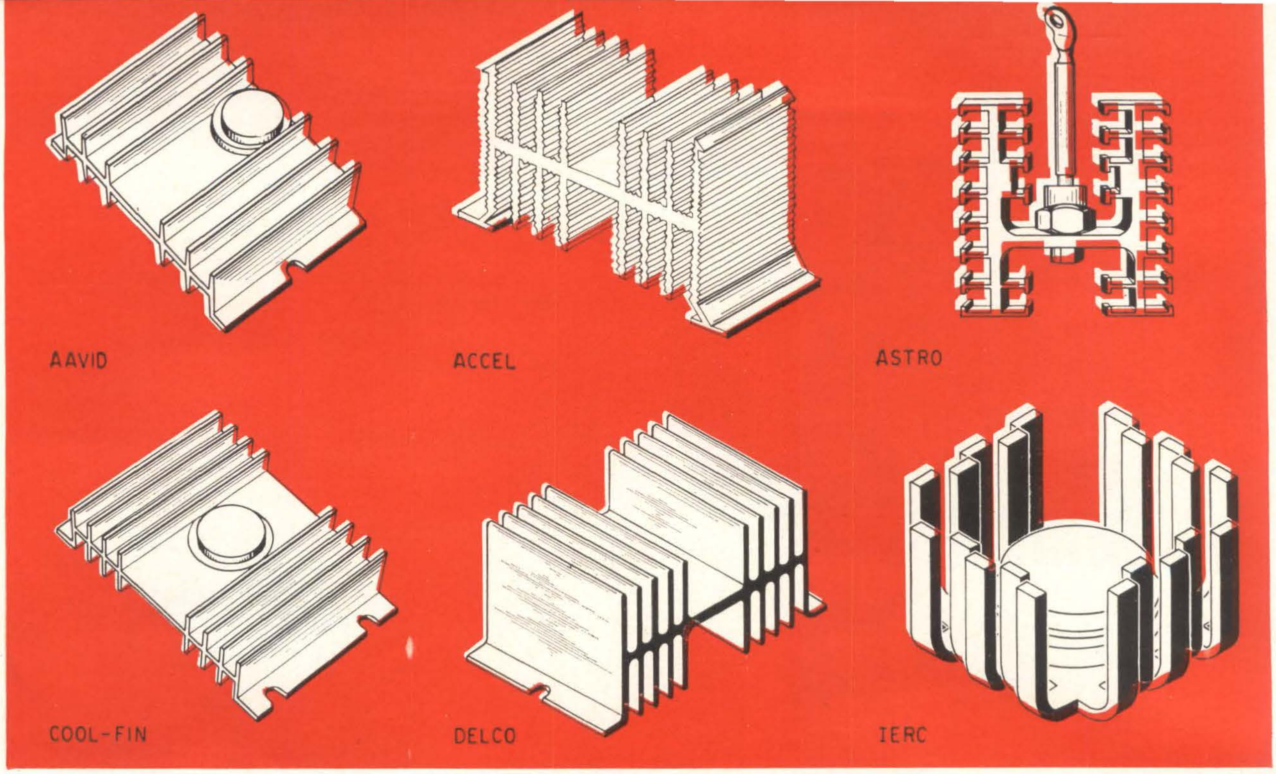
Special report

Transistor heat dissipators

Heat dissipators, also known as heat sinks, are devices which carry off heat from transistors, silicon controlled rectifiers, other products made of semiconductor material and, in some cases, nonsemiconductor devices.

The sensitivity of semiconductor devices to temperature created the need for dissipators. Various studies indicate that a reduction in operating temperature of from 8° to 15°C doubles the lifetime of a semiconductor device.

The ability of a high-power dissipator to lower the case temperature of a power transistor demonstrates its usefulness. At a 2.5-watt power level, without a dissipator, the case temperature for a typical germanium power transistor rises to 80°C (close to the maximum allowable temperature for this device). With a high-power dissipator, but without the added cooling help of a fan, the case temperature can be maintained at 35°C. This represents an approximate increase in lifetime by a factor of three to five for the transistor. Without a dissipator the same transistor cannot be safely operated above three watts. With a dissipator and forced-air cooling, the transistor can be safely operated to 50 watts.



Some of the heat-sink types currently available. The average manufacturer's line of power-transistor dissipators

Profile: the heat-sink industry

The battle for business is hotly fought in a new industry devoted to taking the heat off transistors and other semiconductor devices

By Jerome Eimbinder

Solid State Editor

Heat-sink manufacturers are nostalgic about the early days of their industry. Those "good old days" only go back seven years but, according to the officials of many companies, they were a harmonious, happy time when industry relations were cordial and cooperative. In that golden era no company tried to steal another's customers or design ideas.

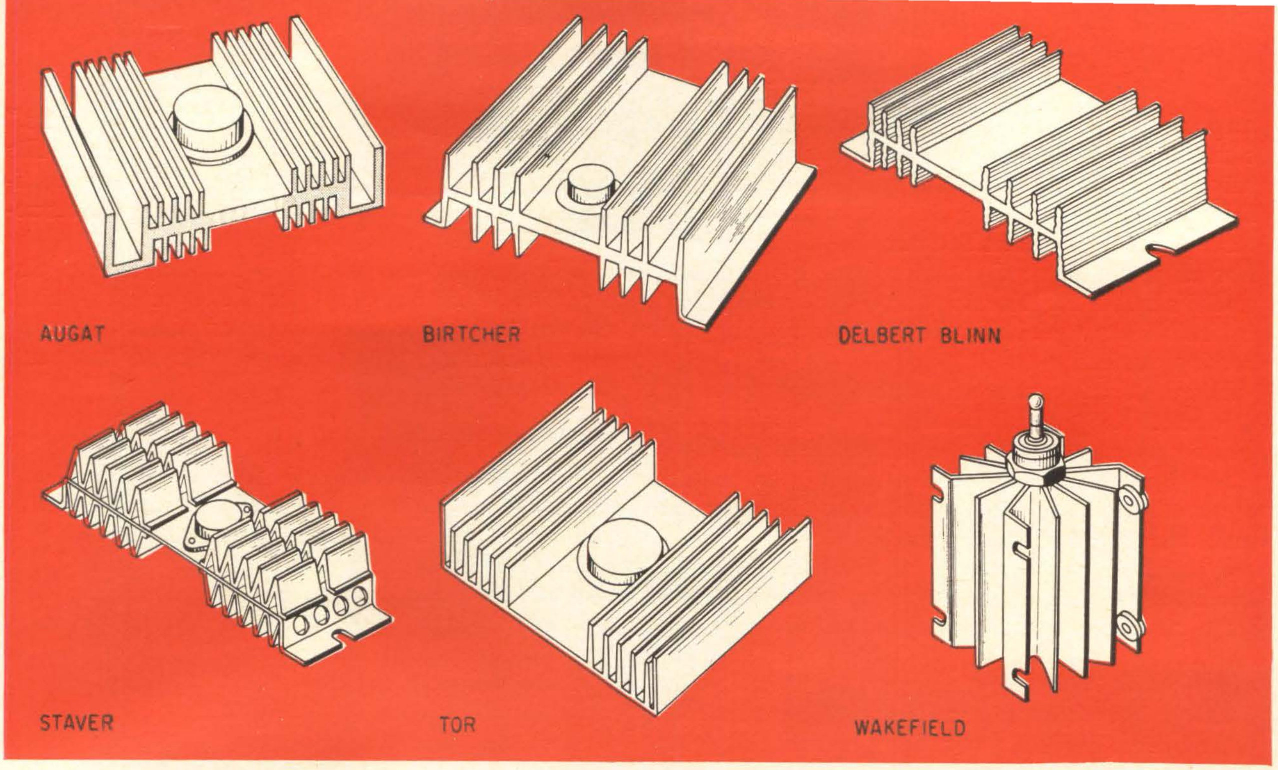
The marketing approach was educational. Salesmen concentrated on acquainting companies, not then using heat sinks, of the advantages of designing them into equipment. Dissipators were often custom-tailored to the buyer's requirements. One manufacturer says, regretfully, "In the beginning all we had to do was convince customers to use heat sinks. Later on, we had to sell them on ours rather than a competitor's."

By last fall the dissipator manufacturers were getting rather cool to each other. More companies had entered the field. Many of the new outfits, it is charged, just imitated the market-accepted shapes of the dissipators already being sold. Suspicion ran high and the original manufacturers started to reexamine each other's lines, as well, for possible infringement of ideas and pending patents.

Philosophy changes

Then too—two changes in basic philosophy were having an effect on the industry. The first was the change from direct selling either by the company's sales force or by manufacturers' representatives to a less direct approach—the widespread use of stocking distributors. The use of the distributors produced the second change. Manufacturers switched the emphasis from custom-made products to standard available-off-the-shelf dissipators.

Though the switch to standard commercial product lines and distributor sales networks is credited with ushering in large-scale operations for the dis-



contains from five to fifteen different basic shapes—each is usually available in several different sizes.

sipator manufacturers, it also introduced a new problem. Obviously, the distributors were not anxious to carry the almost infinite variety of products previously made available by the manufacturers.

Prior to 1962, when a customer selected a power-transistor dissipator he specified material (usually aluminum) and finish, length (usually anywhere from 1.5 to 6.0 inches), hole pattern, number of hole patterns (occasionally two or more transistors are mounted on a single dissipator), diameters and locations of holes for mounting hardware, and other custom touches. The new marketing setup was not geared to the continuance of this practice. Standardization was essential.

Standardization

Deciding on a standard material and finish was hardly a problem. The majority of requirements were satisfied by black anodized aluminum—already the standard in the industry. Those applications which demanded copper's higher thermal conductivity per unit volume would continue to receive factory custom service.

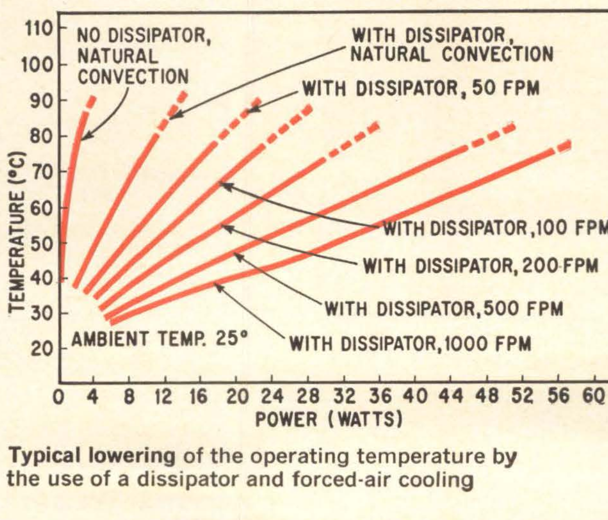
But after deciding on black anodized aluminum, the road to further standardization became rougher. About eight power-transistor hole patterns (see chart of hole patterns on pp. 90 and 91) were already in popular use and more were emerging. In addition, seven different stud sizes were being used for silicon controlled and other semiconductor rectifiers. Thus, if a distributor planned to stock a particular dissipator shape in four lengths, he needed 60 different variations of the basic shape for complete coverage.

One method hopefully introduced to ease the staggering inventory problem was the use of universal hole patterns. These combine two or more of the basic hole patterns in one. Although they do not affect the thermal resistance of the dissipator significantly, there has been reluctance on the part of many engineers to use them because the non-universal hole patterns are also available. As a result, instead of reducing the inventory problem—in providing an extra style—universal hole patterns actually add to the number of inventory types.

The efforts to standardize still have a long way to go. For example, the Birtcher Corp. has more than 10,000 different dissipator types available, including tube coolers. The combined tube and transistor dissipator line of the International Electronic Research Corp. numbers more than 5,000. The situation is similar for other manufacturers.

Product copying

Today the dissipator industry is involved in an



Typical lowering of the operating temperature by the use of a dissipator and forced-air cooling area completely removed from distributors and standard product lines. The once-friendly relationships are giving way to law suits. Companies are fighting product-copying in the courts. Each of three dissipator manufacturers in the immediate Boston area—Astro Dynamics Inc., Pin Fin Inc., and Wakefield Engineering Inc.—for example, have initiated suits against competitors for copying their cooling devices.

You wouldn't expect someone to copy a concept as unusual as that of the Pin Fin Co. It has been pioneering a construction concept radically different from its competitors. Its dissipators rely on an array of needle-like projections which look like porcupine quills to carry off heat (page 99).

John Jacoby, president, says, "When a small machine shop copies one of your heat sink styles for a customer, you may never find out about it." According to Tom Coe of Wakefield: "Copying often results when a customer brings a competitor's type to another manufacturer and asks for a better price." William Venema, president of Vemaline Products Co., Inc., agrees. He notes: "We know of a few cases where our products were copied by competitors at the specific requests of the customers. We've learned to live with this." He concedes, "We've been accused of copying, too." John McAdam, engineering vice president of the International Electronic Research Corp. adds, "They (competitors) pick off the cream of our design, winding up doing very little original work."

Many of the manufacturers feel that the copying is being initiated by the customers. The practice doesn't hurt the customers who justify their action by arguing that it is a step towards standardization. It's also a way of obtaining lower prices.

In one case, a manufacturer okayed copying. Lenhold Katz, president of Astro Dynamics explains: "We recently received a large order with an extremely short delivery date. To protect the customer, we recommended that he also use a second source. We directed him to a competitor with facilities for producing a shape similar to ours."

Katz is not always this generous, however. His company is launching suits against three competitors for alleged unauthorized purloining of Astro-developed dissipator designs.

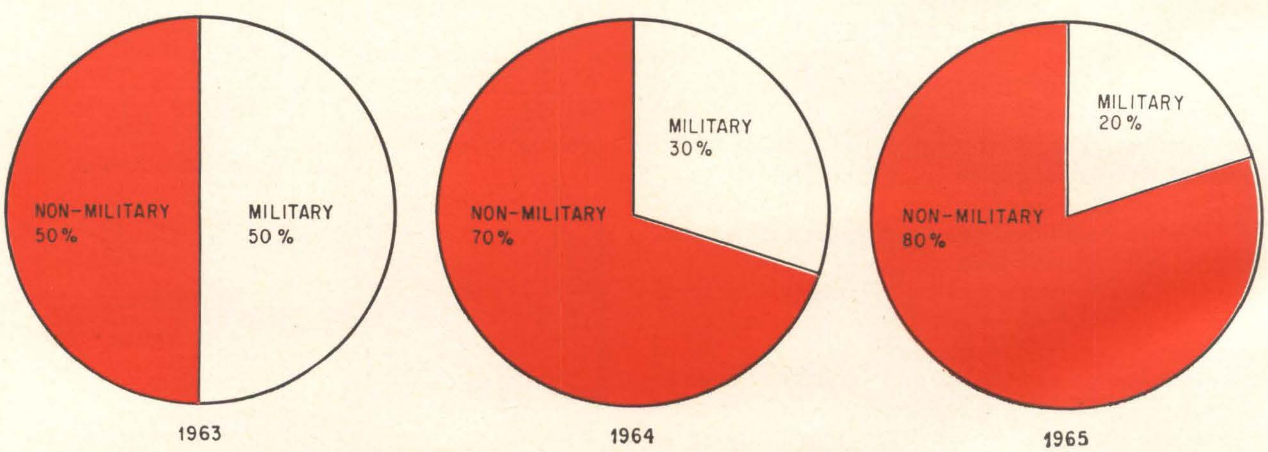
The copying has not been limited to the dissipators. Thomas Coe, president of Wakefield, claims, "A West Coast competitor of ours took one of our catalogs, pasted his name over ours, and then reprinted it."

Customer education

The educational service provided by the dissipator manufacturers is still considerable. Most of the dissipator manufacturers offer to evaluate a customer's needs and recommend the required dissipator size, shape and finish. Occasionally, they are also asked to compare various approaches (such as free vs. forced convection), or to assist in the integration of the dissipator into the design as a structural support.

Because many of the engineers involved in the specifying of dissipators have little previous experience with the heat-transfer devices, the manufacturers are sometimes asked why they don't make magnesium heat sinks. Magnesium does have excellent thermal conductivity, but is expensive and it does not stand up well under salt spray. It is not being used, at present, in standard product lines.

Part of the educational program conducted by the manufacturers is directed toward switching customers from a custom-designed product to a standard product. Katz told us, "Too many engineers make the selection of a heat sink the last step in the design. This often means that only a custom-made shape can fit into the remaining available space. A standard dissipator will often work just as well or better." Everett Nance, vice president of the Cool-Fin Electronics Corp. adds, "If they would only put them (dissipators) at the beginning of the design, they would save money." McAdam of IERC believes, "If systems were designed to include heat



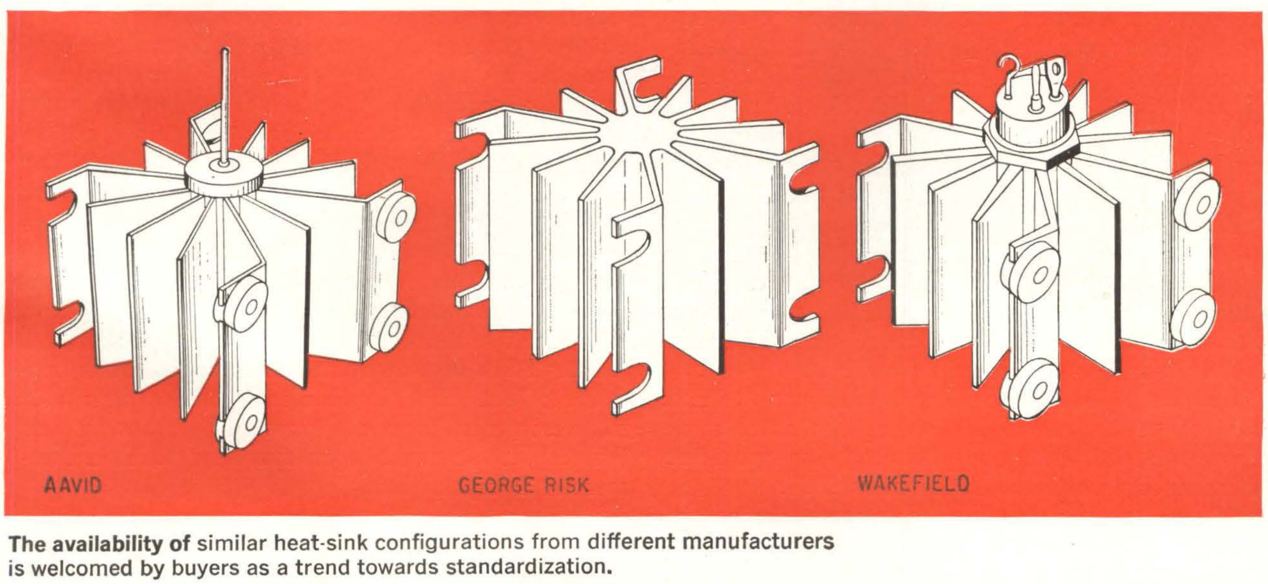
The changing market for transistor heat dissipators.

"Our engineering department is developing a new model."

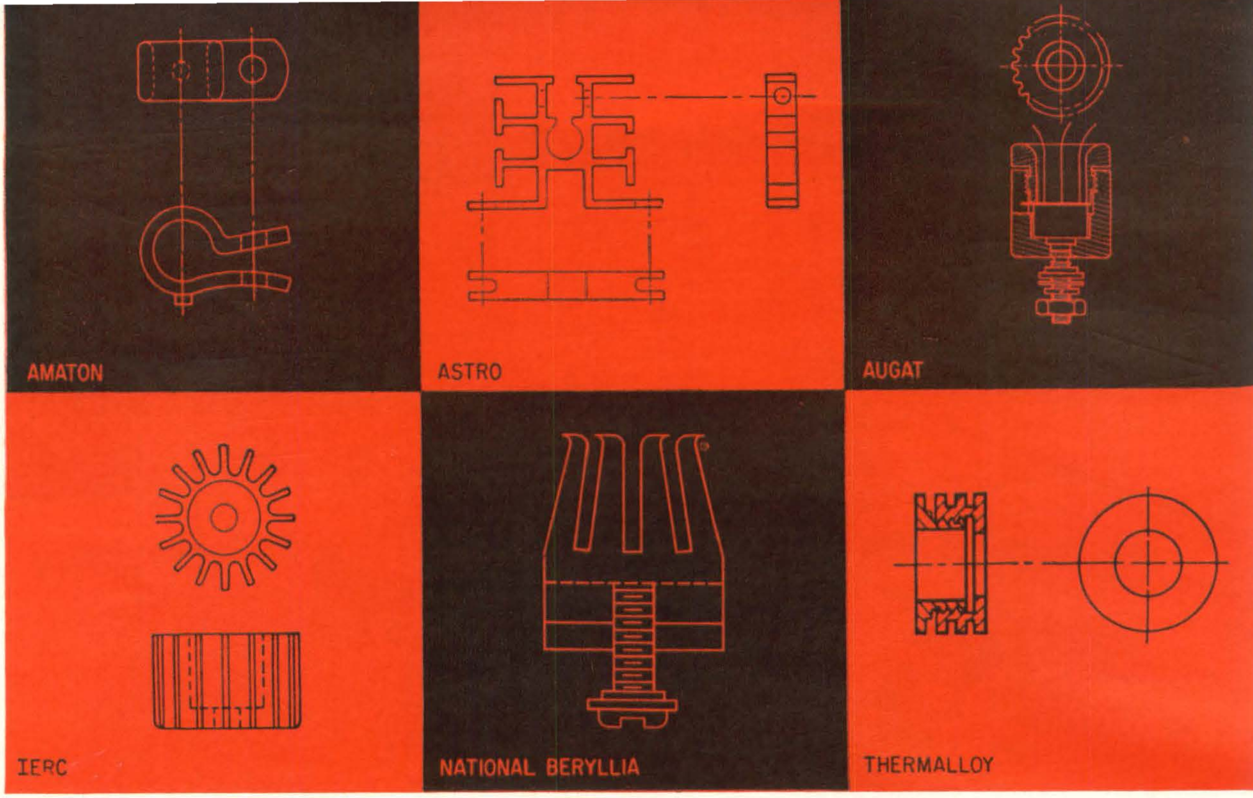
sinks from the start, we wouldn't have the problem we have now—components that won't fit and thousands of part numbers when we only need hundreds."

Business outlook in the East

The recent cut in government spending hasn't bothered the Eastern dissipator manufacturers much. All are experiencing substantial increases in volume. Nearly all of the new business is nonmilitary. Much of it is for computer power supplies, motor speed controls in mills, metal purification and plating systems, and communication system power supplies. Sales for airborne and ground sup-



The availability of similar heat-sink configurations from different manufacturers is welcomed by buyers as a trend towards standardization.



A representative sample of low-power transistor dissipators and retainers

port equipment are reported off.

Sales for Astro Dynamics, Inc. the first half of 1964 were 90% over its sales for the same period in 1963. Bob Keezer, sales manager, expects 1964 sales will be double the sales made in 1963. Three shifts are working around the clock to produce Astro's new forced-convection dissipators. Honeywell Inc. is one of the principal buyers. Astro is particularly pleased with its increasing sales volume in the hobbyist and experimenter field.

Sales for Augat, Inc. the first half of 1964 were more than 25% over its sales for the first half of 1963. The company reports that its military business is holding steady with the gains being made in its commercial product sales.

Pin Fin Inc. is only one year old. During the second quarter of 1964, it tripled the total sales it achieved for the first quarter. Fourteen of its sixteen product lines are intended for use with semiconductor devices; two are for use with special-purpose tubes. Rumors that Pin Fin is affiliated with Augat have been denied by both companies. Pin Fin did discuss the marketing of its products by Augat but the negotiations fell through.

The Staver Co.'s line of dissipators comprises only a small percentage of its total business. Its main products are tube shields and transformer cans. Staver's dissipator sales are climbing steadily, and it expects that its brand-new laminated dissipator will further brighten the sales outlook.

Vemaline's dissipator sales volume for the first half of 1964 is up about 15% compared to the same period for 1963. Vemaline plans to bring out a line of liquid-cooled heat sinks in early 1965.

Wakefield, whose only products are dissipators, reports that it made more money during the first quarter of 1964 than during all of 1963. Wakefield had eight product lines at the start of 1963 and ten at the start of 1964, but will have increased to fifteen by January, 1965. Three-quarters of Wakefield's production is for nonmilitary end use. Its new line of kingsize heat sinks is receiving considerable attention—the buyers already include General Electric and Westinghouse.

In the West

Here the picture is not as bright as in the East. The West Coast dissipator makers depend considerably on military business. IERC is the exception. Because of its national sales setup it reaches the same markets as the Eastern manufacturers.

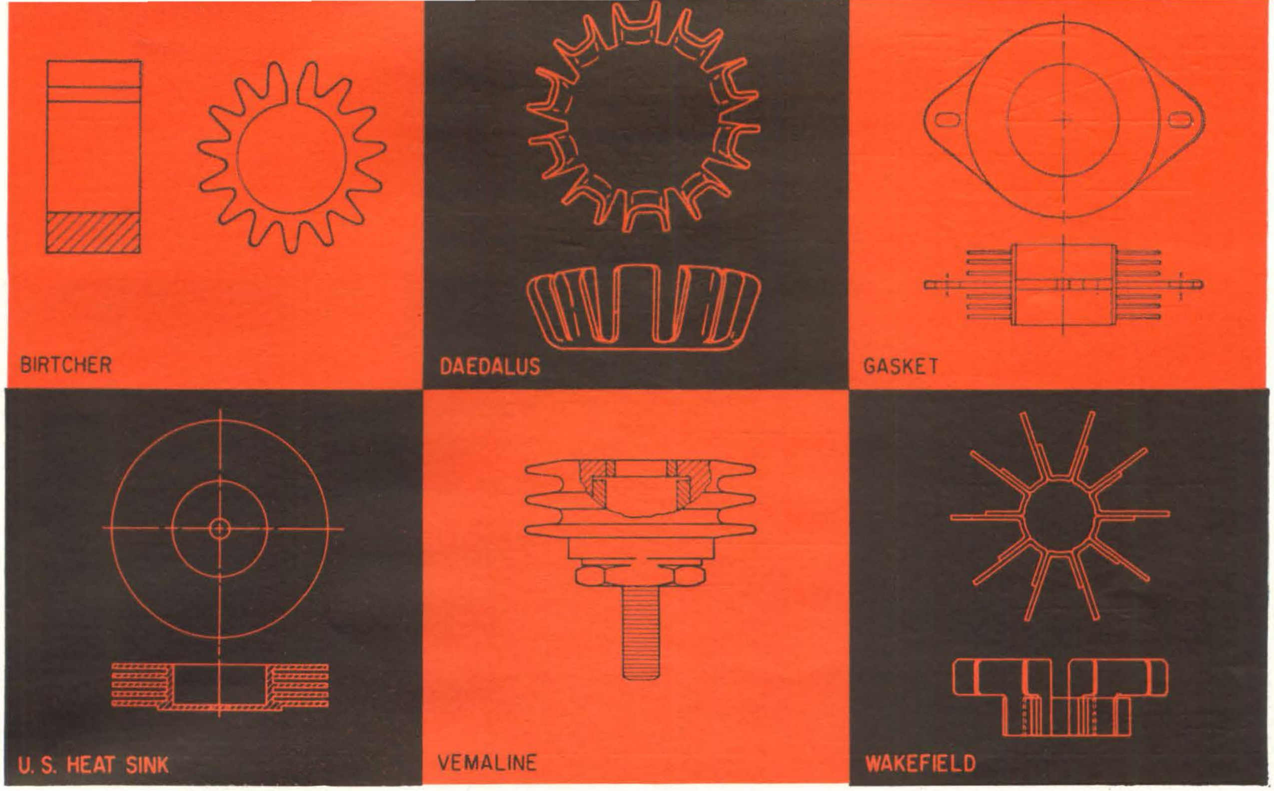
Again with the exception of IERC, the West Coast dissipator manufacturers report that business is disappointing. Nance of Cool-Fin says: "Heat sink sales are picking up but there is no big crashing demand. A year ago, people said that they were the big thing. We got into the business then but this prediction hasn't been borne out." According to Jay Cook, U.S. Heat Sink Co. president, "In general, the situation is not too good. He adds, "The run-of-the-mill heat sink is, for the most part, the rule now. This makes the business a highly competitive one."

IERC's dissipator business was up about 10% during the past year. McAdam is encouraged. "As a whole, our business looks good," he reports.

The TOR Manufacturing Co., originally a producer of extruded aluminum for use by dissipator manufacturers, is not discouraged either. It has jumped on the bandwagon and now offers a commercial dissipator line.

Elsewhere

The Modine Manufacturing Co. of Racine, Wis.



is betting on its line of forced-convection dissipators. This company knows it has to overcome the reluctance of many engineers to use this approach. But it is convinced that ducted forced-convection cooling with heat sinks is the ultimate answer to heat removal problems.

Modine has found that many engineers hesitate to use forced-air cooling systems because of the required fan and associated duct work. Other reasons for this attitude, James A. Mosier, Modine engineer, points out, are "lack of education in heat removal at the design engineer level and approaching the use of heat sinks on a piece part basis rather than total package cost."

George Risk Industries, Inc. in Columbus, Neb. is another newcomer having entered the field in late 1962. The company is marketing four basic product lines—one of which is a forced-convection line. Sales for the first half of 1964 are reported double the first-half sales for 1963.

The Thermalloy Co. of Dallas hasn't decided to market a forced-convection unit as yet but is producing a wide line of free-convection types.

Financial picture

Based on projected sales for the second six months of the year, 1964 factory sales of dissipators for semiconductor devices (excluding sockets, associated hardware, and tube heat dissipators), will top $10 million.

First-half-of-1964 reports for the dissipator industry indicate over-all earnings up about 50% over the first half of 1963, despite the military cutbacks. This figure compares favorably with the 41% net gain in earnings compiled by the New York Times survey of major companies in electronics and associated industries (except defense).

The stability of aluminum prices is comforting to the dissipator manufacturers. The current price of aluminum from the producers to the mills, although up slightly from last year, is still 7.7% below the 1961 price.

Future prospects

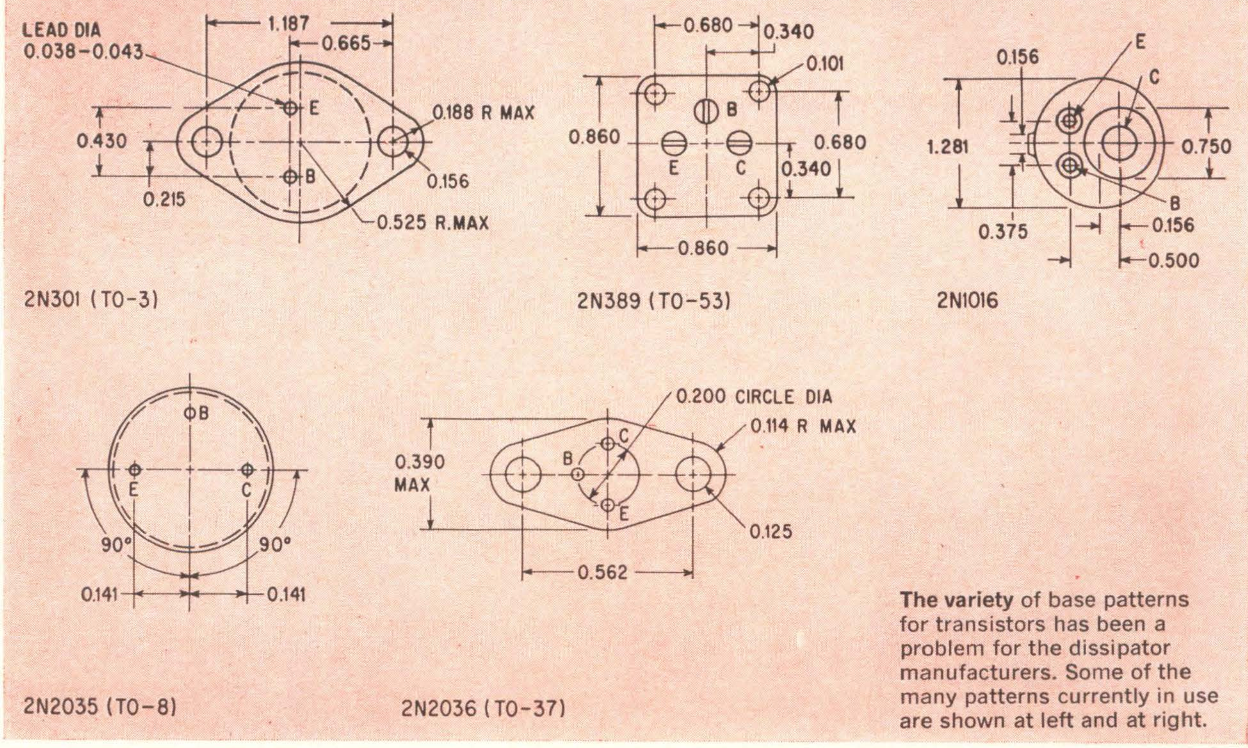
Most manufacturers look for the industry's gross sales to rise slowly but steadily. Few expect to get rich fast even with minor breakthroughs in dissipator technology. Price competition, already being felt, is expected to get stiffer. Some of the shakier manufacturers may be forced out of the market.

Copying of devices is expected to become even more common. Some feel that the law suits, both those launched and those contemplated, will be ineffectual and thus will serve only to open the door to more copying.

The dissipator market has been clearly established. No longer can a design engineer afford to regard the heat sink as a novelty. David Appleton of Augat, Inc. sums it up: "As long as semiconductor devices generate heat, and as long as the use of semiconductors continues to grow, the heat-sink market will continue to grow."

How to order a heat sink

Once the equipment designer has determined the thermal resistance required for a free-convection dissipator, he is ready to make a choice. But even after he selects a dissipator from his file of manu-



The variety of base patterns for transistors has been a problem for the dissipator manufacturers. Some of the many patterns currently in use are shown at left and at right.

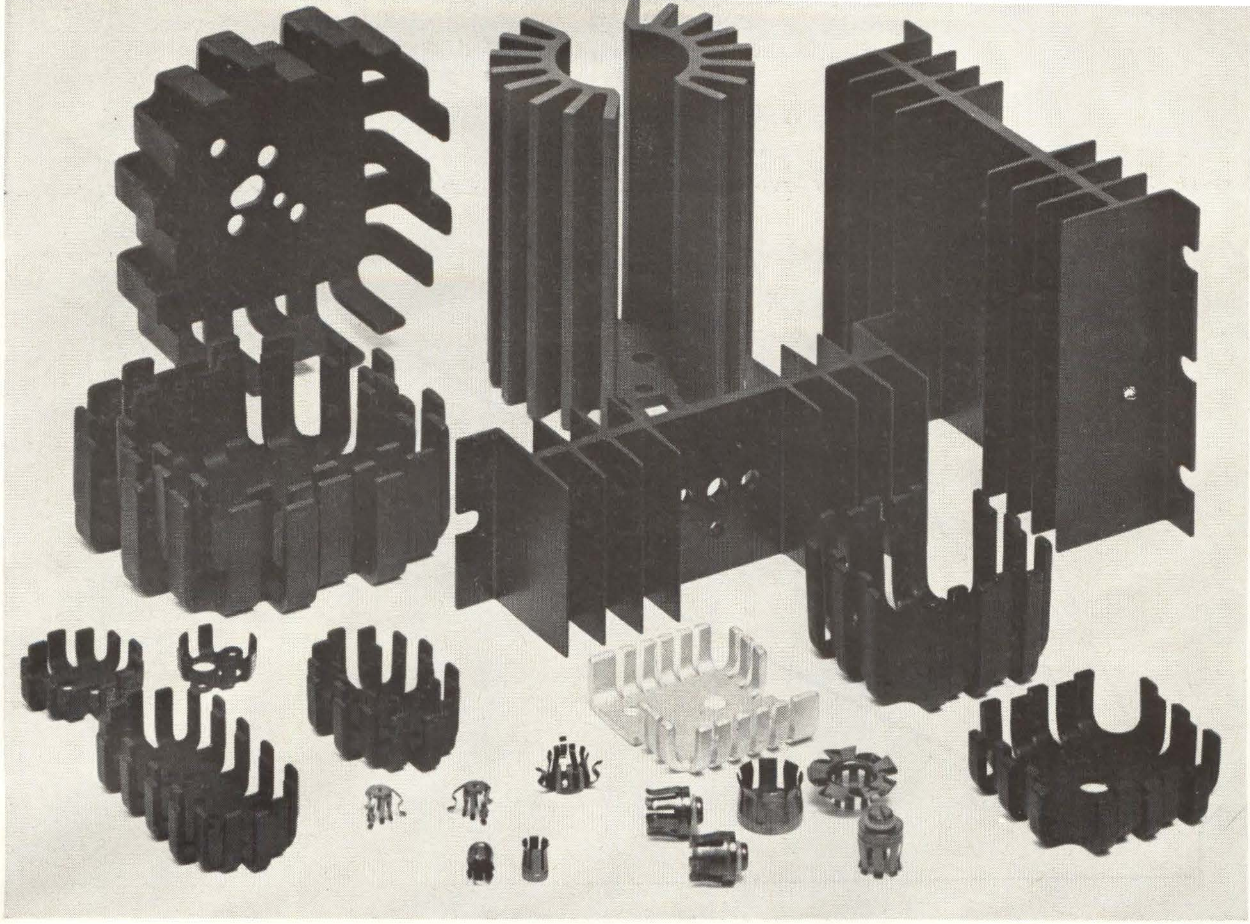
facturers' catalogs his specifying job is not over. In fact, it's only beginning.

The procedure for specifying a dissipator consists of eight basic steps.

1. Select the basic structure from the manufacturers' catalog
2. Specify material—such as aluminum or copper
3. Specify finish—such as black anodized or hardcoat
4. Specify transistor hole pattern or transistor to be accommodated—such as TO-36 or 2N1511
5. Specify number of hole patterns—typically one but occasionally two to four
6. Specify dimensions—lengths from 1.5 to 6 inches are usually available, with a limited choice in width and height dimensions
7. Specify location of transistor hole pattern and locations of holes for mounting hardware—unless otherwise instructed, the dissipator manufacturer will place the transistor hole pattern at the center

Directory of dissipator manufacturers

Free convection dissipators: Low power	Free convection dissipators: High power	Forced convection dissipators	Dissipator manufacturers	Addresses
■	■		Aavid Engineering, Inc.	28 Arch St., Laconia, N.H.
■	■		Accel Electronic Products	P.O. Box 467, Monterey Park, Calif.
■			Amatom Electronic Hardware Co.	432 Main Street, New Rochelle, N.Y.
■	■	■	Astro Dynamics, Inc.	Second Avenue, Northwest Industrial Park, Burlington, Mass.
■			Atlee Corp.	2 Lowell Avenue, Winchester, Mass.
■	■		Augat, Inc.	33 Perry Ave., Attleboro, Mass., 02703
■	■		The Birtcher Corp.	745 S. Monterey Pass Rd., Monterey Park, Calif.
■	■		The Delbert Blinn Co.	P. O. Box 757, Pomona, Calif.
■	■		Compagnie D' Electricite	54 Rue de la Boetie, Paris, France
■	■		COPRIM	130 Avenue de Ledru-Rollin, Paris 11, France
■	■		COSEM	12 Rue de la Republique, Puteaux, Seine, France
■	■		Cool-Fin Electronics Division of Elco Corp.	1717 N. Potrero Ave., South El Monte, Calif.
■	■		Daedalus Company	129½ Rosecrans Ave., Manhattan Beach, Calif.
	■		Delco Radio Division	700 E. Firmin, Kokomo, Indiana, 46901
		■	Gasket Manufacturing Co.	319 West 17th St., Los Angeles, Calif.
■			Horex Electronics, Inc.	2114 Pico Blvd., Santa Monica, Calif.



Typical heat-dissipator shapes: Retainers, medium-duty staggered-finger dissipators and a fan-top radiator are shown in foreground. Heavy-duty dissipators, including staggered-finger (left), appear in the background.

Thermal capacitance[4] is omitted in this discussion but included in the illustration to point out the many time-constants associated with heat power-flow. The total thermal resistance, θ_T, is the sum of the individual thermal resistances through which heat power flows from its origin to the device's ambient environment.

Thermal resistance

Typical thermal resistances for a power transistor dissipating 20 watts and mounted on a medium-size dissipator in natural air (no forced air movement) at 25°C are determined as follows:

1. Transistor junction temperature . . . 95°C
2. Transistor case temperature . . . 79.5°C
3. Dissipator temperature . . . 75°C
4. Ambient temperature . . . 25°C

The thermal resistance between two points is the difference in temperature of the two points divided by the power dissipated between the points. Thus,

$$\theta j - c = (95 - 79.5)/20 = .77\ °C/W$$
$$\theta c - s = (79.5 - 75)/20 = .23\ °C/W$$
$$\theta s - a = (75 - 25)/20 = 2.5\ °C/W$$
$$\theta j - a = \theta j - c + \theta c - s + \theta s - a = 3.5\ °C/W$$

Thermal resistance values vary considerably depending upon the measuring conditions. Thermal resistance will vary depending on the power being dissipated and on the ambient air-flow conditions even though the same transistor and dissipator are being used.

For example, the junction-to-ambient thermal resistance found above will be reduced from 3.5° to 1.5°C per watt if 500 feet-per-minute of air is blown on the dissipator and the power is increased to 90 watts.

Thermal runaway

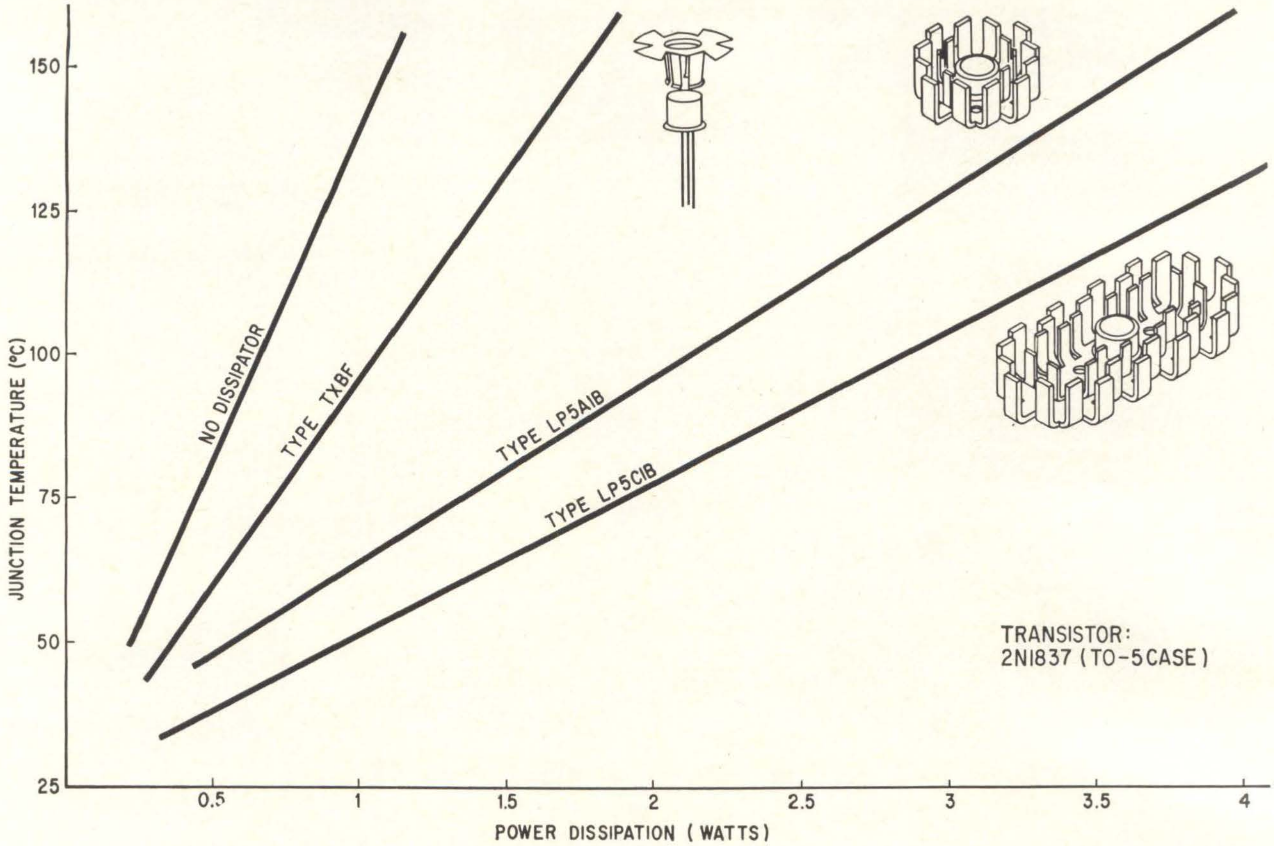
An increase in junction temperature changes transistor parameters in such a way that collector current flow is increased. With high operating junction temperatures, the circuit designer must guard against the possibility of a continuously increasing collector current—accompanied by rising dissipation—leading to transistor ruin. To avoid this chain-reaction condition, known as thermal runaway,[5, 6] the rate at which heat released at the junction increases must not exceed the rate at which power can be dissipated as the temperature rises.

The requirement for thermal stability[7] is:

$$dP_j/d\,\Delta\,T_{j-a} > (dP_j/di_C)\,(di_C/dt_j)$$

where dP_j = change in junction power dissipated
$d\Delta T_{j-a}$ = change in difference between junction and ambient temperatures
di_C = change in collector current
dt_j = change in junction temperature

J. A. Walston[8] describes thermal runaway as the repetition of three physical processes—first, a change in collector current causes a change in the power released at the junction; next, the change in junction power causes a change in junction temperature; and finally, the change in junction temperature causes a change in collector current. "Each



process," Walston says, "may be considered as a black box defined by an input, an output, and a transfer function [as shown on p. 95]. If the loop gain around this network is unity or greater than unity at any frequency, that is, if:

$$(\Delta i_{C1}/\Delta t_{j1})\ (\Delta t_{j2}/\Delta P_{j2})\ (\Delta P_{j3}/\Delta i_{C3}) \geqq 1$$

then thermal runaway is possible."

The quantities in the preceding equation are defined as follows:

i_{C1} = initial collector current change
Δt_{j1} = initial junction temperature change
P_{j2} = change in heat power released at junction
t_{j2} = change in junction temperature caused by ΔP_{j2}
i_{C3} = change in collector current caused by junction temperature change
P_{j3} = change in heat power released at junction caused by change in i_{C3}

The possibility of thermal runaway is increased when the transistor is subject to thermal feedback from another heat source in the system—as when two transistors connected in a Darlington amplifier configuration are mounted on the same heat sink.

Thermal stability, by the way, is usually of concern to the circuit designer only when the transistor is conducting normally and is not in saturation or cut off.

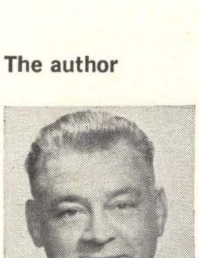
Excursions of characteristics

As if transistor destruction by excessive heat were not problem enough to harass the designer, there is the allowable range of characteristics in the semiconductor devices themselves to consider. By nature they have a normal excursion range for characteristic values which is sometimes tight—but more often considerably loose. For example, one manufacturer's specification sheet for the 2N697 lists characteristic spreads at 25°C which represent differences in the maximum value from the minimum value from 30% to 990%.

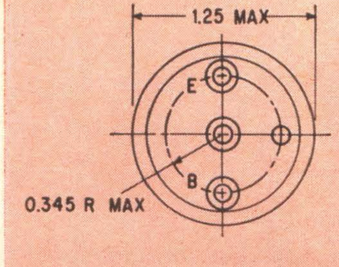
If the semiconductor junction were always operated at 25°C, circuitry could be designed very simply to compensate for these spreads. But unfortunately, semiconductor device junction temperatures quickly rise above 25°C during operation. Therefore the actual excursions of characteristics are greater than indicated by the specification sheet. Furthermore, many variables affect circuit operation, depending on environmental conditions, complicating the determination of actual minimum-maximum ranges for parameters.

In addition to affecting d-c pulse current gain, cutoff current, and saturation voltage, temperature

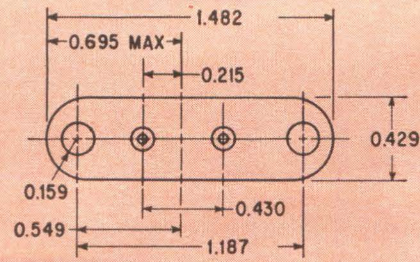
The author



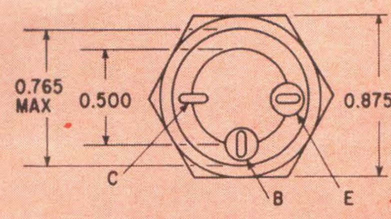
John C. McAdam directs design, development and testing and supervises the research program at the International Electronic Research Corp. He is a technical advisor on international specifications for the Electronic Industries Association and the International Electrotechnical Commission and was one of the delegates to the recent IEC meeting in France.



2N1511 (TO-36)

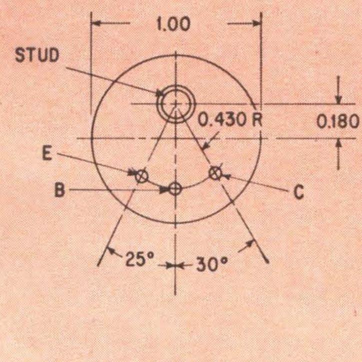


2N1755

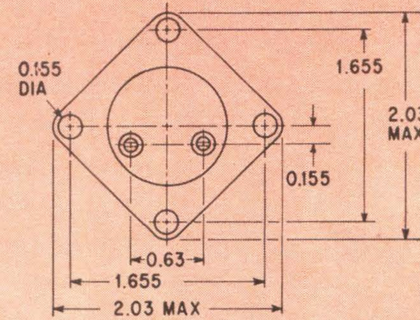


2N1936

The two most commonly used base patterns are the TO-3 (top left, p 90) and the TO-36 (top left above). Some heat-sink manufacturers offer a universal hole pattern which accommodates both.



V15/30 P (BRITISH)



2SB 125 (JAPANESE)

of the heat sink

8. Specify associated hardware to be supplied with heat sink—brackets, washers, nuts, etc.

Once the procedure has been completed, the designer's next job is to find the commercially available heat sink which is closest to his requirements —unless he is willing to pay a premium for a custom-made dissipator.

The designer may wind up revising several of his requirements in order to take advantage of the availability of an inexpensive standard dissipator. He will probably find it wise to alter his equipment package design to accommodate standard heat sinks.

The variety of heat sinks available gives the designer a considerable amount of choice and the modifications he must make in his plans are often minor. Most manufacturers offer each of their basic aluminum heat sinks with a number of different modifications directly from stock.

Free convection dissipators		Forced convection dissipators	Dissipator manufacturers	Addresses
Low power	High power			
■	■	■	International Electronic Research Corp. (IERC)	135 West Magnolia Blvd., P. O. Box 271, Burbank, Calif., 91502
	■		Mideast Aluminum Corp.	Route 130, Dayton, N.J.
	■	■	Modine Manufacturing Co.	1500 DeKoven Ave., Racine, Wis.
■	■		National Beryllia Corp.	First and Haskell Aves., Haskell, N.J.
■	■	■	Pin Fin Inc.	751 Main Street, Waltham, Mass.
	■		Precision Extrusions, Inc.	731 E. Green Ave., Bensenville, Illinois
■	■		Relco Products	2456 West Second Ave., Denver, Colo.
■	■	■	George Risk Industries, Inc.	672 15th Avenue, Columbus, Neb.
■	■		The Staver Co.	41–51 N. Saxon Ave., Bay Shore, N.Y.
■	■		Thermalloy Co.	P. O. Box 26036 414 Exposition, Dallas 26, Tex.
■	■		Tor Manufacturing Co.	1533 E. Walnut St., Pasadena, Calif.
■	■		U.S. Heat Sink	637 S. Isis Ave., Inglewood 1, Calif.
■	■		Vemaline Products Co.	Franklin Lakes, N.J.
■			A.R. Vetter	Box 128 Lemont, Pa.
■	■	■	Wakefield Engineering, Inc.	139 Foundry St., Wakefield, Mass.

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Beating the heat in semiconductor devices

How dissipators reduce operating temperatures, improve circuit performance and save money

By John C. McAdam

Vice President, Engineering
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It's simple and inexpensive to reduce the operating temperature of a semiconductor device. A 30-cent heat sink can lower the junction temperature of a 2N1837 transistor, operating at one watt, from 130°C to 90°C. And with a 42-cent sink, the junction temperature at one watt goes down to 45°C. But why bother?

The answer is that semiconductor operating temperatures represent both a problem and a challenge. They are a problem because they impose an operating limit on transistors. They are a challenge because with deliberate control of temperature the engineer can design new circuitry, improve or simplify existing circuits and often save money.

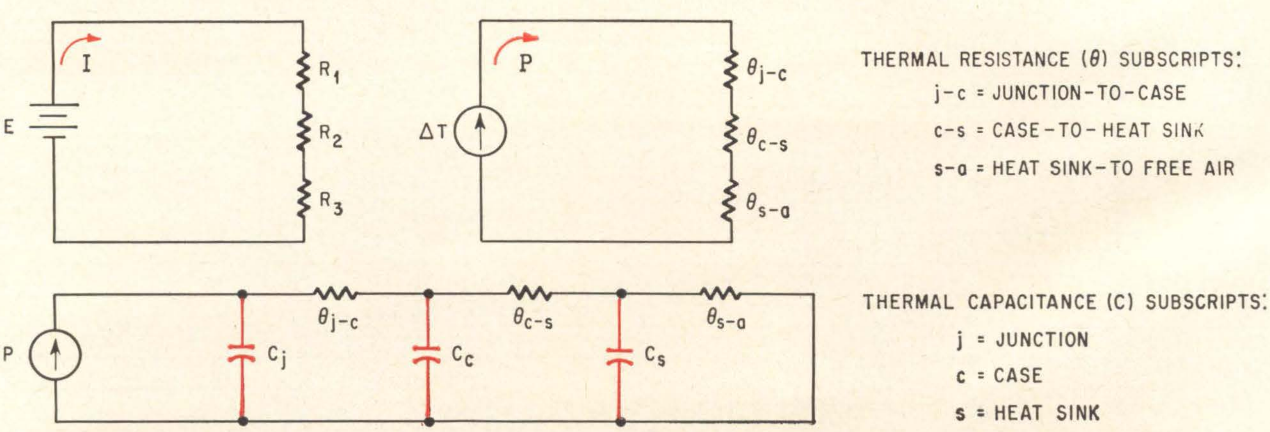
All transistors have maximum allowable operating temperatures—commonly from 85° to 100°C for germanium devices and from 150° to 200°C for silicon transistors. Transistor data sheets usually specify the absolute maximum junction temperature allowable. Exceeding this limit can permanently damage or destroy a transistor. A typical example is the 2N441, a germanium type; without a dissipator it can be operated up to 3 watts, which heats the junction temperature to 90°C—at or beyond the limit at which this type will be damaged. To run this transistor at a higher power level, such as 10 watts, would require a highly efficient heat dissipator which would hold the junction temperature at or below 85°C.

Thermal-flow diagram

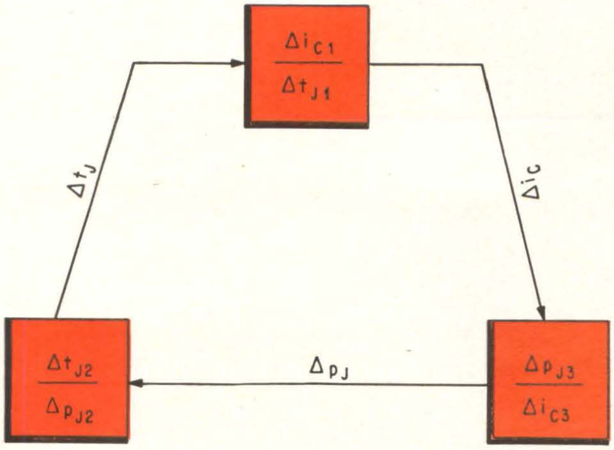
One convenient and commonly used way of expressing the basic flow of heat through a solid is to use an analogy between heat power and electrical power.[1,2,3]

In electricity, moving an electrical charge (coulombs) from one point to another requires a difference in electrostatic pressure (voltage). Impeding this flow is electrical resistance measured in ohms (volts per ampere). In the same manner, to move heat energy (joules) from one point to another, a difference in heat pressure, or temperature, must exist. The impedance to this flow is called thermal resistance measured in thermal ohms, or degrees centigrade per watt.

The analogy is illustrated by the simplified thermal-flow diagram. The transistor is dissipating constant power into an air-cooled heat sink.



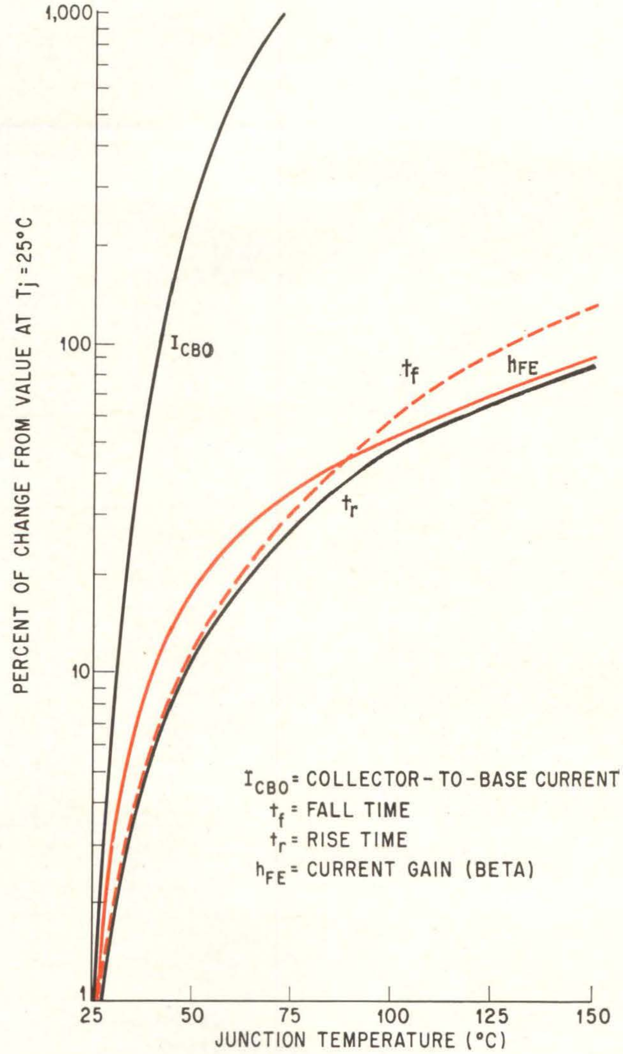
Current-flow diagram, top left. Thermal-flow diagram, top right. Thermal-flow diagram including thermal capacitance, bottom.



Thermal-loop diagram

◀ **The relationship** between dissipation and junction temperature for a low-power silicon transistor using various dissipators

Typical variation of characteristics with temperature for a silicon transistor. ▶



also has a profound influence on switching speeds, small signal characteristics (h parameters), and other parameters as shown at right. As the junction temperature increases from 25°C to 150°C, the collector cutoff current I_{CBO} increases by several orders of magnitude while h_{FE}, rise time, and fall time approximately double from 25°C to 150°C.

Dissipator advantages

The ability of dissipators to retard the increase in junction temperature with an increase in dissipation is shown on page 94 for a TO5-packaged transistor. It is evident that heat-dissipating devices can reduce high-power high-temperature problems. As shown, a silicon device operated at a 1-watt power level with an ambient temperature of 25°C and without a dissipator exhibits a junction temperature of 140°C. By applying a small slip-on fan-top radiating dissipator, the junction temperature is reduced to 95°C. Remounting the transistor in a heavier-duty dissipator further decreases the junction temperature to 65°C.

By holding down the junction temperature I_{CBO} is decreased substantially. The use of the small, inexpensive dissipator reduces the increase in h_{FE} from 50% to 30% above its 25°C value. Use of a larger dissipator further limits h_{FE} to only a 16% increase above its 25°C value.

It can be seen, too, that use of the dissipators decreases the rise and fall times by 20% to 40%. In fact, with a typical silicon transistor, by limiting the junction temperature to 50°C or lower, rise and fall times are decreased an order of magnitude from their values at the maximum junction temperature.

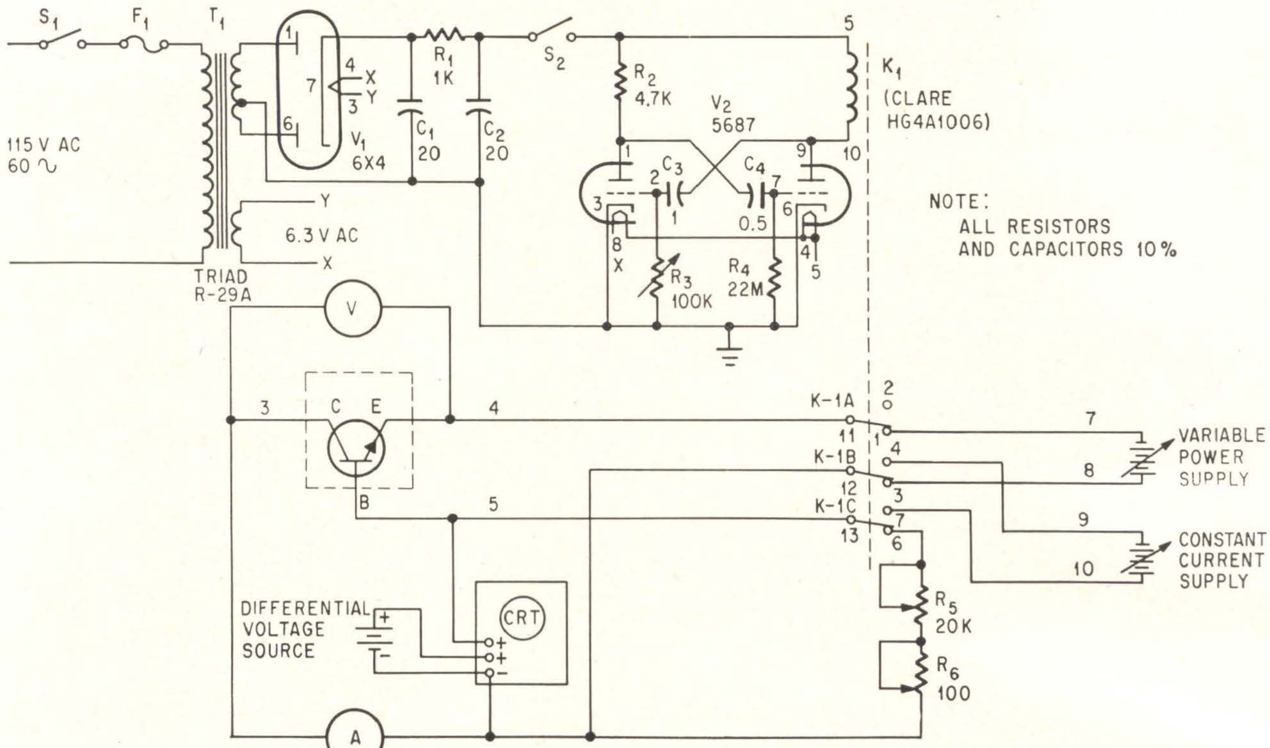
Other improvements with lowered temperatures include:

- Higher small signal gain and higher d-c beta.
- Decreased leakage current. This reduces the loading effects of a circuit. For example, the fan-out capability of computer circuitry is improved by reducing the load on the driver.
- Longer transistor life and greater circuit reliability.

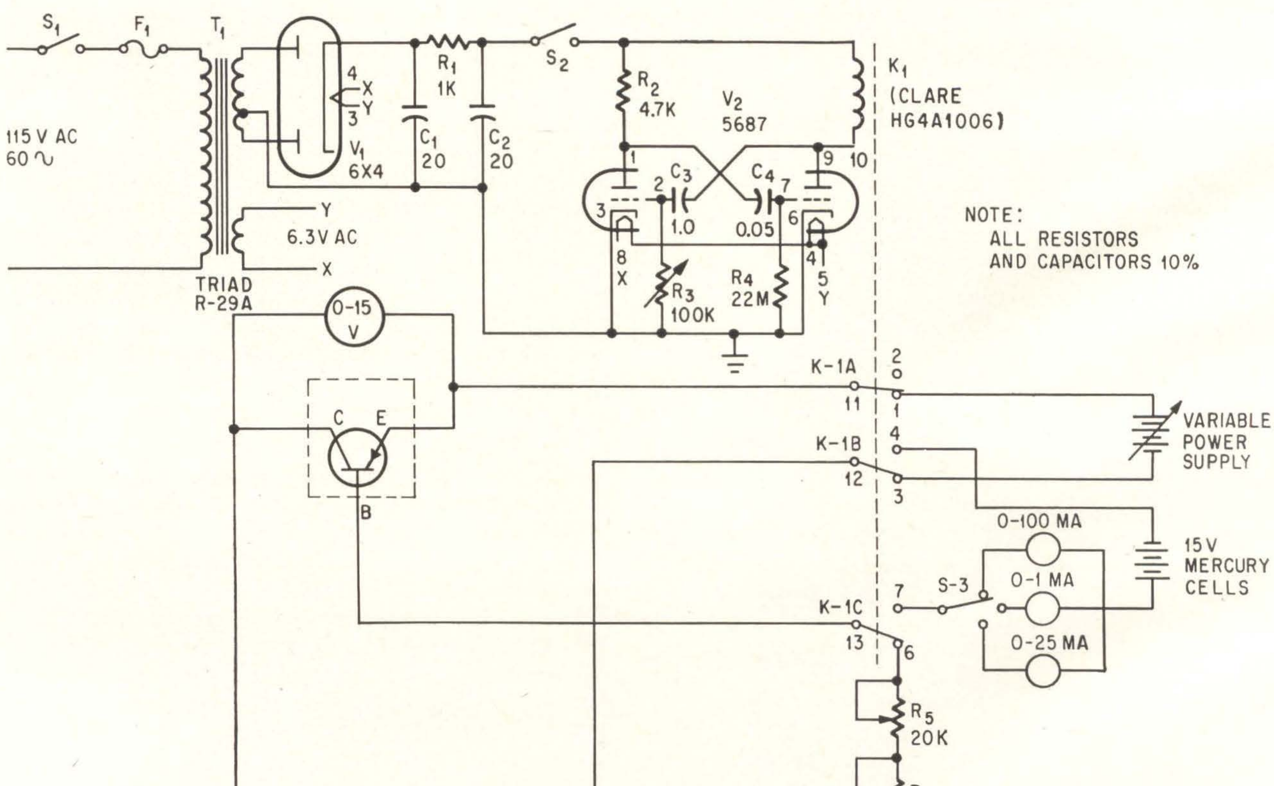
Greater economy in circuit construction may be achieved by using high-beta transistors with dissipators in place of low-beta transistors without dissipators. In one high-current application, three low-beta emitter follower stages were used to provide sufficient current for driving purposes. When high-beta transistors were utilized in the same application, one emitter-follower stage was eliminated. The three transistors, each with a beta of 20, provided a total current gain of 8,000 whereas the two transistors, with betas of 90, provided the same gain.

In another application, each transistor of a pair was operated at 2.5 watts because it was discovered that a single unit at five watts became too hot. The same circuit could have used a single transistor at five watts with a dissipator—saving transistor costs, assembly costs, and probably mak-

Parameter test circuits



Test circuit for measuring transistor junction temperature as a function of forward voltage drop



Test circuit for measuring transistor junction temperature as a function of collector cutoff current (I_{CBO})

ing the over-all performance of the circuit more reliable and predictable.

Measuring junction temperature

An awareness of the thermal aspects of circuit design is half the battle. The other half consists of knowing how to measure and control the temperatures involved.

Junction temperature values at a given power level can be obtained from several sources such as mathematical approximation, tables and curves already compiled for similar applications, and laboratory testing. The curves shown on page 94 for a typical semiconductor device were obtained in the laboratory. For many designs, the use of such curves is sufficient. Another method for obtaining design criteria is described below:

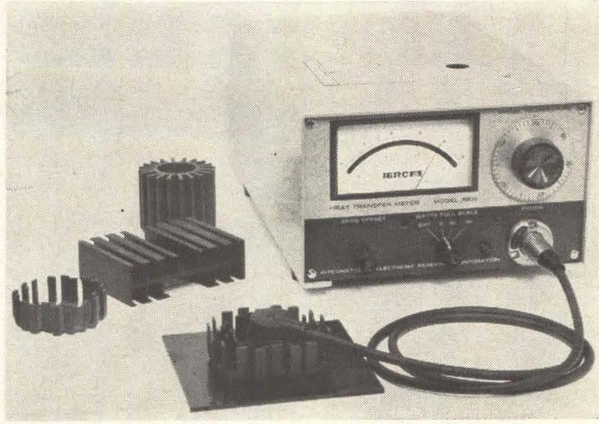
First, T_j is determined by measuring the electrical parameters of the transistors that are functions of T_j. The parameter used for silicon transistors is the forward voltage drop from collector to base, with the emitter open (V_{CBO}). For germanium transistors, the collector junction leakage current (I_{CBO}) is the parameter employed to measure T_j. The circuits used to measure these parameters are shown on page 96.

To determine the relationship of V_{CBO} or I_{CBO} to T_j for a group of transistors, the units are placed in a temperature-controlled chamber. Starting at 25°C, the temperature of the chamber is raised in 5°C steps to the maximum allowable junction temperature of the transistors. There is a 30-minute time interval at each step to insure that the transistor junction temperature is the same as its case temperature. Switch S_2 (in either circuit) is then closed, causing K_1 to energize briefly at set intervals, thereby permitting the I_{CBO} or V_{CBO}, whichever the case may be, to be measured. The measurement of V_{CBO} takes 27 milliseconds and is repeated every two seconds. For I_{CBO}, the measuring time is 150 milliseconds, also repeated every two seconds. Curves of I_{CBO} vs. T_j or V_{CBO} vs. T_j may be constructed from the data obtained.

Measuring heat dissipation

Next it is necessary to determine how much of the device's heat will be drawn away, or dissipated, by the surface (circuit board, metal chassis or heat sink) to which it will be attached.

The heat-transfer meter, shown above was specifically designed to determine thermal resistance. The heat sink under test is initially at room temperature. A front-panel control on the heat-transfer meter sets the desired transistor case temperature. The actual temperature at the heat sink is sensed by the probe and compared to the preset temperature. Any heat imbalance results in an error signal being fed to a high-gain amplifier which provides power to the heating unit in the meter. The operation is similar to the feedback which takes place in a servomechanism. The probe, which is simulating a transistor, continues to be heated and quickly reaches the preset temperature. A wattmeter on the face of the unit indicates the amount of power used to maintain the preset temperature. The power supplied by the heating unit is then reduced to a steady state value necessary to replace the thermal energy flowing into the heat sink and maintain the probe contact point at the preset temperature. The higher the wattmeter reading, the better the heat conduction capability of the heat sink.



Heat-transfer meter and probe for determining thermal resistance

Thus the heat-transfer characteristics of a surface may be measured under specified mounting conditions by attaching the probe, setting the probe temperature-dial for the desired temperature and, after allowing the system to reach a stable condition, reading the dissipated power on the meter. Comparison of various heat dissipating devices, methods of mounting and conditions of air flow may be quickly investigated in this manner.

Also, the temperature contours of a chassis may be plotted, using the heat-transfer meter in conjunction with a thermocouple-pyrometer. The probe is mounted in several places on the chassis, one place at a time, and the meter is set for the expected case temperature of the devices to be mounted at each given spot. The data obtained can be used to calculate the resulting over-all temperature rise of the complete equipment.

To measure the thermal resistance of a heat sink, the probe is applied to the heat sink, and the system stabilized at the case temperature for which the thermal resistance value is desired. From the recorded dissipated power and the temperature rise above ambient temperature, the thermal resistance $\theta_{C\text{-}A}$ is found from:

$\theta C\text{-}A = (T_C - T_A)/P$ °C/Watt

where T_C = case temperature (°C)

T_A = ambient temperature (°C)

P = power reading on meter (watts)

This procedure assumes that the probe dissipation simulates the additional dissipation of a transistor case.

In addition to investigating the thermal resistance of transistors, the meter can also be used to measure the thermal resistance of materials. A constant temperature source is used. The face of the probe is shielded from stray air currents, and the meter is set at zero with the zero offset control. The probe is then placed in contact with one surface of the sample to be tested. The other surface is maintained at a constant temperature on a heat sink. The thermal resistance of the material will be

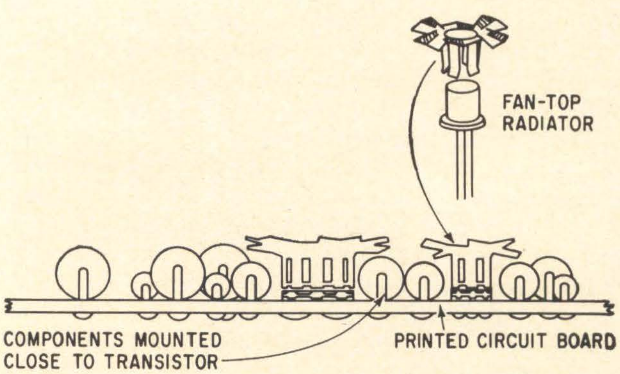
$$\theta = T_P - T_S/P \quad °C/\text{Watt}$$

where T_P = preset probe temperature ($°C$)
T_S = controlled heat sink temperature ($°C$)
P = power reading on meter (watts)

How to lower temperatures

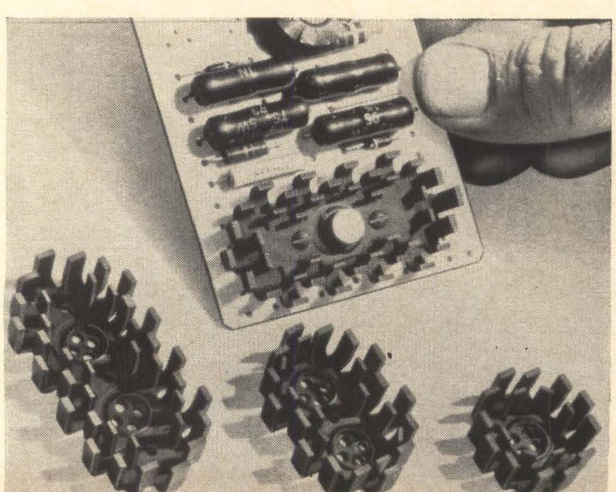
With today's high-power semiconductor devices, knowing how heat dissipators do their job is of great concern to the circuit designer. Once the requirements for the dissipator have been determined, a variety of shapes is usually available, regardless of the power level needed.

Considering only such mechanical factors as surface area and mass when selecting a transistor heat dissipator can be misleading. It may work in the design of a heat exchanger for a power plant which occupies an acre of land; however, when considering dissipating heat from a one-inch device in a crowded electronic system, the efficiency of the dissipating device, as related to its size and weight, is critical. The dissipator should be designed for optimum effective area rather than for available square inches of area. For example, a dissipator designed with the staggered-finger arrangement shown below can dissipate as much power as another type of dissipator, although it is only one-third of the weight and two-thirds of the volume of the second dissipator.



Fan-top radiator fans reach above components and enter forced-air path.

Linking of dissipators may be used to equalize the temperatures of two transistors (lower left and lower center) or to provide greater dissipating ability (lower right and above).



Dissipator construction should be compatible with equipment construction. For example, in equipment using closely spaced printed cards with air forced between them, the dissipator is attached to a transistor that is surrounded by components. For efficient cooling, a portion of the dissipator should extend into the forced air current. This is accomplished as shown below.

In some applications it is necessary to isolate the transistor electrically and reduce its capacitive coupling with the heat sink. This can be accomplished by brazing beryllium oxide material to the bottom of the dissipator. This material is an excellent electrical insulator but has thermal conductivity comparable to that of aluminum.

In many applications it is advisable to use a heat sink compound. The thermal resistance of a typical power transistor mounted to a heat-dissipating device is approximately 0.25° to 0.5°C per watt. Application of a good silicone compound will cut this value in half—or to about 0.1 to 0.2°C per watt. This happens because the compound has a much lower thermal resistance than the dead air in the small cavities of the interface joint. The compound fills in the cavities and allows more heat transfer across the total surface area of the joint. The use of such compounds has reduced many heat dissipation problems.

Circuit applications such as differential amplifiers, push-pull amplifiers, flip-flops and multistage configurations often require characteristic similarity in the semiconductor devices being used. One answer is to purchase matched pairs selected for mated parameters. Temperature control also plays a part here since differences in operating temperatures may cause an imbalance in temperature and affect the sensitive parameters and therefore cause deviation from ideal circuit operation. Thermal linking of two or more semiconductor devices and heat sinks equalizes junction temperatures and maintains matched or similar characteristics.

The thermal requirements of a circuit should be determined and the appropriate dissipators chosen early in the design. Any circuit design is incomplete if it is concerned solely with the electrical requirements of an application.

References

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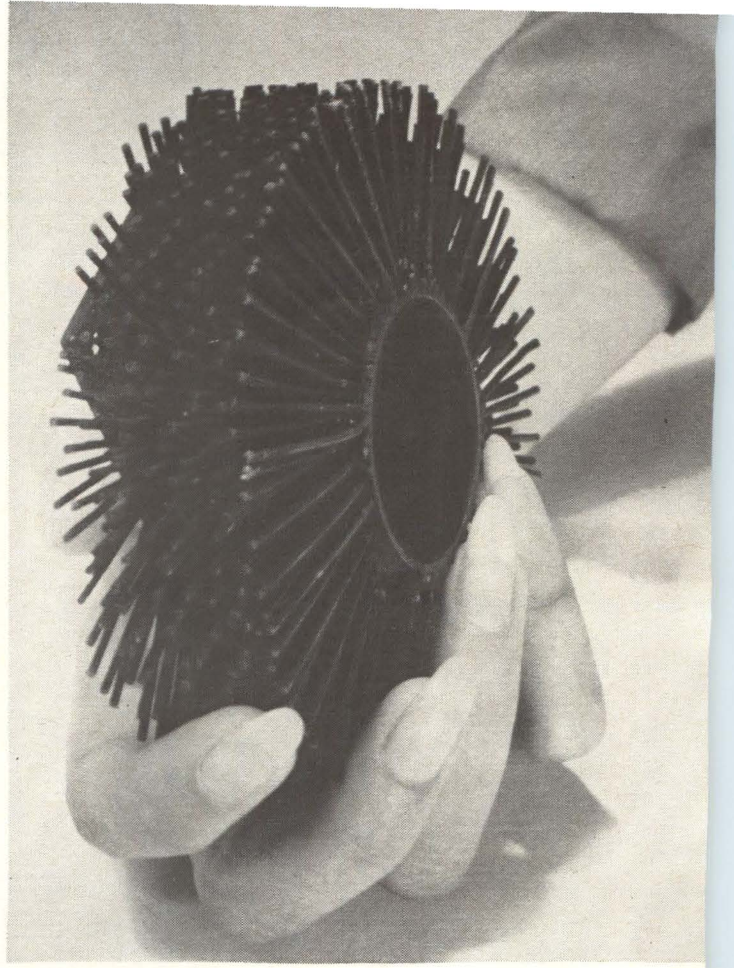
Long-pin approach to dissipator design

One of many possible methods of removing heat from semiconductor devices is examined

By John H. Jacoby

President, Pin Fin, Inc., Waltham, Mass.



Typical long-pin dissipator

Of the many designs for dissipators that will remove heat effectively from semiconductor devices, the standard finned heat sink is the most popular because of its proven cooling capability and low fabrication cost. But pin-fin construction is another approach with some advantages. It is already being used in computer power supplies, microwave transmission equipment, thermoelectric systems, and other applications.

In such a device, an array of pin projections (or pin fins) transfer the heat from the semiconductor device to the surrounding fluid (usually air). A typical pin dissipator is shown at the right. Heat removal by such devices was reported by W. M. Kays and A. L. London[1] several years ago. Although they reported favorably on this type of construction, the technique did not appear practical from an economical standpoint. As a result, little effort was made in this direction until recently.

Thermal conductivity of air

Free-air convection is the method most commonly used to carry off heat from a heat sink even though air is inherently a poor heat-transfer agent. Therefore, for adequate heat dissipation in compact electronic equipment, care must be taken in dealing with the thermodynamic problems involved.

The power-handling capability of an air-cooled heat sink is a function of many variables including the exposed (or effective) surface area, finish, airflow rate, temperature levels of heat sink and air, and thermal conduction paths within the heat sink. The most influential factor of all the variables is the geometry of the surface area. If the design is poor here, overdesign of the other variables is not likely to compensate.

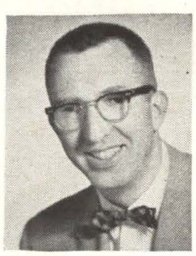
The long-pin approach allows a large area to be exposed while maintaining short conduction paths to the core of the heat sink. In addition, the rate of fluid activity at the metal surface is desirably high.

Since air has low heat conductivity the flow of a significant quantity of heat from a heat sink into free air must be accomplished by moving the surrounding air mass. Whether the cooling system uses natural- or forced-air convection, its effectiveness depends on the rate at which the heated air at the heat-sink surface is displaced by cooler air.

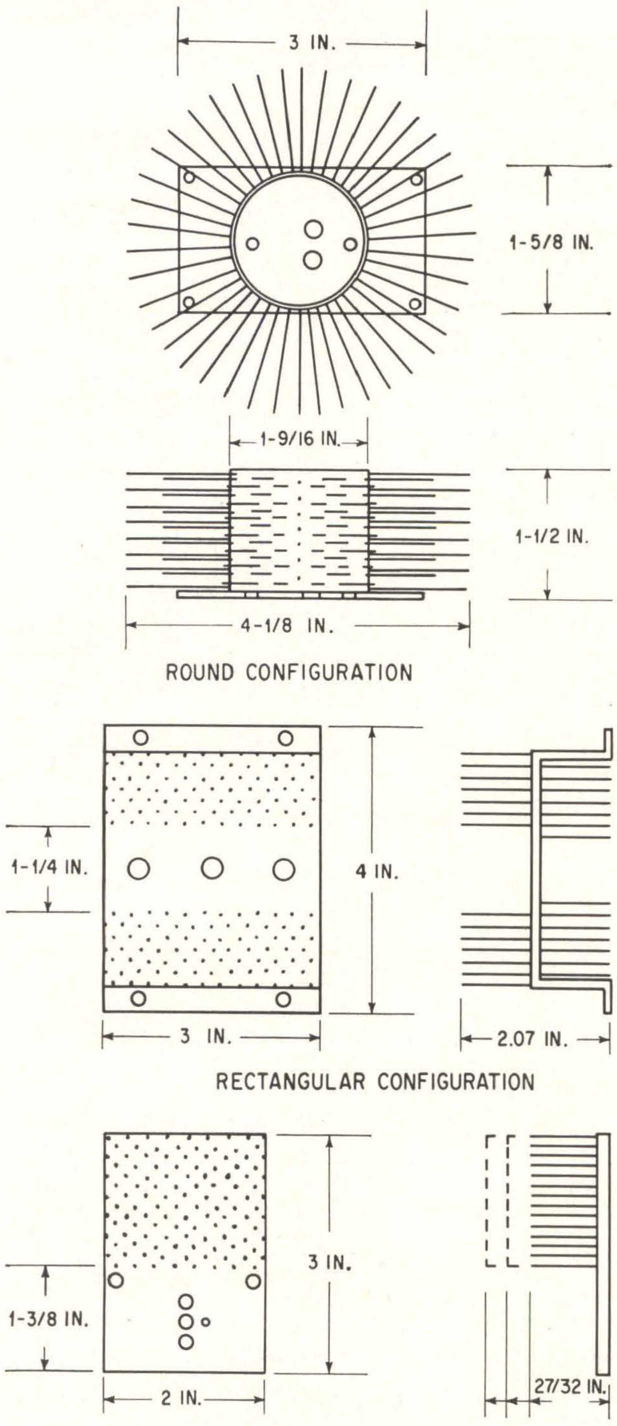
Boundary-layer considerations

The phenomena of increasing the heat-transfer rate, or dissipation capacity, from a surface without changing the fluid stream properties or temperature levels is achieved by increasing the "h" factor, or film coefficient. The film coefficient of a fluid in contact with a solid surface can be considered as an indication of the insulation effect of the thin layers of fluid clinging to the surface. The films, or so-called boundary layers of fluid, in contact with a surface tend to be stagnant, trapped by microscopic surface irregularities. They form an insulating blanket between the solid and the main fluid stream. Further from the solid surface, the fluid

The author



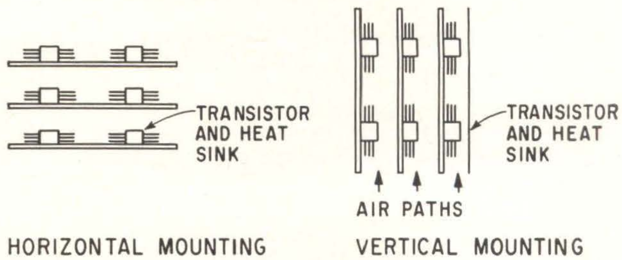
John H. Jacoby, 41-year old president of Pin Fin, Inc., spent 10 years designing liquid and vapor process equipment in New England and on the Texas Gulf Coast. Another eight years was devoted to managerial posts. During his spare time, he experimented with long-pin dissipators and in June, 1963, he formed Pin Fin, Inc.



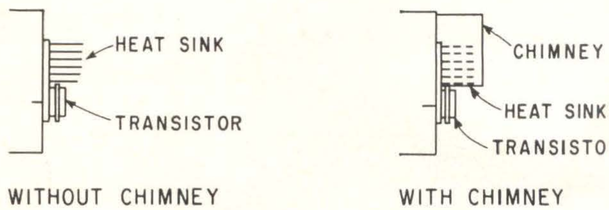
Typical dissipator shapes

Case-to-ambient thermal resistances

Thermal Resistance (°C/Watt)	Configuration Rectangular	Round	Flat
Natural convection:			
no enclosure	1.2	1.1	6.1
flush enclosure	0.6	0.6	2.8
Forced air:			
at 10 to 30 CFM	0.5 to 0.3	....	....
at 5 to 20 CFM	....	0.4 to 0.16	....
at 3 to 15 CFM	....	....	1.7 to 0.8



Printed circuit-board layouts. Arrangement at left has boards placed in horizontal position. This prevents heat sinks from developing effective natural convection drafts. Layout at right, with boards vertical, increases heat-sink dissipation in proportion to height of chimney formed by boards. The layout at right can provide up to three times the dissipation of the layout at left.



Isolated heat-sink arrangements. The heat-sink arrangement at left will dissipate essentially the same power when placed in either a vertical or a horizontal position in a location with ample surrounding air space. Installation of an open-ended chimney, shown at right, can double the dissipation rate of the heat sink. With the heat sink on a horizontal chassis, the chimney must be raised slightly to allow air access under the bottom edge.

molecules can slide over each other with relative ease, and the film layers become more active. The insulation effect of these boundary layer films, or the film coefficient, is the major barrier to heat flow in air heat-transfer systems.

Breaking up the layers

The value of the film coefficient in a given application is related to the viscosity, heat capacity, thermal conductivity, temperature, and stream velocity of the fluid. These properties are usually fixed or limited by the application requirements, and the only remaining method of improving the film coefficient value is to break up the film layers mechanically. This can be done by arranging the surface configuration so that the kinetic energy of the moving fluid molecules continually breaks up or reduces the film layers. The ideal surface produces this required fluid activity with a minimum loss of energy from the stream. To attain high film coefficient values with a flat-plane heat transfer surface requires high velocity impingement of the fluid on the surface. Consequently, high energy, or pressure-drop losses occur when a large surface area is compacted into a small space. Arrays of long pins have low energy loss because of their ability to maintain high fluid turbulence.

Heat-sink chimney

The natural convection conditions under which heat sinks are evaluated can be misleading. What is considered natural convection in one case may be equivalent to a low-velocity forced-flow condition in the next, by virtue of the induced drafts created by component arrangement and vent locations. It is often feasible to gain considerable performance improvement in natural convection applications by arranging components in vertical columns with top and bottom cabinet venting, or by installing a chimney above the heat sink. Surfaces without blind areas or that do not block air motion in any direction are the most desirable.

One other basic characteristic of heat-sink construction that contributes to its effectiveness is low metallic mass in proportion to the surface area—assuming good convection occurs from all exposed areas. The long-pin array structure provides extremely high surface area-to-mass ratios.

Continued investigation of fabrication techniques for long-pin cooling devices is expected to uncover new methods which will lower production costs. The adaptability of long-pin surfaces to direct bonding to component cases also has distinct space-saving advantages. Semiconductor devices with pins directly bonded to the cases could provide space savings in the order of 50% to 75% over combinations of transistors with conventional heat sinks.

Liquid cooling

Polaris and Apollo use it to take the heat off transistors. Now industry is taking another look

By John H. Sununu

Astro Dynamics, Inc., Burlington, Mass.

Almost always, a designer starts investigating heat-dissipator shapes with one assumption clearly made. He'll use free-air or forced-air convection cooling. Almost never does a designer even consider liquid cooling.

Yet, liquid cooling of semiconductor devices is neither new nor unknown. It has been effectively employed for several years in many areas, including the Polaris program. Its chief drawback is that it is expensive. Because of its cost, liquid cooling has been used mainly in the high-budget systems of military and aerospace equipment.

If the performance of a liquid-cooled system is, in fact, far superior to that of an air-cooled system of similar size or larger then the weighing of economic factors becomes extremely complicated. One must consider such factors as greater cooling density, longer lifetime of semiconductor devices, and even operating costs, before accurately defining the relative costs of the two approaches.

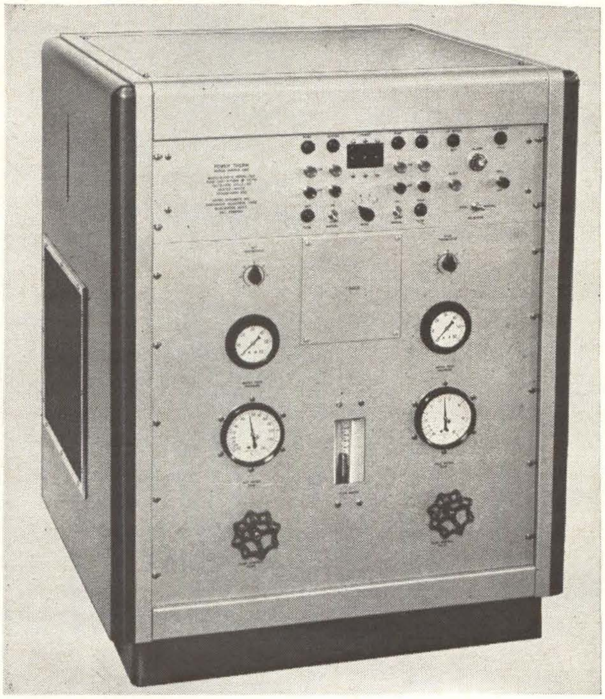
First, let's see if a liquid-cooled system really is a marked improvement over an air-cooled system. A comparison of the heat transfer coefficients for liquid and air cooling shows heat transfer can be increased 133 times by using water instead of air.

To start this comparison, the heat transfer coefficient h is defined by:

$$h = q/A\Delta T \qquad (1)$$

where q = rate of heat transfer area in sq. ft.

A = effective heat transfer area in sq. ft.

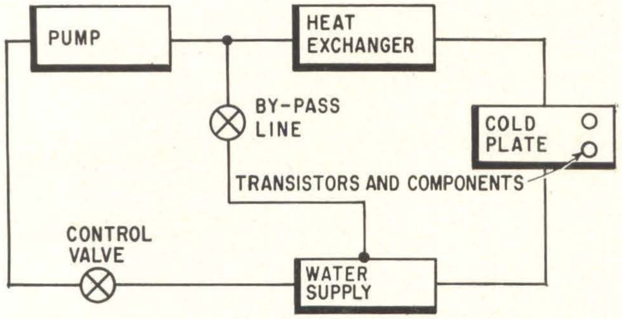


Transient-temperature generator delivers hot and cold fluids in repetitive cycles to the cold plate

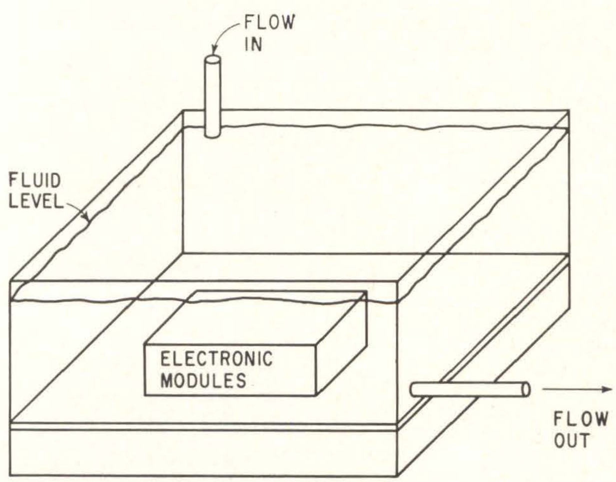
ΔT = Temperature difference between heat transfer surface and coolant in °F

The approximate expression for the heat transfer

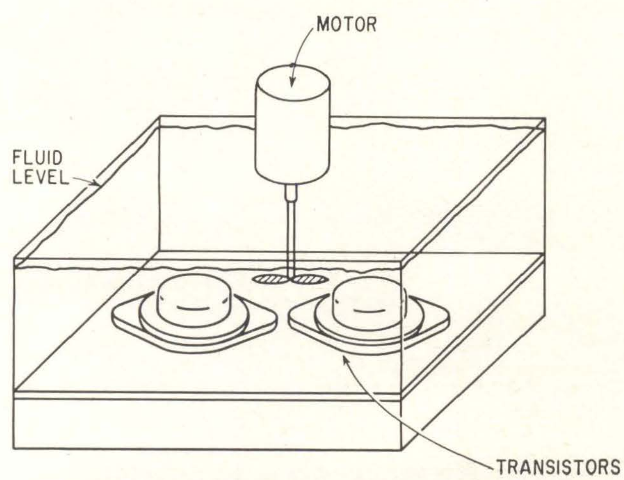
Other approaches to liquid cooling



Typical flow diagram for cold plate system



A simple approach to liquid cooling. Direct cooling is accomplished by the flow of the liquid.



Direct liquid cooling by agitation. With this method, the liquid remains in the tank.

coefficient for forced convection in ducts, is:

$$h = 1.86\ (K/D)\ [(N_R)\ (N_P)\ (D/L)]^{1/3}$$

where N_R = Reynolds Number $= DV\rho/\mu$ (2)
(the ratio of the inertia forces to the viscous forces)

N_P = Prandtl Number $= C_p\mu/K$
(the ratio of momentum rate to thermal-diffusion rate due to molecular motion)

D = Duct diameter (ft.)
L = Duct length (ft.)
ρ = coolant density (lbs/cu.ft.)
C_p = Specific heat of air in BTU/(lbs) (°F.)
μ = coolant viscosity (lbs/hr.ft.)
V = coolant velocity (ft./hr.)
K = thermal conductivity of fluid [(BTU/hr.)] (sq.ft.) (°F./ft.)

For a given duct of constant diameter and length, a ratio may be written for the heat transfer coefficients of a liquid and air passing through the duct. Assuming equal velocity for both liquid and air we obtain:

$$\frac{h_{\text{liq.}}}{h_{\text{air}}} = \frac{K_{\text{liq.}}}{K_{\text{air}}} \left[\frac{(\rho_{\text{liq.}})(\mu_{\text{air}})(N_{R\text{liq.}})}{(\rho_{\text{air}})(\mu_{\text{liq.}})(N_{R\text{air}})} \right]^{1/3} \qquad (3)$$

Using water as the liquid to be compared with air, the constants involved are:

For water:
K = 0.35 [BTU/(hr.)] (sq.ft.) (°F./ft.)
p = 62 lbs/cu.ft.
μ = 2 lbs/hr.ft.
N_R = 8

For air:
K = 0.016 [BTU/(hr.)] (sq.ft.) (°F./ft.)
p = 0.07 lbs/cu.ft.
μ = 0.045 lbs/hr.ft.
N_R = 0.7

Substituting these values in equation 3, we obtain:

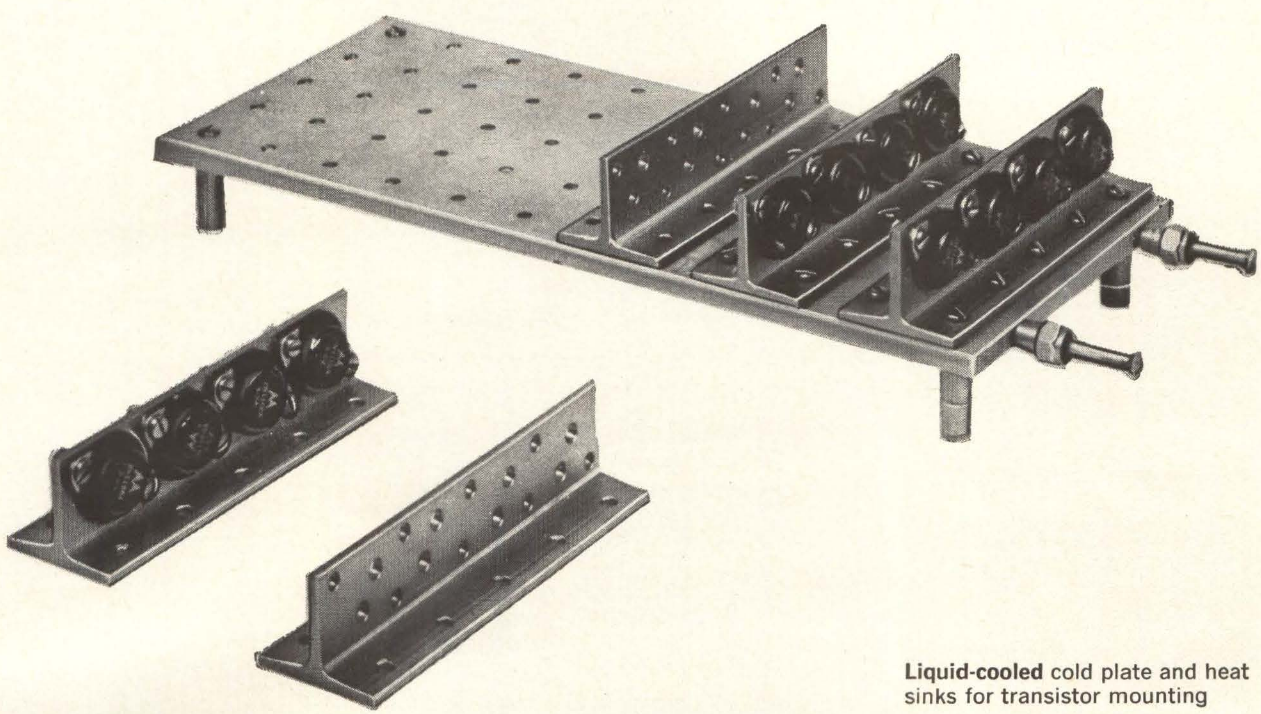
$h_{\text{water}}/h_{\text{air}} = 133$

This indicates that heat transfer from a fluid to a duct wall can be increased 133 times if the fluid is water instead of air and if both travel at the same velocity. The above calculation is based on the characteristics of water. However other fluids are also used in liquid-cooling systems. These include water-glycol mixtures for operation at temperatures below the freezing point of water, and fluorocarbon liquids for operation in environments subject to temperatures which range from above the boiling point to below the freezing point of water. For these liquids, the parameters are slightly different, but the results are generally the same or better.

Aluminum cold plate

Efforts are being made to design liquid-cooled dissipation devices which will provide high-density cooling at a price attractive to industrial equipment producers. One possibility is the aluminum cold plate—a thin device containing ¼-inch internal tubing through which a coolant flows.

The cold plate method of transistor cooling has been accepted for use in space vehicles. In the Apollo spacecraft, for example, virtually all of the critical components, including the inertial measure-



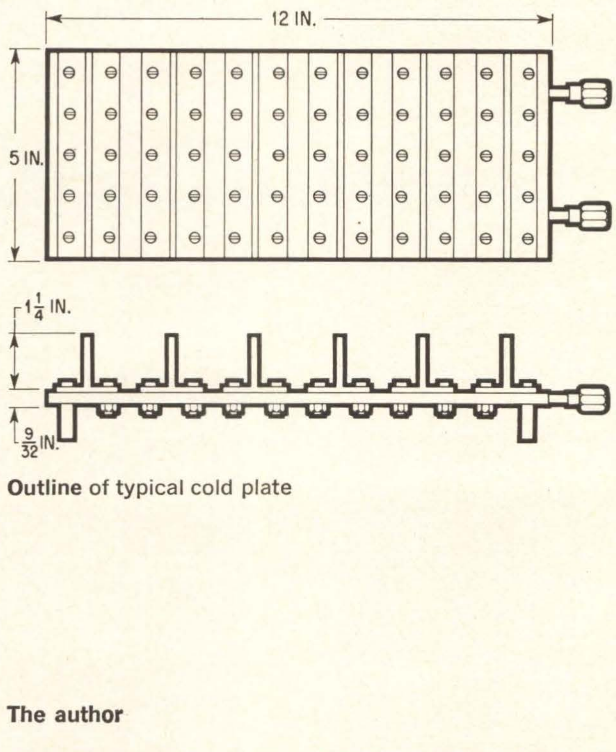
Liquid-cooled cold plate and heat sinks for transistor mounting

ment unit and the navigation computer, will depend on cold plates to protect the systems from overheating.

The cold plate handles coolants at pressures greater than 500 psi and, because of its efficient performance, permits the mounting of transistors on both top and bottom surfaces of the plate. Typical heat loads handled by the cold plates may approach two kilowatts per square foot of plate cross section.

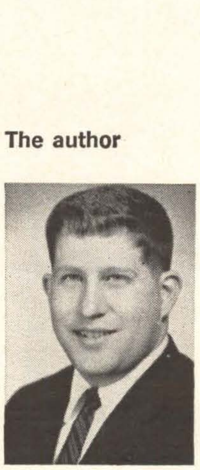
The surface of a cold plate may be used in conjunction with a temperature-controlled water supply when it is desired to expose components to a precise thermal environment. In addition, the cold plate may be used with a transient-temperature generator, shown on page 101, for observing the effects of various temperatures and thermal transients on electronic components. The transient-temperature generator contains a temperature-controlled water supply and may be programed to generate square waves of temperature. For example, the cold plate can be cycled repetitively between $-40°F$ and $+240°F$ with cycles as short as three seconds.

The cold plate and other liquid-cooling methods offer highly efficient cooling for high-density systems. With standard commercial units becoming available in an area that previously was strictly a custom-basis business, the liquid-cooled dissipator has a promising future.



Outline of typical cold plate

The author



John H. Sununu has been designing dissipators, heat exchange systems and electronic equipment packages for the past four years at Astro Dynamics. His duties include assisting customers in using and designing Astro products into electronic systems. He received his bachelor's and master's degrees from the Massachusetts Institute of Technology.

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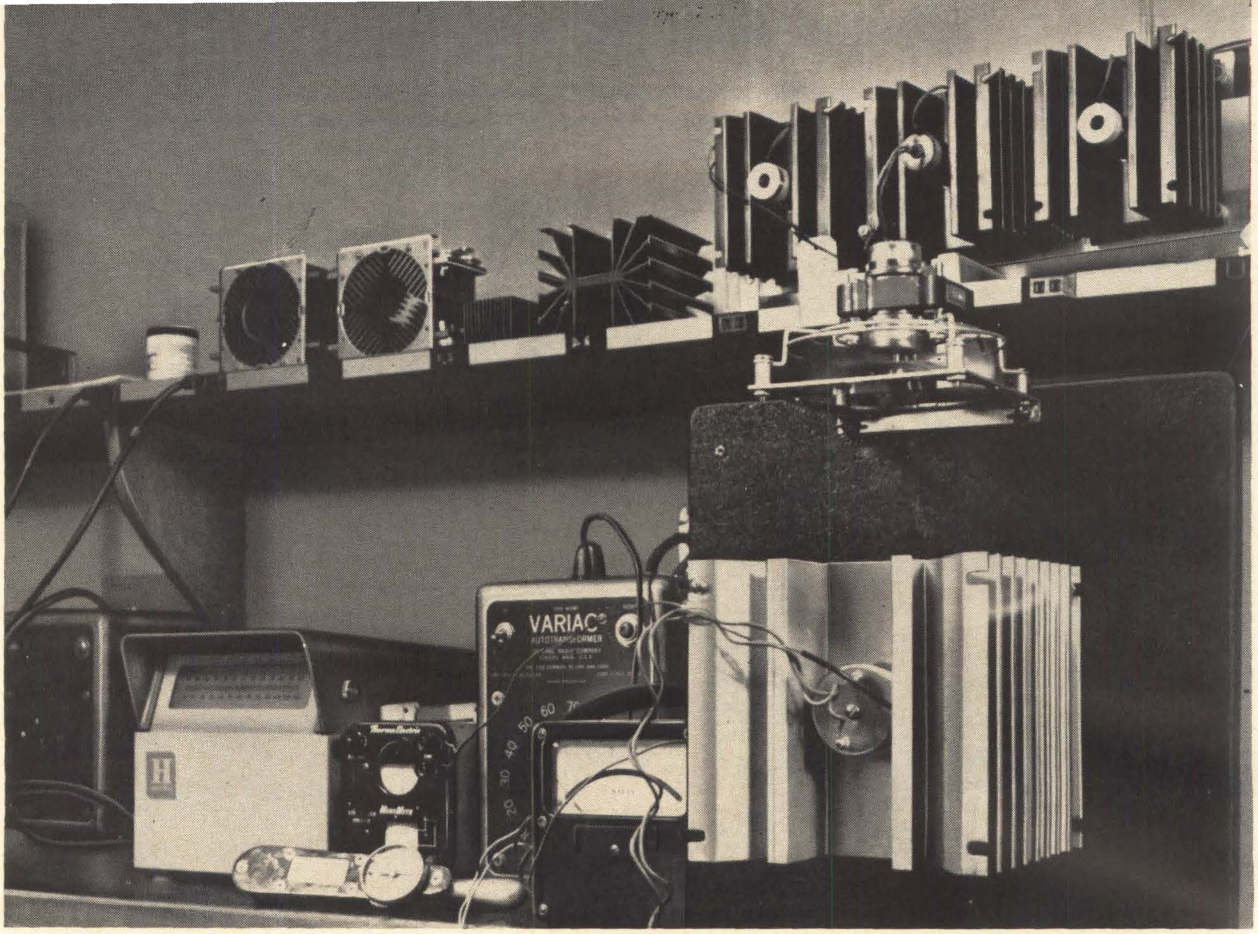


Actual test setup. The heat sink is placed in a vertical position with the fan mounted directly above.

Torque and thermal resistance

Testing determines optimum torque setting; use of compound doubles conductivity

By Wayne E. Goldman

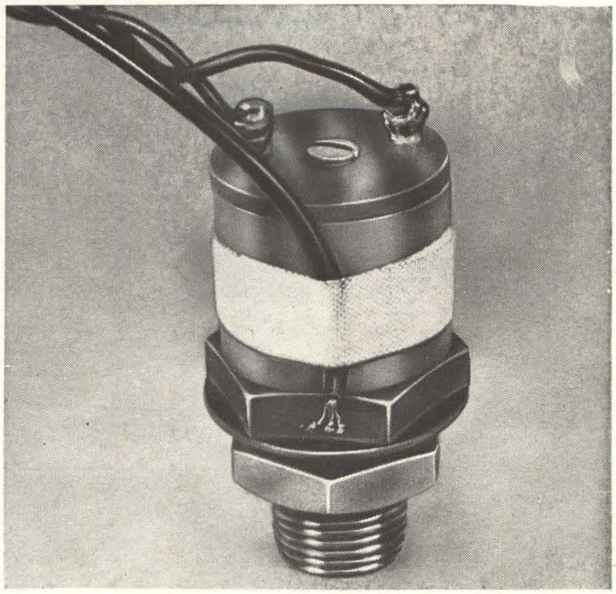
Wakefield Engineering, Inc., Wakefield, Mass.

Both torque and conductive greases between mating surfaces have an effect on thermal resistance. This effect must be examined in cooling stud-mounted semiconductor devices to determine the optimum conditions for operation.

The extent to which torque affects the value of the case-to-sink thermal resistance can be determined by a test setup such as the one shown above. The thermocouples measure the temperature at the hottest part of the load and at a point on the hottest part of the heat sink directly below the load. The thermal resistance (θ c-s) is then obtained from: θ c-s $= \Delta T/P$ °C/watt where ΔT = temperature difference between case and heat sink in °C and P = power dissipated in watts.

Thermal compound

Because of the irregularities in the surfaces of the heat sink and the base of the semiconductor device, air pockets occur when the two surfaces are mated. A thermal joint compound is generally used to eliminate these thermal insulators. The resulting reduction in thermal resistance may also be demonstrated by the torque test setup.

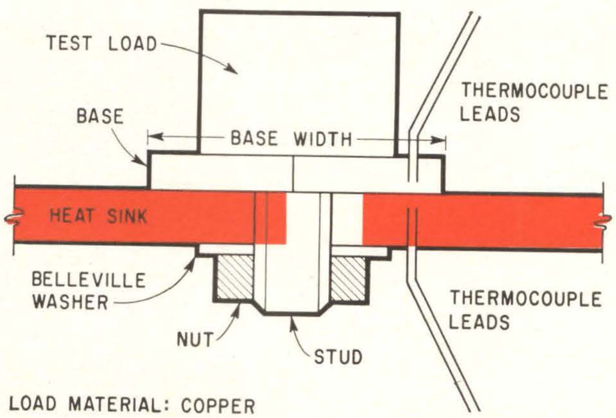


Close-up of the test load.

◀ **The heavy-duty** NC1541-6 heat sink contrasted with a model 201 lightweight cooler. Both dissipators are also shown on the cover. The NC1541-6 was used in the first test run.

In the experiments described, type 120 compound manufactured by Wakefield Engineering, Inc., was used to fill the air gaps. This compound is a blended mixture of silicone fluids and purified metallic oxides and has a thermal conductivity which is 20 times greater than that of still air.

Other thermal conductive greases intended for the same use include type 340 made by the Dow Corning Corp., Midland, Mich.; types G640 and G641 made by the General Electric Co's Silicone Products department, Waterford, N. Y., and Thermate, produced by the International Electronic Research Corp., Burbank, Calif.



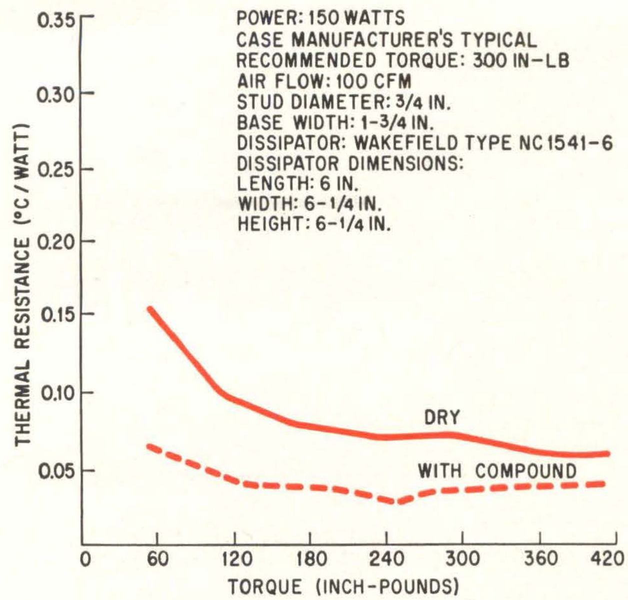
Test setup for measuring thermal resistance at various torque settings

Torque studies

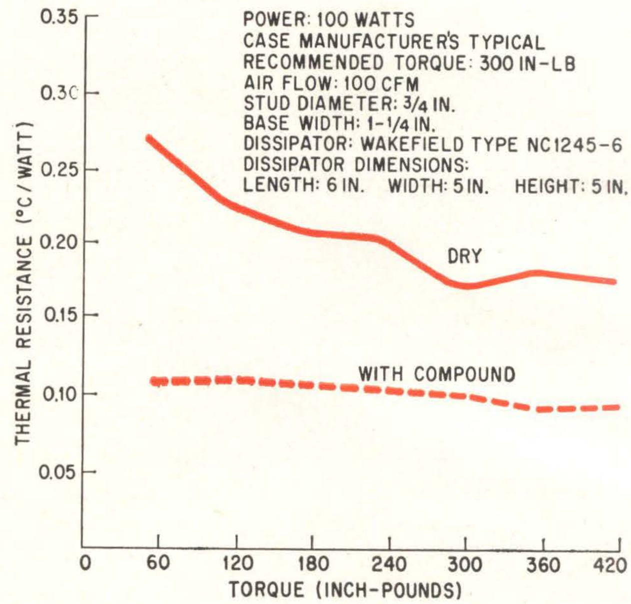
The test setup was tried for a large heat sink with a fan, moving 100 cubic feet per minute, mounted above the heat sink. The case simulated by the test load was a package with a ¾-inch stud and a hexagon base measuring 1¾ inches in width. The test was first conducted without compound between the heat sink and load mating surfaces. It was then repeated with a thin coating of the type 120 compound applied between the mating surfaces. The results are shown on p. 106. Two conclusions can be made from the results obtained. The first is that an optimum torque exists at which the thermal resistance is at its lowest value. The second is that the use of a thermal conductive grease also reduces the case-

The author

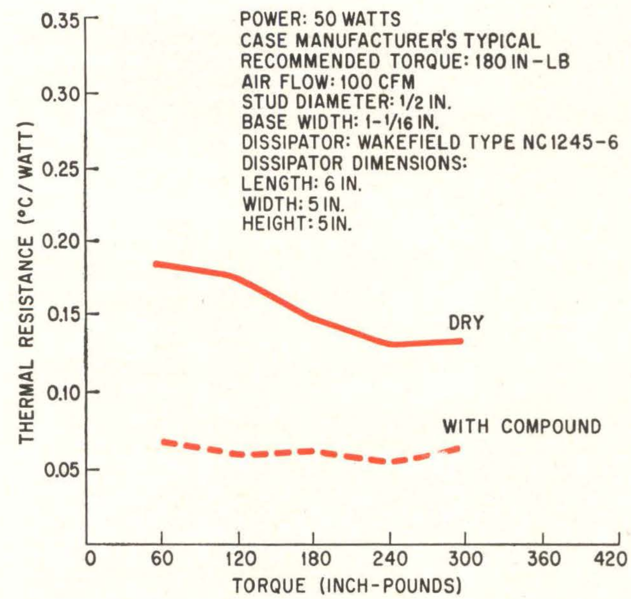
Wayne E. Goldman's main assignment at Wakefield is to help customers design dissipators into electronic equipment as a structural support. This is not a new area for Goldman; before joining Wakefield he designed commercial and residential buildings.



◄ **Initial** test results



Second test results

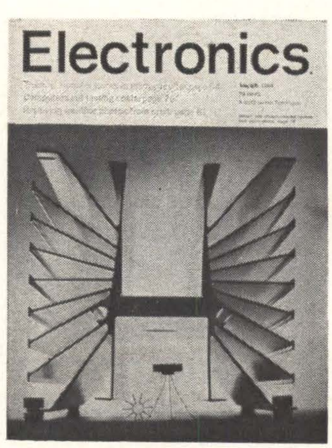


◄ **Third** test results

to-heat sink thermal resistance.

To substantiate the results obtained in the first test, two additional tests were conducted using different test loads, and power levels. As shown by the curves given above, the additional tests verify the conclusions made from the initial test.

Another conclusion from the test results is that minimum thermal resistance may not be achieved at the maximum torque setting recommended by the manufacturer unless a thermal conductive grease is used. The use of the compound in the tests reduced the thermal resistance substantially at all torque settings. At the torque setting recommended by the manufacturer, the decrease in thermal resistance was approximately 50%.



The cover

Tibor Hirsch, photographer, conveys the feeling of heat in this color study. The big unit is a heavy-duty fin sink, roughly 6 in. by 6 in. by 6 in. The small one is a clip-on device for cooling TO-5 cans. Both are made by the Wakefield Engineering Corp.

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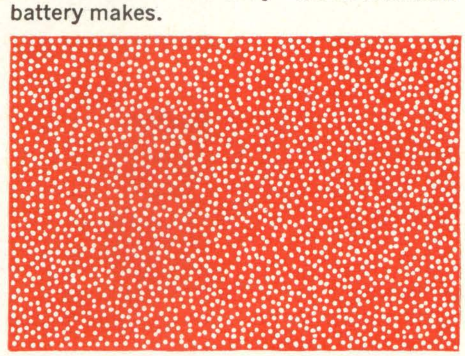

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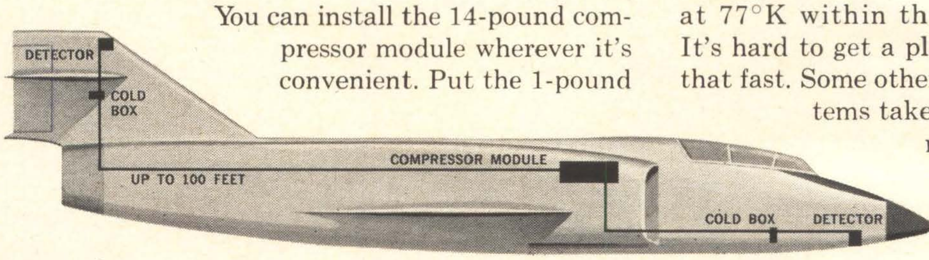

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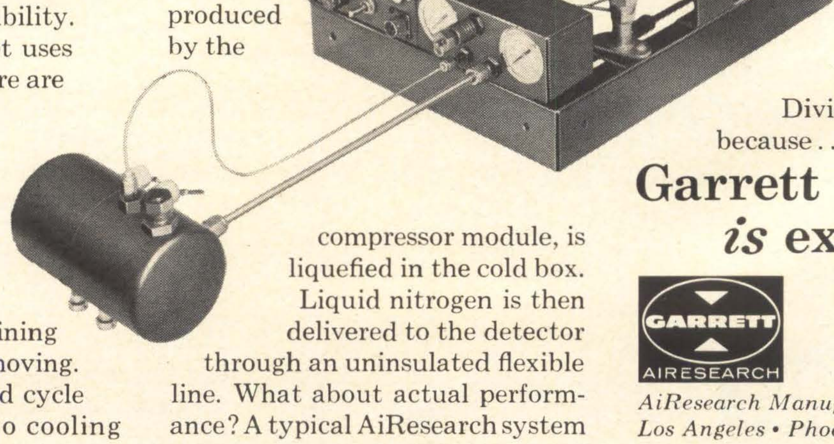

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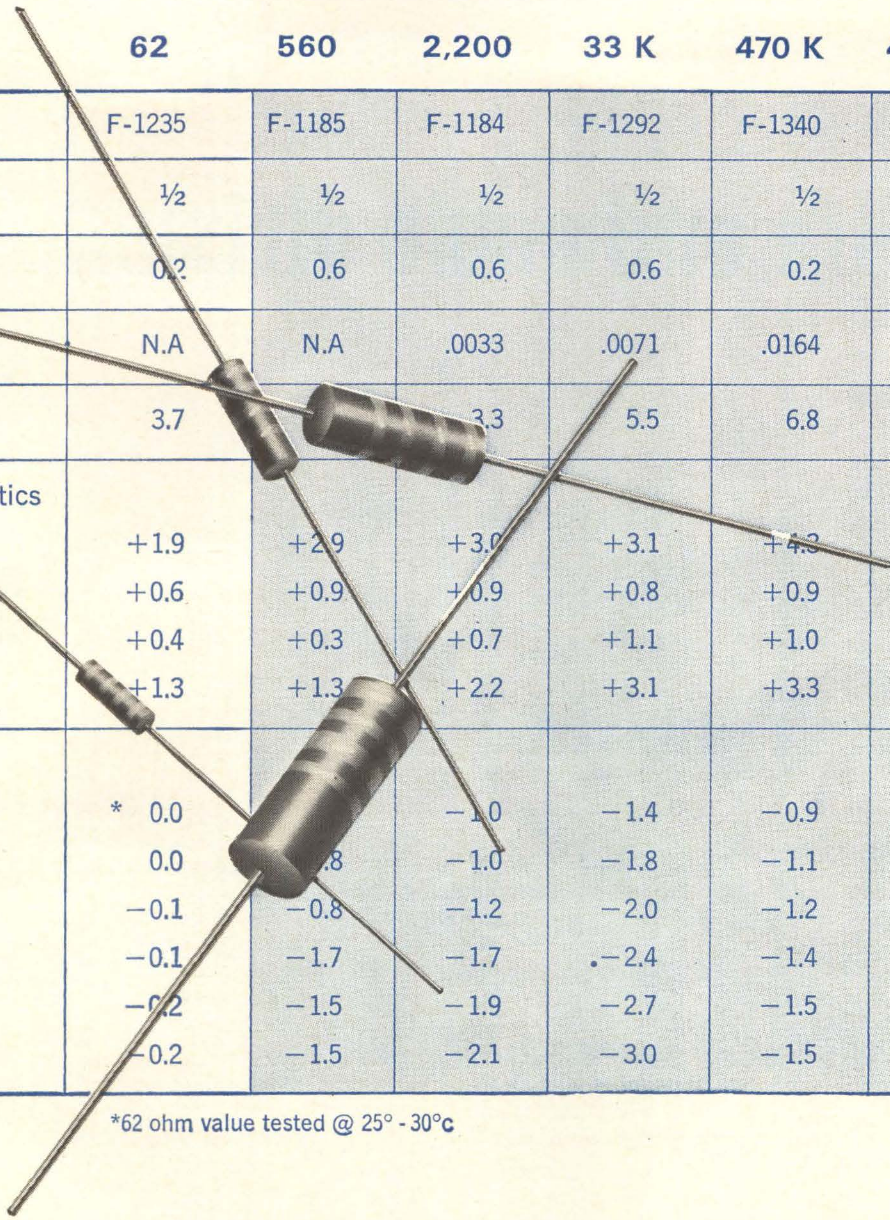
PRODUCTION TEST REPORT



	62	560	2,200	33 K	470 K	4.37 M
Lot No.	F-1235	F-1185	F-1184	F-1292	F-1340	F-1419
Size - Watts	½	½	½	½	½	½
Solder Change %	0.2	0.6	0.6	0.6	0.2	0.5
Voltage Coefficient	N.A	N.A	.0033	.0071	.0164	.0166
Moisture Resistance %	3.7	[illegible]	3.3	5.5	6.8	8.3
Temperature Characteristics						
−55° C%	+1.9	+2.9	+3.0	+3.1	+4.3	+7.1
−15° C%	+0.6	+0.9	+0.9	+0.8	+0.9	+2.2
+65° C%	+0.4	+0.3	+0.7	+1.1	+1.0	+0.4
+105° C%	+1.3	+1.3	+2.2	+3.1	+3.3	+1.9
Load Life @ 70°						
75 Hrs. %	* 0.0	[illegible]	−1.0	−1.4	−0.9	−0.6
150 Hrs. %	0.0	[illegible].8	−1.0	−1.8	−1.1	−0.7
250 Hrs. %	−0.1	−0.8	−1.2	−2.0	−1.2	−0.7
500 Hrs. %	−0.1	−1.7	−1.7	−2.4	−1.4	−1.2
750 Hrs. %	−0.2	−1.5	−1.9	−2.7	−1.5	−0.8
1,000 Hrs. %	−0.2	−1.5	−2.1	−3.0	−1.5	−0.7

*62 ohm value tested @ 25° - 30°c

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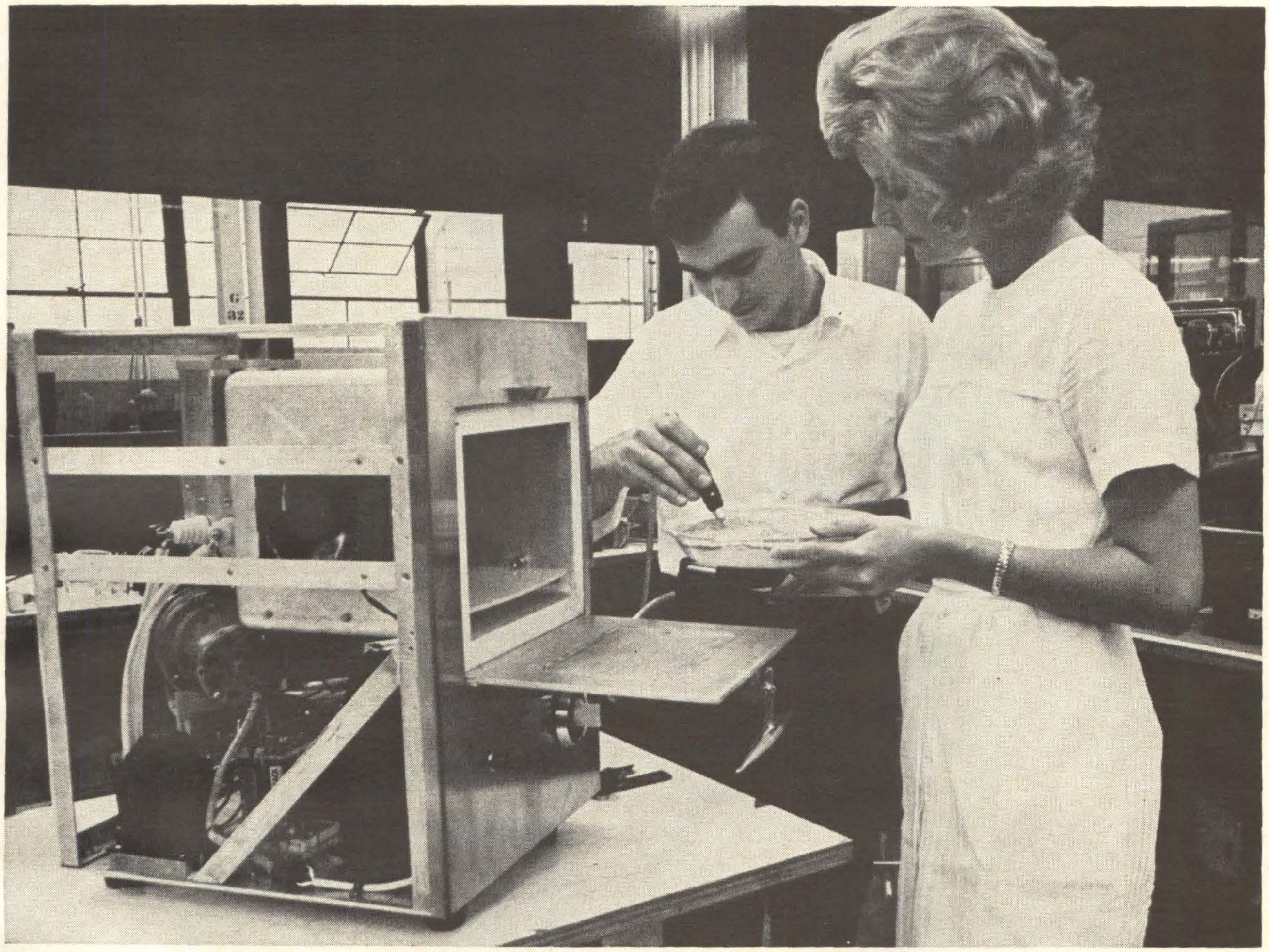
Probing the News



Prototype of microwave oven for home use built by Amperex in developing its new magnetron and associated circuitry. A technician makes a pyrometer temperature test of a cake baked in the oven.

Consumer electronics

Microwave at the kitchen door

Electronic ovens have a bridgehead in commercial food-dispensing; now they're preparing to invade the home

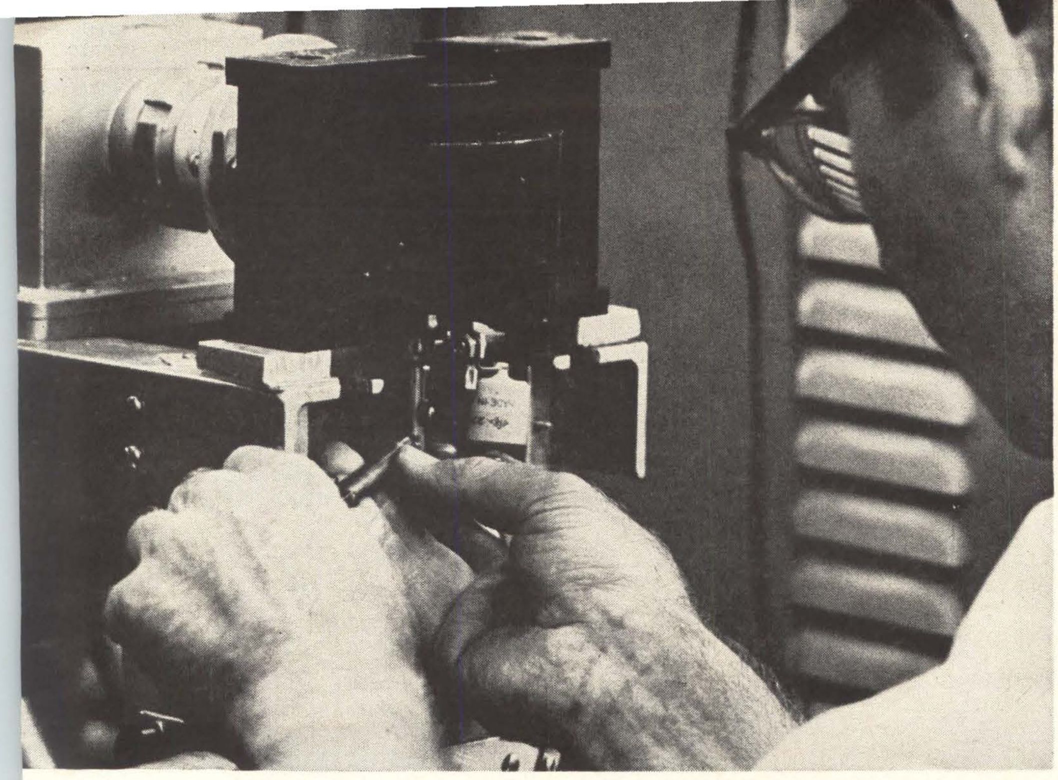
By Leon H. Dulberger

Staff writer

What's cooking in microwave ovens? Plenty.

In terms of technology, the big advance is a low-cost magnetron, developed by the Amperex Electronic Corp., that is expected to allow home oven prices to be cut to $400 from the present low of $800.

In terms of home oven sales, 1964 volume has been forecast at 1,500 units at a total cost of $400,000. This is expected to climb to 20,000 units and $9 million next year, 45,000 units and $17 million



Engineer works on low-cost magnetron developed by Amperex. Rated at 1,200 watts, it uses permanent magnets instead of conventional electromagnets. A ceramic output window is employed.

in 1966, and 100,000 units and $35 million in 1967. By 1970, the industry expects to be selling a million microwave ovens a year.

In terms of food, it's packaged, pre-cooked items ranging from family meals to dinners for big groups of company employees, hospital patients and the like.

I. Success breeds success.

As with any new industry, sales and technology will advance hand-in-hand if either is to advance at all. Improvements such as the magnetron should reduce prices from the cafeteria level to the kitchen range. And as more of the lower-priced ovens are sold, food processors are likely to expand the present meager variety of frozen pre-cooked foods; this in turn should encourage more families to add microwave ovens to their lists of "must" appliances.

Edward King, Amperex's assistant manager of industrial products, predicts: "Food-product manufacturers such as Swift (& Co.), General Foods (Corp.) and Campbell Soup (Co.) will be turning out products for highly effective use in microwave ovens to a greater extent than they do now. In time, electronic ovens will take their place in lower-middle-class homes along with air conditioners, clothes dryers and dish washers."

$300 barrier. Market men predict that a mass market will appear when the price of a microwave oven falls to $300, below the price of a cheap color television set. The new Amperex tube, together with associated components and circuits, is expected to spur a big part of that price cut.

Amperex has used several engineering developments in designing its new magnetron. Chief among these is the use of permanent magnets instead of electromagnets to supply a magnetic field for the tube. A high-temperature magnet, Ticanol CG, is used, made of an alloy that retains magnetic strength at high temperature.

A compact tube design is achieved by running the tube at 200° instead of 100° C. This permits air-cooling to be used instead of water. The magnetron, which is 55% efficient with the power supply used with it, is rated at 1,200 watts with an end-of-life rating of 1,000 watts. A fast-heating filamentary cathode eliminates the need for time-delay circuitry to control the application of anode high voltage. The filament, of thoriated tungsten, heats in about three seconds. Life tests, made with the magnetron coupled to an oven and over a range of cycling conditions, indicate that tubes should give more than three years of service.

Other techniques that bring the magnetron's price down include: use of a ceramic microwave output window in place of special glass; self-jigging assembly techniques in tube construction, such as mating an insulator with a conductor using a dual-cone mating; multiple use of common parts, such as input and output connector mounts made from the same basic molding.

Breaking the waves. Microwave ovens normally employ a mechanical technique to break up standing waves present within the oven cavity. This eliminates hot spots to achieve uniform heating in the cooking cavity; another technique incorporates a rotating turntable that supports the food.

Amperex has developed a broadband coupling technique for delivering magnetron energy to the cooking cavity, which does not require moving parts or active elements. The company explains that this coupling method eliminates hot spots.

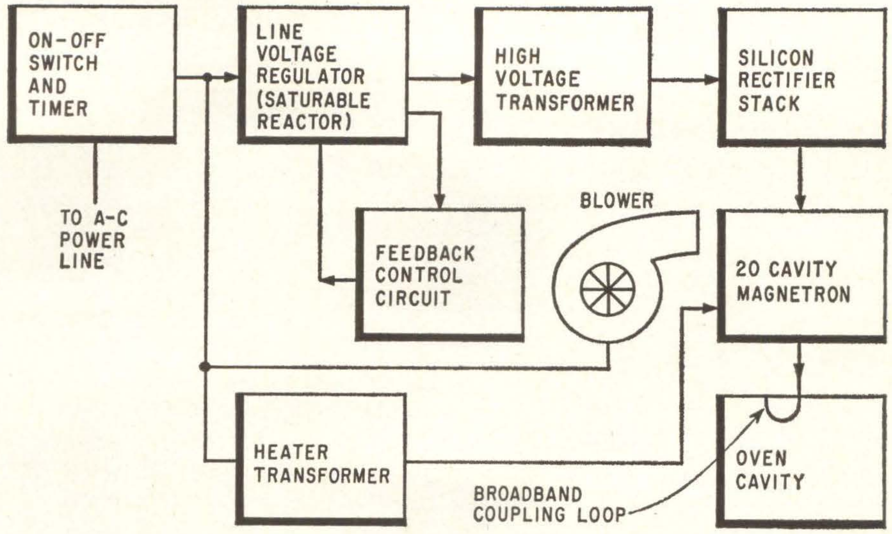
Amperex will provide engineering assistance in oven design to buyers of its tube. The company has worked out a computer technique that permits optimizing the cooking cavity in oven design for maximum uniformity of standing wave pattern without laborious cut-and-try methods. If the oven maker supplies rough cavity dimensions, the computer method determines which wall of the cavity to vary in dimension to achieve this optimum pattern. For example, if a 10-by-12-by-16-inch cavity is desired, information is obtained to determine which dimension to vary in one-eighth inch increments over a two-inch range while holding the other two dimensions constant.

Amperex has also developed a cold-oven check method for production runs of microwave ovens without operating them with live magnetrons. A dummy antenna is used to simulate a magnetron and feed system that is usually coupled to the cavity. A commercial microwave test-set, which includes a slotted line and signal generator, provides the necessary instrumentation. This permits oven manufacturers who may not be familiar with microwave techniques to optimize ovens using a production test fixture.

II. Future called bright.

Amperex predicts that many companies will enter the home microwave oven market, and that its magnetron and kit of components will permit concerns to become competitive quickly.

The industry's big need, according to many marketing men, is a compact, economy model for the kitchen. B. C. Palmer, marketing manager of the Thermowave Corp., says: "The industry has been building trailer-trucks; now, to satisfy the housewife, compact-car ovens are needed to achieve the price goals that will allow a volume market." He adds that food processors "must develop foods the housewife wants to buy."



Control and power supply circuitry for Amperex's low-cost microwave oven magnetron. A negative 5,600 volts is applied to the magnetron filamentary cathode. Broad-band coupling from the magnetron to the oven cavity reduces standing waves.

Combination ovens. Bruce Cameron, advertising manager, says Tappan will introduce a combination oven and promote it "above and beyond the regular advertising budget." Tappan's combination oven will include a conventional oven, conventional surface units and a full-size microwave oven. It will sell for $900 to $1,000."

The General Electric Co. is testing a combination unit. It, with a price-tag of about $800, is being test-marketed in the Detroit and Los Angeles areas.

End to burn-out. This year, manufacturers will build into home microwave ovens a means of preventing magnetron burn-out when the oven is accidentally operated while empty. Under these conditions, standing-wave feedback of energy tends to overload the magnetron. Standing-wave traps or other techniques will be used.

The problem of door-arcing in home ovens will also be eliminated on an industry-wide basis. One method is to use choke door-seals, a form of wave trap. Another involves a dielectric seal to insulate the door from the oven cavity to prevent leakage and arcing. A capacitance is thus formed that permits microwave cavity parameters to be maintained.

Tappan's plans. Tappan, which dominates the consumer market, expects to sell 3,000 units this year, both for homes and business. Its newest entry in the domestic market, will use a full-wave, power supply and deliver 1,000 watts to the microwave cooking cavity.

The home microwave oven operates at 2,450 Mc and uses water cooling of the magnetron. Unlike other microwave oven-makers, Tappan uses a full-wave power supply that is regulated over the range of 200 to 250 volts input a-c and permits achieving 80% magnetron efficiency. Tappan is able to use several commercial magnetrons in its ovens; for the bulk of its ranges it purchases tubes from Litton Industries, Inc., and also from Amperex.

Tappan provides two heat settings, with "low" delivering 650 watts to the cavity and "high" delivering 1,000 watts to the cavity. Low is used for high-protein foods such as eggs and dairy products.

More users seen. The Raytheon Co., the pioneer in microwave ovens, expects the biggest sales growth to occur in the commercial market — restaurants and vending machines — through 1967. After that, according to Carl Bixby, manager of marketing for the company's Radarange operation, "consumer sales of microwave ovens should pass commerical sales."

Raytheon has supplied ovens to customers ranging from restaurants along the Indiana Toll Road to the nuclear-powered merchant ship Savannah. Its Radarange vending-system oven uses preset selector buttons to control heating periods.

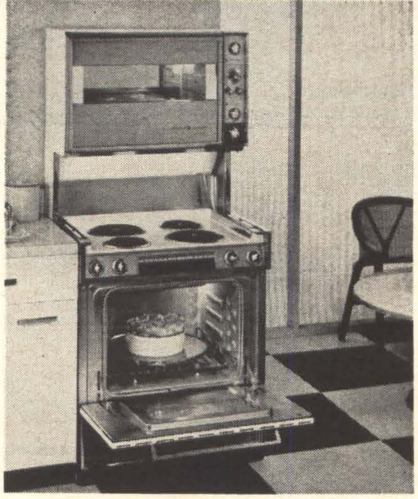
In the air. Marketing men talk hopefully of putting microwave ovens in commercial aircraft so that airlines can abandon the routine of bringing hot lunches aboard before takeoff.

On the rails. Microwave ovens have already been tested on railroads. When the New York Central Railroad first installed them, the car carrying the ovens was called Meal-A-Mat and was equipped with a Radarange able to turn out hot sandwiches in 10 seconds and main courses in minutes. The Radarange is installed in a car that has automatic dispensers of food products; the cooker requires only one attendant, who serves drinks and makes change.

The New York Central says: "the oven worked very well for the purpose for which it was intended, gives little trouble, and requires very little repair."

The railroad is concerned temporarily about the power requirements for the oven which, it says, "places a heavy load on the carborne diesel generator."

Litton. Litton Industries banked on its experience as a major producer of high power microwave tubes when it entered the micro-



General Electric combination home range is being test-marketed in Los Angeles and Detroit. A conventional oven on the top, range units at center and a microwave oven with a browning unit in the lower portion provide a complete kitchen instrument. The concern uses a magnetron operating at 915 Mc developed for microwave oven use.

wave-oven field. Litton now produces various microwave ovens for commercial use and plans to introduce one soon for the home market. The company is said to have spent $1.5 million so far in developing its microwave ovens.

Litton offers various models for commercial service, but other companies—such as Tappan—build the oven using the Litton tube. When Litton enters the home-oven market, a major promotional campaign is expected. Litton also has a new commercial oven, using a magnetron protection system that turns off the power if the oven is operated unloaded.

Rudd-Melikian. For years Rudd-Melikian, Inc., in Warminister, Pa., has dominated the food-vending machine business. Four years ago it added microwave ovens to its product line, starting with purchased ovens. Now Rudd-Melikian manufactures its own equipment.

The Rudd-Melikian unit uses a water-cooled magnetron operating at 2,450 megacycles. This summer, the company says, its microwave ovens "became one of the highest-volume products, doubling its sales over the previous year." Their oven sells for $995.

The Rudd-Melikian oven, which is used for reconstituting food in vending machines, employs a timing dial with eight basic time settings. The timer is continuously variable and permits infinite settings between eight calibrated points. This allows the user to suit individual preferences for food temperature.

III. Trends in design.

GE's new consumer unit uses a special GE magnetron and operates at 915 megacycles. A 30-inch double-oven design is used. The top portion is a conventional oven unit; conventional surface units are provided at the mid-portion, and a high-speed microwave oven is included in the lower half of the instrument, along with a browning unit to crust foods. The two ovens can be used separately or simultaneously; and in the microwave oven, cooking and browning may be done at the same time. A turntable in the microwave oven rotates food to assure uniform cooking.

GE says a six-pound roast can be cooked by microwaves in 30 minutes, compared with the three hours required with a conventional unit. The company says it spent almost $3 million dollars over 18 years to develop the combination range.

Commerical units. The microwave ovens built by GE for the commercial market are nearly all air-cooled. The latest designs use a low anode voltage on the magnetron, about 600 volts, to increase reliability by reducing voltage stresses in both the power supply and magnetron. Most commercial microwave ovens use about 6,000 volts on the anode.

Military electronics

Electronics in the Mekong Delta

Feedback from U.S. troops in South Vietnam provides valuable data for electronics designers

By John F. Mason

Senior Associate Editor

One hundred combat troops in South Vietnam recently got lost, could not contact the other units by radio, and wandered around all day long, in a jungle of bamboo, palms and marshes. One man was critically wounded, all of them were demoralized, and a valuable day was wasted. They were lucky not to have fallen into the hands of the Vietcong.

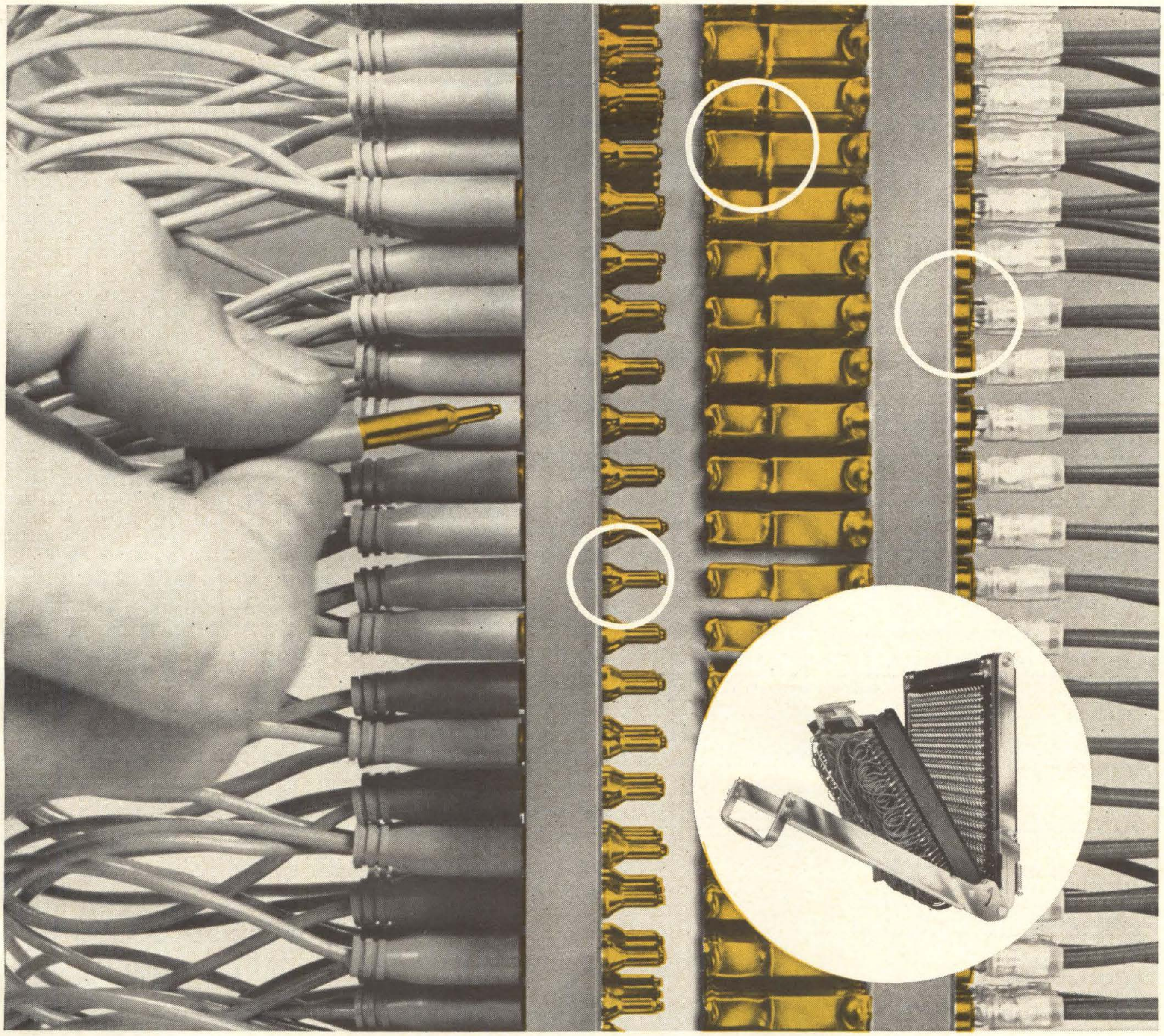
The reason these men couldn't communicate with the other units was that the radio equipment being used in South Vietnam can't penetrate the lush vegetation and 100-foot-high trees for more than a mile. Sometimes it won't even do that. Further complicating the communications picture in Southeast Asia are the severe thunderstorms that plague the area, and the radical way in which the ionosphere and troposphere fluctuate.

The United States forces in South Vietnam, however, are learning to combat some of these problems. "We're learning more about the art of communications by being over there than we ever could in the United States," says Col. Robert W. Garrett, chief of the Special Warfare Office in the Pentagon. Garrett, a paratrooper and a Ranger, has had extensive duty in Vietnam, Panama and the Pacific.

I. Clearing the obstacles

One solution to the propagation problem is to get the antenna above as many obstructions as possible. Discovering new ways to do this tests the ingenuity of the men in South Vietnam as well as engineers in the United States.

On occasion, the Army's Special Forces have improved transmission by tying the antenna to a rock and hurling it as high as they could into the branches of a tree. This is



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easier than climbing the tree, but sometimes it's hard on the arm.

The Army has been experimenting with an antenna sent 500 feet up on a balloon developed by the Aerospace division of the Goodyear Tire and Rubber Co. Next week, the Army will send five antenna-equipped balloons to South Vietnam for testing. A folded dipole antenna hangs about 20 feet below the balloon and is attached to the tether. A 300-ohm twin-lead television wire is used as the transmission line.

The Air Force, which has its Special Warfare Forces (air commandos) in Vietnam too, has several projects designed to lick the foliage and line-of-sight problems.

The Rome Air Development Center, which handles research and development for the air commandos, is undertaking the development of a group of engineering models of 50-foot, inflatable uhf antennas. (Rome already has worked on inflatable antennas for low-frequency transmission).

For the uhf effort, Rome has bought two 35-foot inflatable antennas that weigh 4 pounds each. This off-the-shelf equipment will be tested by the air commandos in Panama. The objective will be to develop antennas that will extend 100 feet up.

Relays. Another way to get above the trees as well as over the horizon is to use a radio relay in an elevated place. One relay the Air Force is testing is the Jungle Buoy, a two-radio unit that receives on one frequency and transmits on another. Built with a counterrotating blade, the relay can be dropped by an aircraft into the high branches of a tree. The device, conceived and developed by Litton Industries, Inc., is now being tested at the Special Air Warfare Center at Hurlburt Field, Fla.

Another relay station developed by Litton, called Sir, can be mounted in a pod and hung from the wing of a plane like the AN/RRQ-5 made by the Radio Corp. of America. Sir can be hung in a tree, placed on a ridge or in any elevated spot that appears to be safe. Sir differs from Jungle Buoy in that it receives, records on tape, and replays on interrogation. A prototype of Sir went to the Air Force in May for testing.

The Air Force would like a relay to have another attachment: a low-drain sensor, or electronic switch that, with very little power, could wait for a signal to tell it when to turn on the main power for relaying the message.

The Bendix Corp. has developed a repeater relay that receives and retransmits on the same frequency.

II. Guiding planes

One item the Army, Air Force and Marines want in South Vietnam is a homing beacon for guiding an aircraft to a drop zone where paratroops or cargo are to be delivered [Electronics, June 1, p. 83].

The best one available is the old Rebecca-Eureka beacon used during World War II—a 200-megacycle system that uses lobe-switched antennas to determine azimuth. Because of its poor accuracy, however, the Army Special Forces won't use it. They rely instead on ordinary aircraft navigation to get them close to the drop zone; then railroad flares guide them to the precise spot. The obvious disadvantage of a flare is that it is visible to foes as well as friends.

Too many lights. Flares also present problems for the pilot. Farmers in Southeast Asia burn rice husks that smolder and flare up in little bursts of light from dusk until dawn. These lights confuse a pilot looking for the drop zone flare.

Another disadvantage of flares is that they burn for only four minutes. In that time the pilot has to get over the drop area and get the troopers lined up and out of the plane.

Missing the drop zone in Vietnam is a serious matter. If a paratrooper lands in a tree he may have to hang there until dawn. Cutting himself loose in the jungle in the dark is even more risky than remaining in the tree.

Manpack transceiver, the AN/PRC-10, is used by South Vietnamese troops and U.S. advisers.

Beacons tested. The Army, Air Force and Marines are testing candidates for a good homing beacon. By June the three services hope to write up performance requirements they all want in a beacon, and to ask industry for bids. The beacon selected will be used not only by the Army Special Forces but by conventional ground forces of all three services.

The beacon sought will weigh less than 35 pounds, transmit on specific frequencies and emit an identification code that can be changed for each mission. It must also be compatible with existing

---

equipment in military planes, and bring the plane in to a specific spot with an error no greater than 600 feet.

The Army's candidate is being developed by Matrix Systems, Inc., under the direction of the Army's Limited-Warfare Laboratory at the Aberdeen Proving Ground, Md. The Matrix beacon operates at low frequency, weighs 19 pounds including a 35-foot pole antenna, and has voice capability. It works on only one frequency. The Army will get six prototypes for more extensive testing.

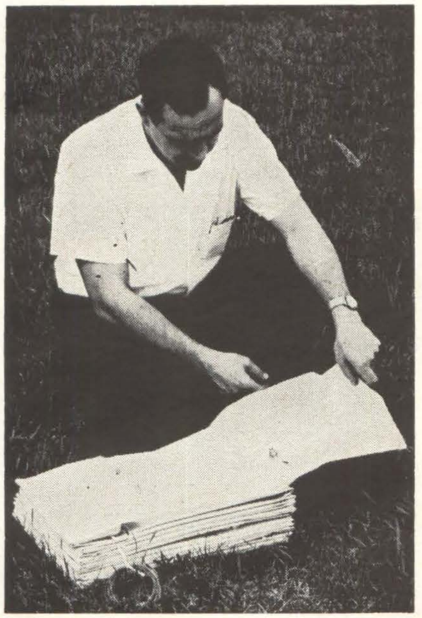
The Marines are also testing a low-frequency beacon. It is equipped with a synthesizer, a frequency-generating device that provides the operator with a variety of discreet frequencies. Built by Tridea, Inc., of Pasadena, Calif., the beacon is designated AN/TRN-19. The latest version is still too heavy, but Tridea is redesigning the antenna and hopes soon to get the total weight down below 35 pounds.

The Air Force is interested in several beacons. Litton Industries has developed the AN/TRN-20, a low-frequency transmitter in the 260- to 520-kilocycle band. The Wilcox Electric Co. built and delivered to the Tactical Air Command an X-band beacon, the AN/PPN-16, that is now being tested on maneuvers in the United States.

A precision beacon that would guide a plane to the center of the drop zone with an accuracy of 100 feet is being developed for the Air Force by the G. C. Dewey Co. of New York. Operating on two modes, high-frequency (30 Mc) and low-frequency (500 Kc), the whole system would weigh about 10 pounds.

At the Farnborough Air Show in Britain, this month, Rank-Bush Murphy, Ltd., will show for the first time a new beacon for the Rebecca-Eureka. The company says the beacon has a 20-mile range for a plane flying at 500 feet. Called Eureka MR 343, the beacon operates with standard Rebecca airborne equipment. It is transistorized, has 100-watt power and operates at 200 Mc. The device weighs 24 pounds and measures 4½ by 11½ by 11½ inches.

Bundle beepers. The absence of good homing beacons is not only



Inflatable package can become a 50-foot antenna, thereby getting over some of the foliage that blocks transmission in South Vietnam.

a danger for paratroopers, but may cause cargo to fall outside the drop zone. Ground troops then must spend valuable time—often risking their lives—looking for it. The Army Special Forces would like to put a radio beeper on the bundle to lead the troops right to the spot. Since thousands of bundles are dropped, the beacon would have to be cheap. It has not yet been decided whether to make it a throw-away beacon or a more expensive device that would be recovered and used again. The Army wouldn't want them to be too expensive because the enemy might get to some of them first.

A small survival beacon, attached to parachute harnesses, works well for Navy pilots. Transmitting from the flat ocean to an aircraft above, however, is not as difficult as from the jungle where foliage and ground clutter distort the transmission and reduce the range.

The Army has no solution yet, but hopes industry will soon come up with something.

III. New radio frequencies

Although the Army has in production a standard, transistorized manpack radio for patrols—the AN/PRC-25—and a new vehicular radio for headquarters—the AN/VRC-12—the troops in South Vietnam are not getting them. The reason is that the new radios operate

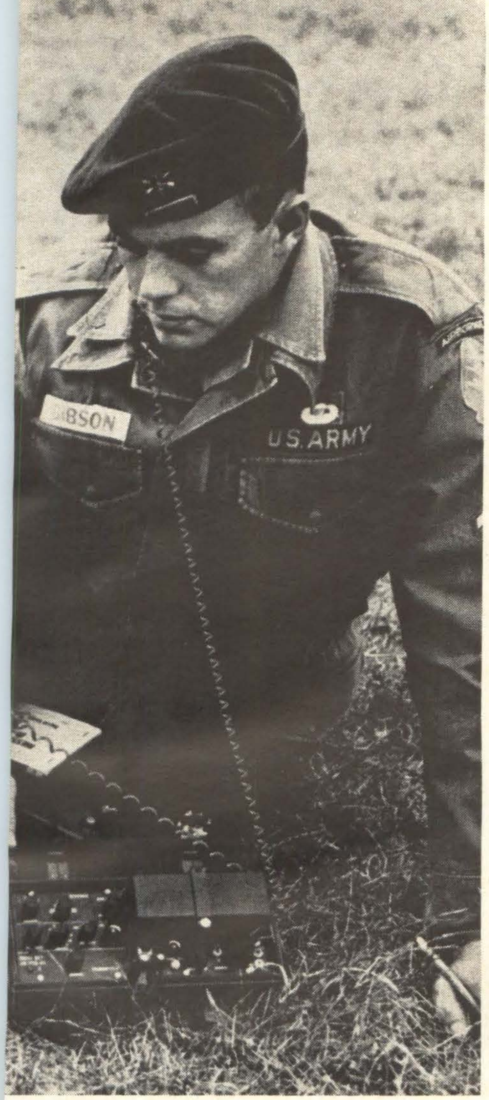
Long-range transceiver, the AN/PRC-64
Limited-War Laboratory. Developed by
unit has a range, under ideal conditions,
The Army has not yet approved it.

on frequencies different from the old ones, and therefore would not be compatible with the network of existing gear. Introduction of the new units would require an across-the-board change in equipment throughout South Vietnam. That's why South Vietnam is keeping the older gear and the new sets will go to Europe.

The equipment being used in South Vietnam includes the PRC-10 manpack, vhf/f-m with a rated range of 3 to 5 miles, and the jeep-mounted VRC-10 with a range of 35 miles.

The frequency was changed on the new equipment for two reasons: to provide a broader frequency spectrum to get more channels, and to avoid intereference that was being picked up by the old equipment that used frequencies below 30 Mc.

For longer distances. Longer-

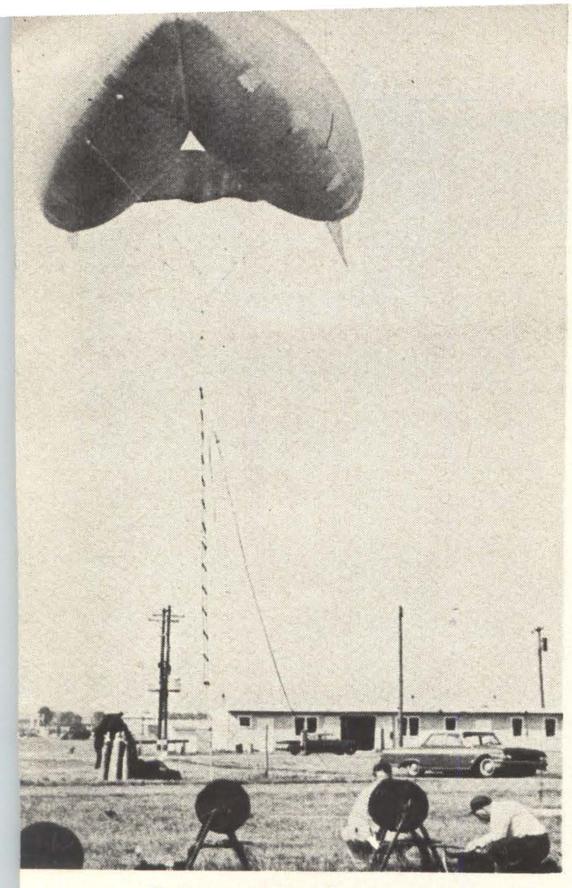


was tested in Hawaii by the Army's
General Motors' Delco division, the
of 200 miles for voice, 500 for c-w.

range equipment is being developed, however. The Army Special Forces have been testing a radio set that promises to take care of many needs of long-range patrols. Designated the AN/PRC-64, the unit is transistorized and weighs only seven pounds. Tested in the United States under ideal conditions, the PRC-64 provided a voice range of 200 miles, and c-w up to 500. In Vietnam, the Army hopes to transmit voice 50 miles and c-w 100 miles.

The PRC-64 evolved from a set built for an unrelated project by the Delco Radio division of the General Motors Corp. Although the Army Special Forces like the equipment, Army headquarters has not yet approved the formal requirement for it that was submitted by the overseas command.

Another long-range radio under development is the AN/PRC-62, a



Balloon, designed by the Goodyear Tire and Rubber Co., will be used to lift antennas above the dense foliage of the South Vietnam jungles.

single-sideband, high-frequency (2 to 30 Mc) unit weighing 30 pounds. Its range should be measured in the thousands of miles. The PRC-62 is being developed by RCA and is expected to be ready for service testing in December.

A new unit being tested in South Vietnam is the HC-162, a high-frequency (2 to 12 Mc) single-sideband radio built by the Hughes Aircraft Co. The transistorized unit weighs 25 pounds and uses a log-wire antenna.

Meanwhile, the Army Special Forces in Vietnam are using the AN/GRC-109, an a-m, c-w unit that operates in the high-frequency band (3 to 22 Mc). It has a 15-watt power output and weighs 40 to 55 pounds, depending on the power supply used. The GRC-109 has been used to communicate between Okinawa and Thailand.

Still in the advanced study stage is the AN/PRC-70, a microminiaturized transceiver designed to provide coverage between 2 and 76 Mc. Transmission can be single-sideband a-m, f-m or c-w. The unit must weigh no more than 30 pounds. Putting all this into a 30-pound package would strain the state of the art. A contractor will be chosen soon to study the feasibility of developing the equipment.

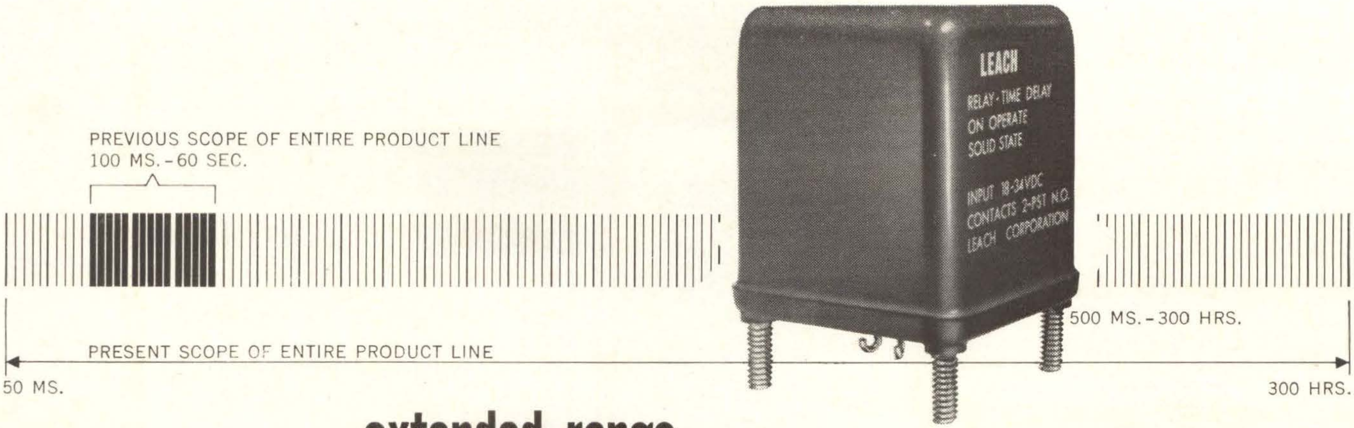
Ground-to-air. The Air Force has bought 40 TR-500A Forward-Air-Control Packs made by Sylvania Electronic Products, Inc. (Electronics, Aug. 24, p. 17). This four-radio unit weighs 51 pounds. Whether the Air Force will buy more of these sets or ask for proposals for a lighter one of 20 to 25 pounds has not been decided. RCA has proposed specifications for a unit weighing 30 pounds.

The Air Force is already developing two very light radio sets for use by air controllers: the PRC-66, a uhf set, and the PRC-65 for vhf. The breadboard model of the PRC-66 will be ready this month for inspection by the Air Force. It will operate on all channels in the 225- to 400-Mc band and weigh 6.75 pounds. The unit is being built under a three-year contract with the Collins Radio Co.'s Canadian subsidiary. The first 18 months' work will be carried out in Cedar Rapids, Iowa, and the remainder in Canada.

The PRC-65 will weigh 5.5 pounds and operate on 1,120 channels in the 100- to 156-Mc range. It will combine advanced digital techniques with thin-film radio-frequency circuits. The heart of its frequency selection is a one-cubic-inch digitally controlled synthesizer that includes a voltage-controlled oscillator 0.1 cubic inch in volume using 1.5-octave thin film. Simmonds Precision Products, Inc., is developing the set for the Air Force.

Power sources. The General Electric Co. recently finished a six-month study for the Rome Air Development Center on advanced power sources of 100 watts or less. The Air Force would like to replace batteries with a light, long-life power source for radios for combat-control teams.

GE studied thermionic and thermoelectric converters, fuel cells and ferroelectric and thermo-photovoltaic devices. Results of the study, made at GE's facility in West Lynn, Mass., may pass from the Air Force to the Army at Fort Monmouth, N. J., where work on power sources has also been going on.



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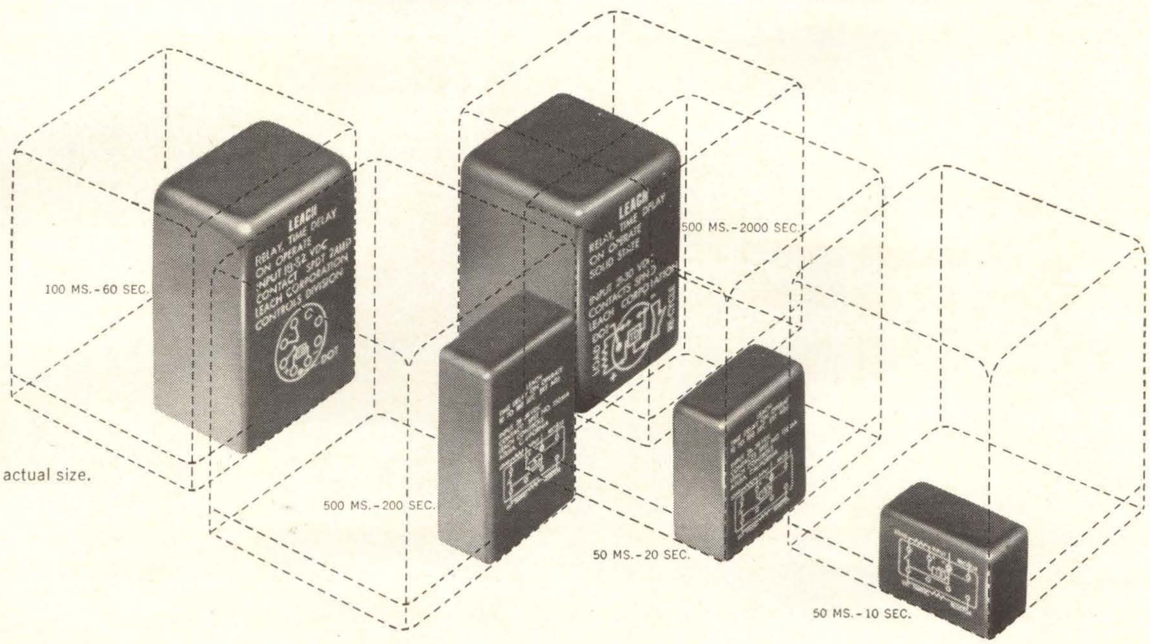

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Here's an ideal oscilloscope for the traveling engineer —Tektronix Type 321A.

The Type 321A is small and light— weighs only 18 pounds. It operates from almost any convenient power source—typically from 4 to 4½ hours on self-contained rechargeable batteries (recharging them through its own recharging circuit), from any dc source of 11.5 to 35 volts—or from any source of 105 to 125 volts, at frequencies from 50 to 800 cps.

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It's easy to maintain—with all components readily accessible, and no selected transistors or tubes.

It's dependable—practically solid-state throughout and built to exact Tektronix standards to operate efficiently over a wide range of temperature and altitude conditions.

Passband is dc to 6 Mc, with writing speed and triggering capability necessary for bright, steady traces over the entire passband.

Precise linearity and accurate calibration assure exact time and amplitude measurements and make the Type 321A suitable for applications involving the most modern complex electronic circuitry.

Type 321A Oscilloscope . . . . . . (without batteries)	$900
Rechargeable battery set	70
Protective Carrying Case . . . . (as illustrated)	30

U. S. Sales Prices f.o.b. Beaverton, Oregon

Send for complete specifications—ask your Tektronix Field Engineer for a demonstration of the Type 321A's ability to meet your particular requirements.

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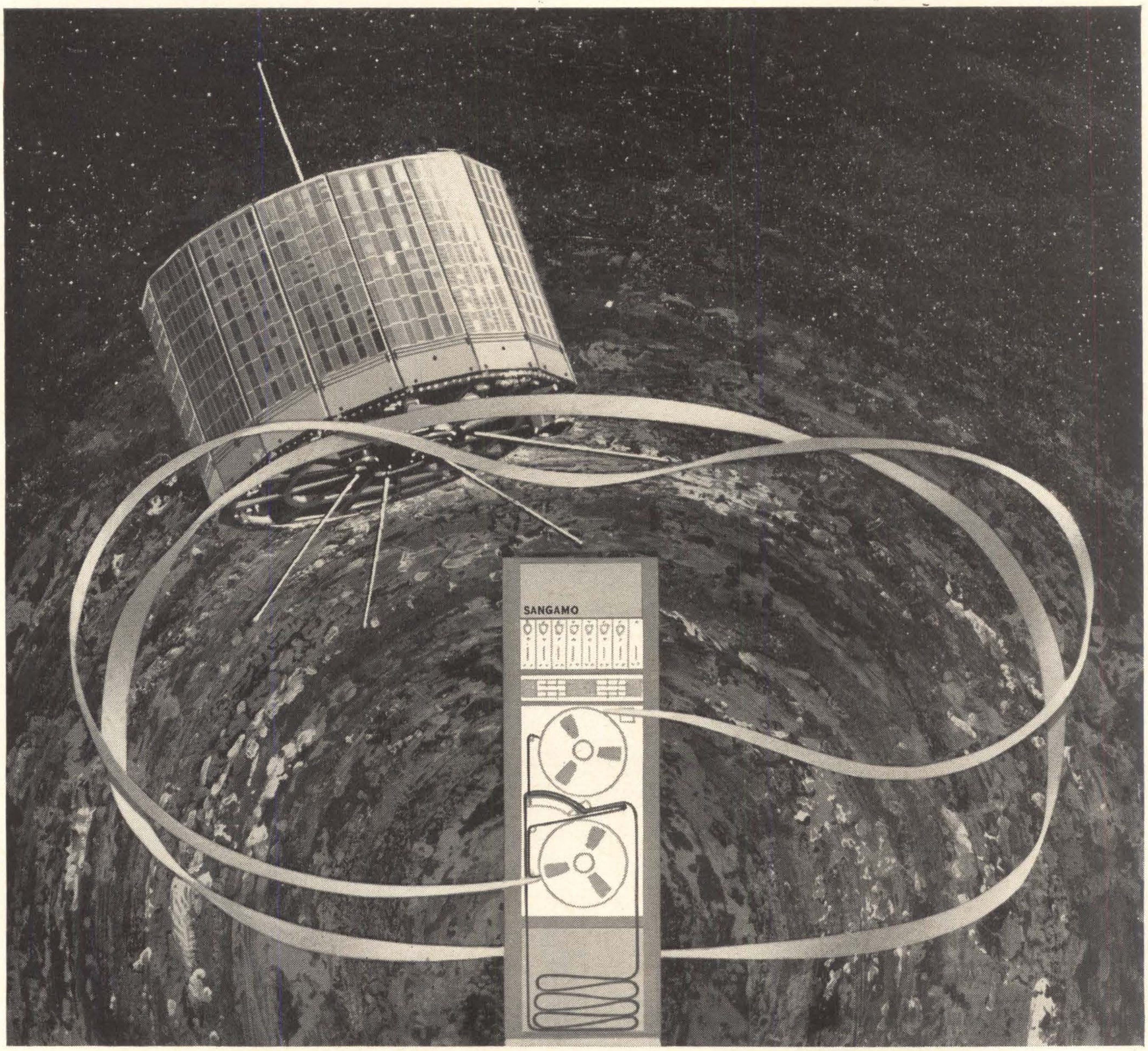


Another Sangamo first in Magnetic Tape Flexibility

NOW THE SANGAMO 4700 HANDLES BOTH 1" AND ½" TAPE SIMULTANEOUSLY

Record or Reproduce either width without mechanical or electrical changes.

Make continuous loop dubs from original tapes on one recorder. Operating at your choice of 8 electrically-selected tape speeds, Sangamo 4700 now has an optional feature which allows you to handle two different tape widths at the same time. One width operates in reel-to-reel mode . . . the other width operates as a continuous loop.

Flexibility is unparalleled. Without time-consuming mechanical or electrical changes—without even changing heads or guides—the 4700 will handle ½" or 1" tape, either on reels or in a loop.

The Sangamo 4700 is unique in analog tape instrumentation. Its light mass capstan drive and unmatched servo speed control provide unsurpassed data accuracy in FM (DC to 20 KC) and Direct (300 to 300,000 cps) ranges.

Be sure to investigate the 4700 for general recording applications and the 480 time delay magnetic tape recorder/reproducer for auto- and cross-correlation applications.

ELECTRONIC SYSTEMS

ES64-1

SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS

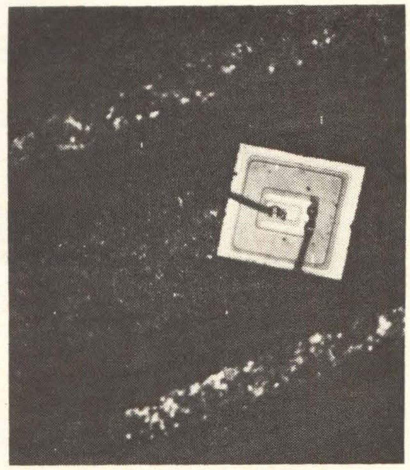
Microcircuit uses matched input transistors

Advanced multichip technology produces high-performance differential amplifier

A microelectronic differential amplifier has been developed with a d-c stability typically 5 μv per 1°C, and a common-mode rejection ratio typically 100 db. Designed for use in critical operational amplifier and transducer amplifier applications, the PC-201 microcircuit is said to achieve its unusual performance through an extremely close matching of two 2N930-type input transistors and the use of both npn and pnp high performance transistors in a unique circuit configuration.

A multichip microcircuit, the PC-201 employs 7 silicon transistors, 6 multiple resistors and 1 capacitor. All the dice are mounted on a ceramic substrate, measuring approximately 0.570 by 0.325 in. and the entire package is epoxy encapsulated. The complete device measures only 0.625 by 0.375 in. and is less than 100 mils thick. According to the manufacturer, advanced multichip technology permits construction of the high performance PC-201 without compromise on gain, input impedance or temperature stability. Similar close matching of input transistors is not possible with conventional monolithic microcircuits, it was noted.

Construction. Since the d-c stability of the differential amplifier depends largely on the matching characteristics of the input transistor pair, careful procedures are employed during production to insure the closest possible match, the company reports. The transistor dice are first selected from the same silicon wafer. Because transistors of this type change characteristics in manufacture, each silicon die is first premounted on a small gold-plated ceramic substrate, measuring approximately 60 mils by 60 mils, bonded to the substrate, wire-bonded for electrical connection and then heat-soaked for several hundred hours to insure complete stabilization. Tests are then performed to insure matching without additional contact to the active device. After final inspection procedures, the units are incorporated into the differential amplifier microcircuit.



Microphotograph shows one of the input transistors, premounted, with connections from base and emitter.

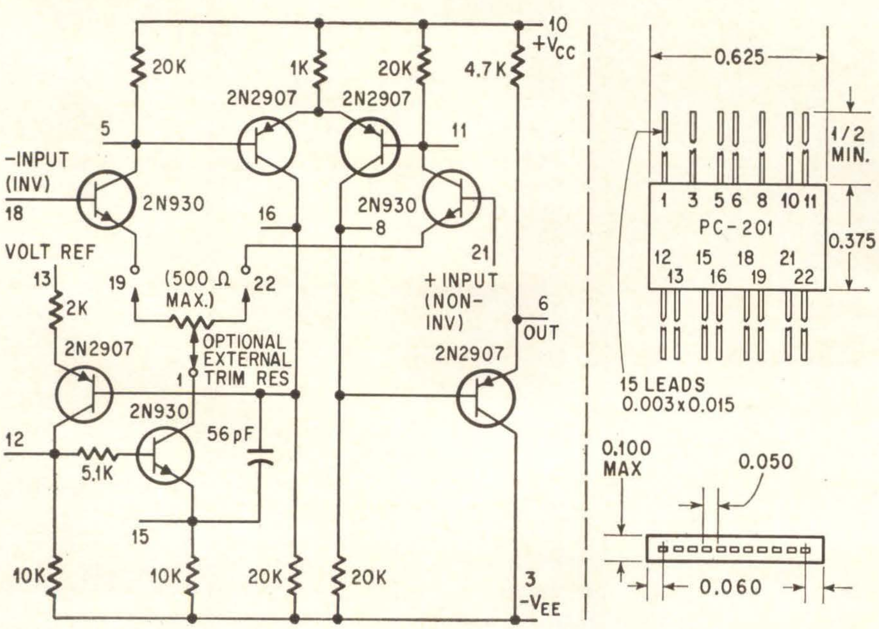
The new microcircuit has a single-ended open loop gain typically 73 db, and a differential input of 200 kilohms. The two input transistors have an initial base-to-emitter voltage match typically 1 mv—compared with the industry standard of 10 mv. The V_{BE} match with temperature is typically 5 μv per 1°C from −55°C to +125°C—compared with the industry standard of 25 μv per 1°C.

The amplifier has an operating range of −55°C to +125°C and a storage temperature range of −65 to +200°C. Maximum electrical ratings include: power supply voltage, $+V_{CC}$, 25 v; negative supply voltage, $-V_{EE}$, 25 v; reference supply voltage, 25 v; input voltage, 8 v.

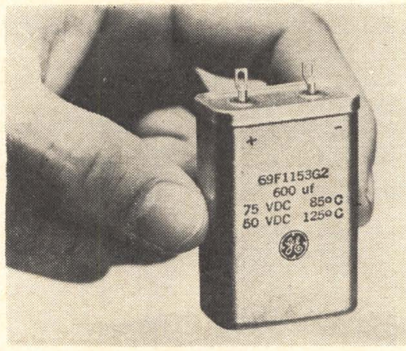
Prices for the new microcircuit are as follows: quantities of 1,000 and up—$90 each; 500 to 999—$100; 100 to 499—$120; 1 to 99—$150.

Semiconductor Products Group, General Instrument Corp., 600 West John St., Hicksville, N.Y.

Circle **301** reader service card



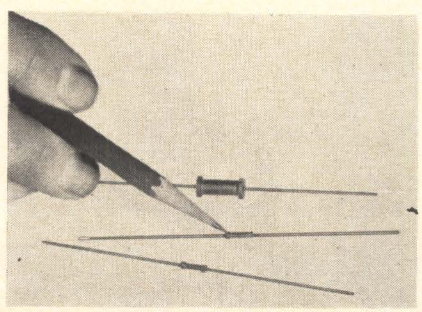
Circuit and outline diagrams of PC-201 microelectronic differential amplifier.



Tantalum capacitor with 3,500 microfarads

A new 125°C tantalum electrolytic capacitor is claimed to have the industry's highest microfarad rating for such a unit. It offers bulk capacitance by providing as high as 3,500 μf and features a hermetic seal which gives long life by virtually eliminating electrolyte leakage. The capacitors are well suited for military and aerospace filtering applications. Providing up to 150 v with polar construction, the units are available in five case sizes and operate over a temperature range of -55°C to $+125$°C. The new jelled acid electrolyte line meets the requirements of MIL-C-3965/21, CL55.

General Electric Co., 392 S. Stratford Rd., Winston-Salem, N.C. **[311]**



Tiny coil forms come in variety of shapes

A series of miniature CeraMag coil forms and matching sleeves are said to permit large inductance in small space. The forms are used in fixed-inductance applications where it is advantageous to wind the coil directly onto the core and attach the coil ends to wire leads. Advanced grinding techniques permit many shapes. CeraMag coil forms can be furnished with one or two flanges, or with none. They are available as small as 0.200 in. long, 0.064 in. in diameter with 0.069-in.-diameter flanges. There are 16 material grades to cover frequency ranges from 10 kc to 200 Mc. These materials have initial permeabilities ranging from 10 to 2,500. The coil forms are being manufactured with leads of Dumet, gold-plated, standard and other types, and in dumbbell form, without leads.

Electronic Components Division, Stackpole Carbon Co., St. Marys, Pa. **[312]**

Microminiature tuning fork resonators

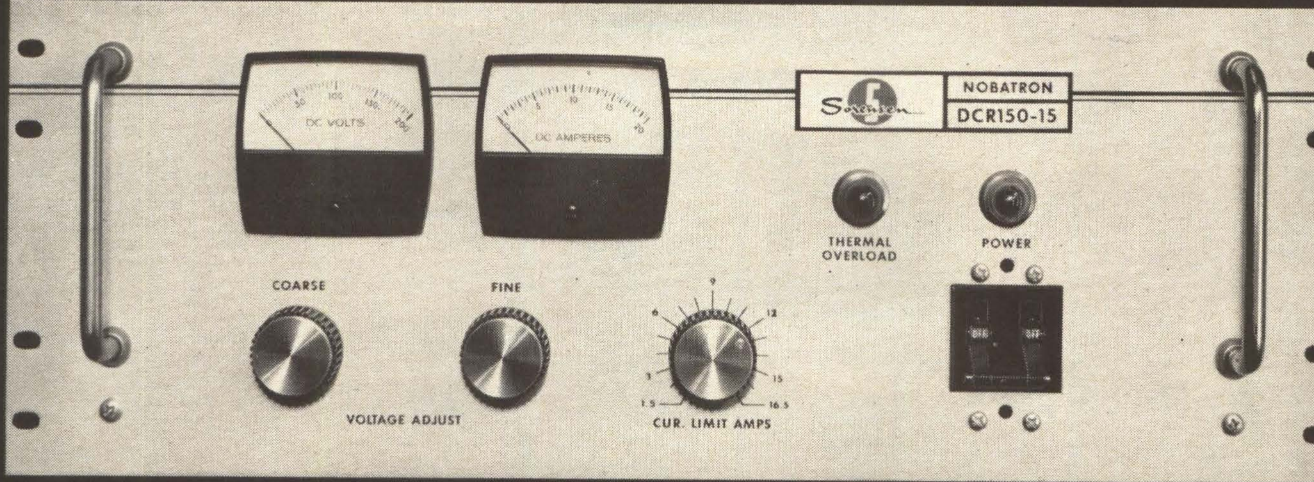
Four new series of miniature and microminiature precision tuning fork resonators are designed to generate audio frequencies between 400 cps and 18,000 cps. Available accuracies range from $\pm$0.05% to $\pm$0.005% over military temperature ranges without the use of ovens. Smallest size is 0.16 cu in. in volume and weight is 0.4 oz. Accuracies of $\pm$0.001% are also available in solid-state oscillator packages.

Philamon Laboratories Inc., 90 Hopper St., Westbury, N.Y. **[313]**

Packaged blowers are rfi-shielded

A series of packaged cooling equipment has shielding in the airstream to overcome and suppress

New from Sorensen...40 volts at 10 amps in a constant current power supply for $325.00



Now...19 DCR supplies from 0-400 to 0-2400 watts

1. **19 SILICON CONTROLLED RECTIFIER SUPPLIES AVAILABLE...** Delivery in 30 days or less.
2. **LOW PRICES...**Starting at $325 (Voltmeter and Ammeter included with no increase in price)
3. **COMPACT PACKAGING...**7″ or 5¼″ Rack Height
4. **HIGH EFFICIENCY**
5. **CONSTANT VOLTAGE REGULATION...**with continuously adjustable current limiting.
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7. **AUTOMATIC CROSSOVER...** full automatic transition from constant voltage to constant current operation, or from constant current to constant voltage operation, at any operating point.
8. **REMOTE PROGRAMMING...**Voltage and Current
9. **REMOTE SENSING...**At distances up to 200 feet
10. **SERIES OR PARALLEL OPERATION**
11. **VOLTAGE REGULATION...**(as low as ±0.1% or 15 mv) Line and Load combined
12. **CURRENT REGULATION...**As low as ±15 ma
13. **LOW RIPPLE...**0.5% + 50 mv (RMS)
14. **UNITIZED CONTROL CIRCUITRY...**for easy maintenance
15. **COARSE AND FINE CONTROLS...**for Voltage Output

For complete data on the DCR series and other Sorensen products, send for the new, 140-page "Controlled Power Catalog and Handbook." Write to: Sorensen, Richards Avenue, South Norwalk, Connecticut. Or use Reader Service Card Number 200.

DCR ELECTRICAL AND MECHANICAL SPECIFICATIONS:

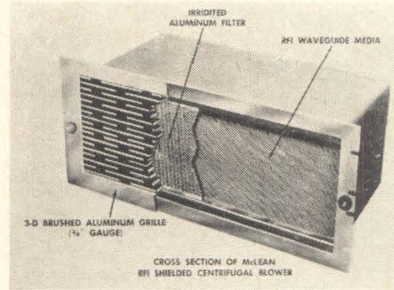
MODEL NUMBER	VOLTAGE RANGE (VDC)	VOLTAGE REG. (LINE & LOAD COMBINED)	OUTPUT CURRENT (AMPS.)	CONSTANT CURRENT RANGE (AMPS.)	CURRENT REG.	RMS RIPPLE	TRANSIENT RESPONSE	PACKAGE SIZE (INCHES) WIDTH	HEIGHT	DEPTH	WEIGHT (LBS.)	PRICE
DCR 300-1.25	0-300	±.1% or 60mv	0-1.25	0.125 to 1.37	±15ma	0.5% + 50mv	30msec	19	5¼	15	52	$325
DCR 150-2.5	0-150	±.1% or 30mv	0-2.5	0.25 to 2.75	±15ma	0.5% + 50mv	30msec	19	5¼	15	52	325
DCR 80-5	0-80	±.1% or 30mv	0-5	0.5 to 5.5	±15ma	0.5% + 50mv	30msec	19	5¼	15	56	325
DCR 40-10	0-40	±.1% or 15mv	0-10	1 to 11.0	±20ma	0.5% + 50mv	30msec	19	5¼	15	55	325
DCR 300-2.5	0-300	±.1% or 60mv	0-2.5	0.25 to 2.75	±15ma	0.5% + 50mv	30msec	19	5¼	18	77	525
DCR 150-5	0-150	±.1% or 30mv	0-5	0.5 to 5.5	±15ma	0.5% + 50mv	30msec	19	5¼	18	77	525
DCR 80-10	0-80	±.1% or 20mv	0-10	1.0 to 11.0	±20ma	0.5% + 50mv	30msec	19	5¼	18	77	525
DCR 60-13	0-60	±.1% or 15mv	0-13	1.3 to 14.3	±20ma	0.5% + 50mv	30msec	19	5¼	18	77	525
DCR 40-20	0-40	±.1% or 15mv	0-20	2.0 to 22.0	±25ma	0.5% + 50mv	30msec	19	5¼	18	77	525
DCR 300-5	0-300	±.1% or 60mv	0-5	0.5 to 5.5	±15ma	0.5% + 50mv	30msec	19	7	18	95	710
DCR 150-10	0-150	±.1% or 30mv	0-10	1.0 to 11.0	±20ma	0.5% + 50mv	30msec	19	7	18	95	710
DCR 80-18	0-80	±.1% or 20mv	0-18	1.8 to 19.8	±25ma	0.5% + 50mv	30msec	19	7	18	98	710
DCR 60-25	0-60	±.1% or 15mv	0-25	2.5 to 27.5	±25ma	0.5% + 50mv	30msec	19	7	18	100	710
DCR 40-35	0-40	±.1% or 15mv	0-35	3.5 to 38.5	±35ma	0.5% + 50mv	30msec	19	7	18	102	710
DCR 300-8	0-300	±.1% or 60mv	0-8	0.8 to 8.8	±20ma	0.5% + 50mv	30msec	19	7	18	115	825
DCR 150-15	0-150	±.1% or 30mv	0-15	1.5 to 16.5	±25ma	0.5% + 50mv	30msec	19	7	18	115	825
DCR 80-30	0-80	±.1% or 20mv	0-30	3.0 to 33.0	±30ma	0.5% + 50mv	30msec	19	7	18	120	875
DCR 60-40	0-60	±.1% or 15mv	0-40	4.0 to 44.0	±40ma	0.5% + 50mv	30msec	19	7	20	130	900
DCR 40-60	0-40	±.1% or 15mv	0-60	6.0 to 66.0	±60ma	0.5% + 50mv	30msec	19	7	20	131	925

Sorensen

A UNIT OF RAYTHEON COMPANY

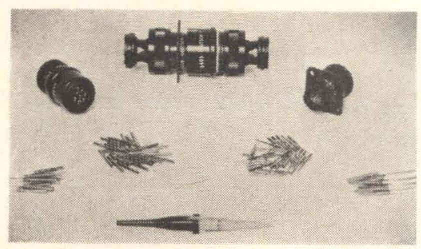
CIRCLE 200 ON READER SERVICE CARD

New Components



radio frequency interference. Units maintain a 100-db attenuation through the range of 15 kc to 10 Gc when installed to specification. Airflow ratings are from 150 cfm to 1,000 cfm. All models are without r-f noise generation or transmission. The Computer Age rfi-shielded line is certified by government agencies and all models conform to a variety of applicable Mil-Specs. They are quickly and easily installed. Filters can be serviced without tools.

McLean Engineering Laboratories, P.O. Box 228, Princeton, N.J. **[314]**



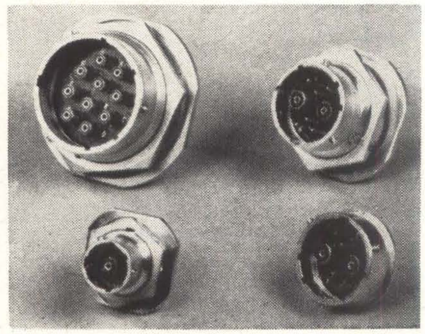
Connectors feature push-pull coupling

Advanced push-pull coupling is incorporated in the DBA70 line of of high-reliability connectors. The push-pull has a ball-lock coupling mechanism that features five keyways to guarantee against mismating. Operation is always in the direction of plug travel—push for positive lock and seal, pull for instant disengagement. No lock wiring or twisting is required. Mating can be checked visually or by probe. The connectors feature Big Brutus contacts, interchangeable accessory hardware, rear entry insertion-removal and a wide range of shell sizes and layouts. The line is available in square-flange

New Components

mounted receptacles and push-pull plugs.

Deutsch Electronic Component Division, Municipal Airport, Banning, Calif. [315]



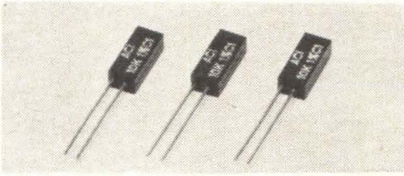
Coaxial connectors with hermetic seal

Sealed connectors for coax and shielded circuitry provide closed entry and positive spring retention in a one-piece contact member. The connectors meet or exceed MIL-C-26482 and MIL-C-26500 helium leakage requirements and mate with Hyfen Bantam coax or proprietary configurations. Insulation is of hard-compression blue glass, making contact identification extremely legible. The connectors are available with outer conductors either fully insulated or grounded to connector shell. The various designs accept any shielded wire using No. 20 Awg center conductor, covering standard and miniature coax applications. They may be obtained in solder, box, or jamnut mounting, with a choice of solder pot, solder eye or special wiring terminations, and in a variety of plated finishes. The units are also available as a feed-through coax and as a composite, with both power and coax contacts in a single connector.

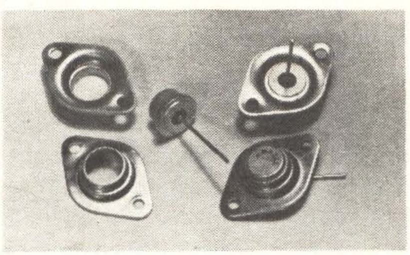
Burndy Corp., Norwalk, Conn. [316]

Metal-film resistor saves board space

A miniaturized, molded, precision resistor of metal-film, type PE-¼, is designed to conserve printed-



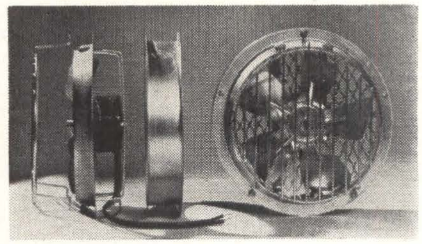
board area, and in performance surpasses MIL-R-10509E characteristic E and C levels. Power rating is 1/4 w at 100°C, and 1/8 w at 125°C. Voltage rating is 250 v while resistance range coverage is 10 ohms to 0.5 megohm. Dimensions are 0.140 by 0.200 by 0.468 in. high. Leads are 3/4 in. long, and can be trimmed to suit the application. Standard tolerance is ±1%. The unit features low noise and temperature coefficients of ±25 ppm/°C, ±50 ppm/°C, and ±100 ppm/°C. Prices range from $2 to 45 cents depending on tolerance, temperature coefficient, and quantity.
American Components, Inc., 8th Ave. & Harry St., Conshohocken, Pa. [317]



Flange adapter offered for press-fit rectifier

Latest addition to a line of transistor heat-sinks is Part 700, a TO-3, flange adapter for 0.500-in. press-fit rectifiers. The metal chassis and printed-circuit structures found in the electronics industry are not inherently compatible with the principle of the press-fit rectifier. The new flange adapter enables the customer to convert the rectifier into the traditional TO-3 outline with which the industry has extensive experience. The rectifier can be inserted easily into the adapter, using a drill press as an arbor and a 9/16-in. socket as a bucking fixture. A multistrand wire can be inserted during the process. This provides a swaged second electrode that is more reliable than the conventional solder-lug techniques commonly used with TO-3 and other semiconductor configurations. The rectifier can be replaced without damaging the flange adapter.

Daedalus Co., 129½ Rosecrans Ave., Manhattan Beach, Cal. 90266. **[318]**



Ultra-thin fans benefit designers

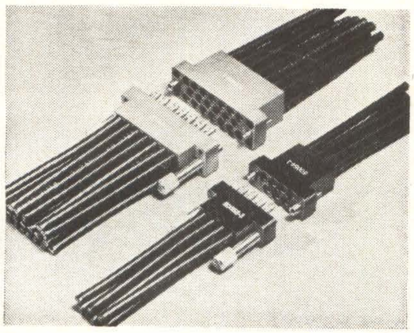
Four new models in a two-part series of ultra-thin fans offer design latitude to those concerned with electronic cabinet cooling. Both blower and suction models are just 3⅛ in. deep overall. Blower models are designed to insure broad distribution of cooling air to all corners of the cabinet. This is achieved by inclusion of a substantial radial component, rather than straightforward chimney flow. This family line comprises a whole range of sizes, from 165 cfm to 800 cfm. Flexible thin fan suction models, for direct mounting to the side panel or rear door of typical electronic cabinets, will also drop into the base, thus clearing side walls and most or all of panel space. Intrusion into cabinet need be only from 2⅞ in. to 4⅜ in. to obtain air deliveries ranging from 165 to 800 cfm.

Kooltronic Fan Co., P.O. Box 504, Princeton, N.J. **[319]**

Metal film resistor meets MIL-R-10509E

A $\frac{1}{20}$-w miniature resistor, designated FE5, dissipates 0.05 w to 125°C and derates linearly to 175°C. It meets all MIL-R-10509E requirements. The FE5 features cap and lead construction for greater mechanical strength and assurance of positive electrical contact under most stringent environmental extremes. Noise levels are less than 0.2 μv per v. The resistor is available in resistance ranges from 50 ohms to 100 ohms, tolerance of $\pm 1\%$, and temperature coefficients of 0 ± 50 ppm. It is transfer encapsulated with a high-density epoxy material which is said to provide better environmental protection than the commonly used molding or conformal coating materials. The FE5 measures only 0.150 in. maximum length by 0.054 in. maximum diameter. Its standard No. 26 Awg gold-plated nickel lead can be welded and soldered.

Mepco, Inc., Morristown, N.J. **[320]**



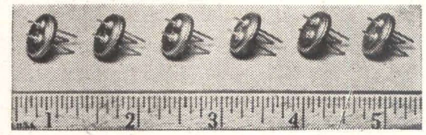
Coaxial connectors have snap-in contacts

Availability of 20-position, 14-position and 7-position coaxial cable connectors has been announced. They are miniature pin-and-socket connectors with snap-in contacts, designed for high-density, multiple-coaxial connections. Both connectors feature one-step termination of inner conductor, outer braid and cable support. Both accommodate cable sizes from RG55B/U to RG188/U. The snap-in contacts utilize a special type of retention spring that assures firm seating in the connector block and acts as a shield over crimping ports.

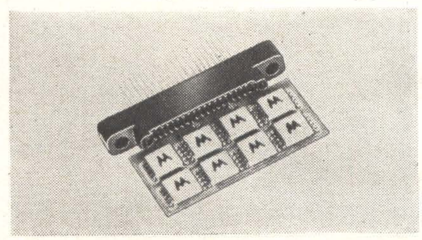
AMP, Inc., Harrisburg, Pa. **[321]**

Ceramic-to-metal header for power transistors

A ceramic-to-metal seal header in the TO-8 JEDEC configuration, available for packaging power transistors, consists of 0.030-in.-diameter nickel iron leads, silver-brazed into a pure copper base. The leads must withstand bending over a

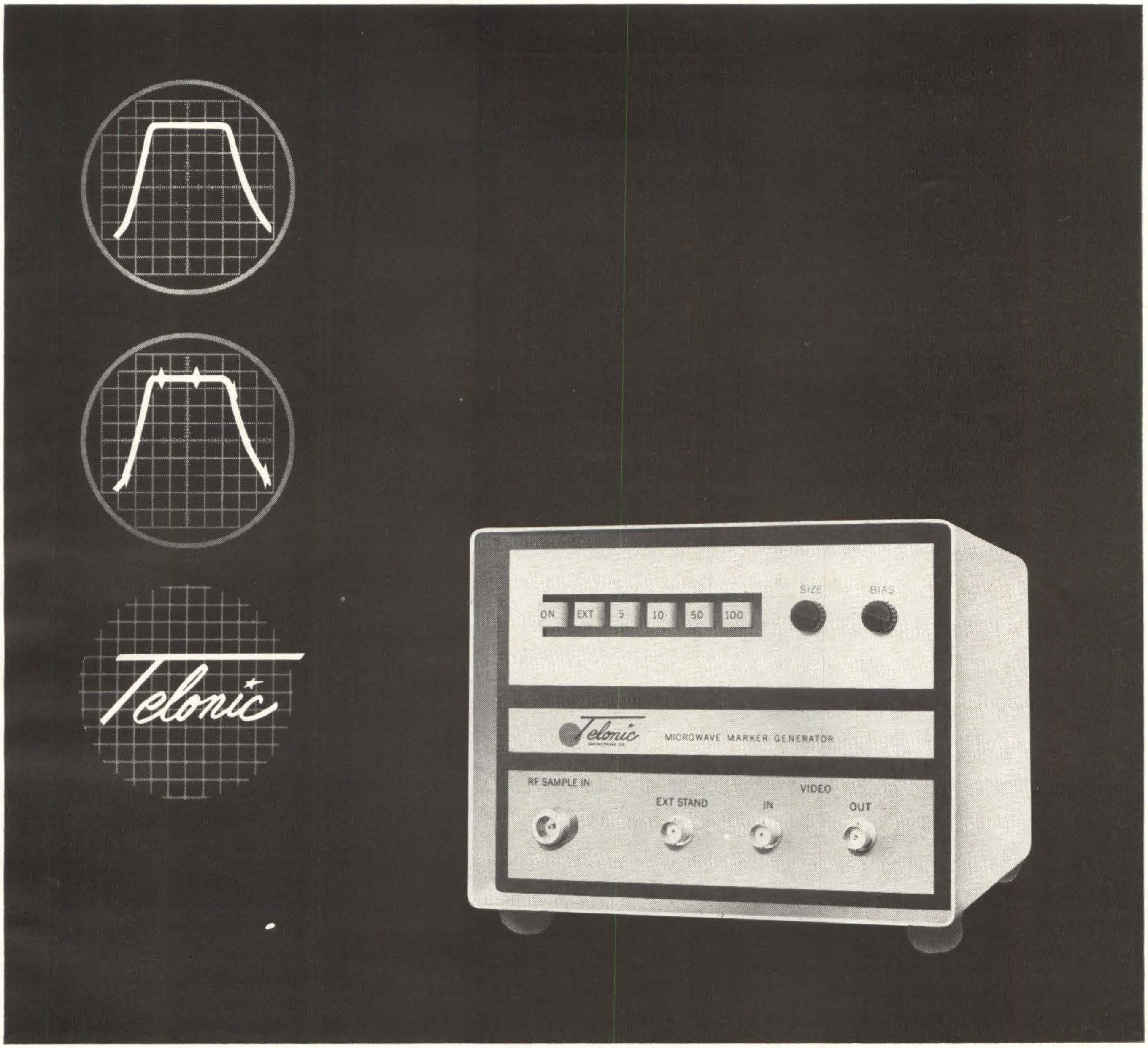


30° arc to meet specifications. A nickel-coated molybdenum disk is mounted on the face of the header to match the thermal expansion of silicon that is also mounted on the header. The entire header can be gold-plated, if desired, to meet thermal cycling as high as 500°C. Advac Products, Inc., 174 Richmond Hill Ave., Stamford, Conn. [322]



P-c connector in varied sizes

A new connector has been announced for printed card and tape cable applications. Designated series 600, these receptacle-type units are made in a variety of single and dual readouts with sizes from 6 to 210 contacts capable of accommodating board thicknesses of $\frac{1}{32}$ in., $\frac{1}{16}$ in., $\frac{3}{32}$ in. or ⅛ in. Illustrated is a 40-terminal microminiature unit with 0.050 center-to-center spacing assembled with a micromodule integrated circuit on a $\frac{1}{32}$ in. p-c board. This connector is also available with 128 terminations. Connectors meet or exceed applicable MIL-C-21097 specifications. Wiring styles include eyelet lug for soldering, solderless-wrap termination for wire-wrapping technique, taper tab solderless wiring and contacts for dip soldering. Molding material is usually glass-reinforced diallyl phthalate type GDI-30 per MIL-M-19833 specifications although other materials are used and available on order. Continental Connector Corp., 34-63 56th St., Woodside 77, N.Y. [323]



TMS MICROWAVE MARKER GENERATOR
1 Gc to 10 Gc

The new Telonic TMS Marker Generator lets you know precisely where you're operating, frequency-wise, from 1 to 10 Gc. It provides continuous indication of frequency by producing Birdy-type markers on the oscilloscope every 5, 10, 50, or 100 Mc. Designed to be used with a sweep generator, the new TMS system obsoletes every other type of frequency meter in accuracy price, and convenience.

Marker intervals are selected by convenient push-button for speed and precision. If intervals other than the four standard are desired, an RF connection and selector button allows use of an external oscillator for any frequency from 2 Mc to 200 Mc.

Accuracy of the new TMS is .001%, or 100 times better than that of a frequency meter. Its accuracy approaches that of a frequency counter but at a fraction of the price.

Contact your local Telonic representative for a demonstration or write direct for complete details and specifications.

GENERAL SPECIFICATIONS

FREQUENCY RANGE	1 Gc to 10 Gc
MARKER INTERVAL	5, 10, 50, 100 Mc
ACCURACY	.001%
CONNECTIONS	Sample in, external oscillator, video in, and video out
POWER REQUIREMENTS	115V, 60 cycle
DIMENSIONS	6" high x 8" wide x 10" deep

Telonic® **ENGINEERING CO.**

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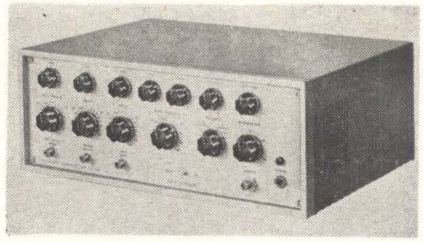
New Instruments

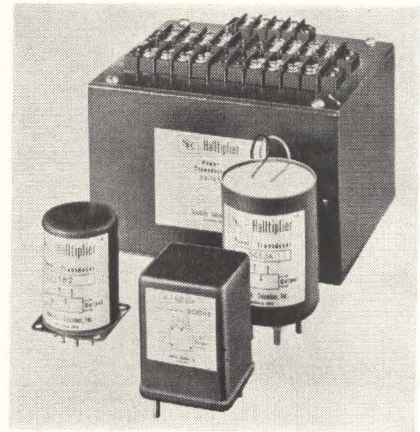


Pulse generator with fast rise time

An all-solid state pulse generator has been introduced. Model 139 features fast, variable, ultralinear 6 nsec to 100 μsec rise time. Repetition rate is continuously variable from 1 kc to 20 Mc. Base line offset is ± 2 v, adjustable, either polarity. Delay, width and amplitude are fully controllable. Price is $1,275.
E-H Research Laboratories, Inc., Oakland, Calif. **[351]**

F-m detector offers d-c to 400 kc response

This wide-band, tunable, direct carrier f-m discriminator can demodulate, with very low distortion and wide frequency response, f-m signals. Model FMD-1 can be used for accurate measurements of frequency response, pilot phasing, distortion, and stereo separation in f-m broadcast transmitters as well as for measurements in phase and f-m telemetry transmitters. Specifications include: carrier center frequency, 85 to 115 Mc; frequency response, d-c to 400 kc; distortion, less than 0.1%; sensitivity, 0.05 v/1 v per 75 kc deviation; input impedance, 50 ohms; vswr, less than 1.2:1; maximum input level, ½ w; output impedance, 10,000 ohms; size exclusive of knob and connectors, 4 in. wide by 2½ in. deep by 3 in. high; price, $89.50.
Belar Electronics Laboratory, 1204 Childs Ave., Drexel Hill, Pa. **[352]**

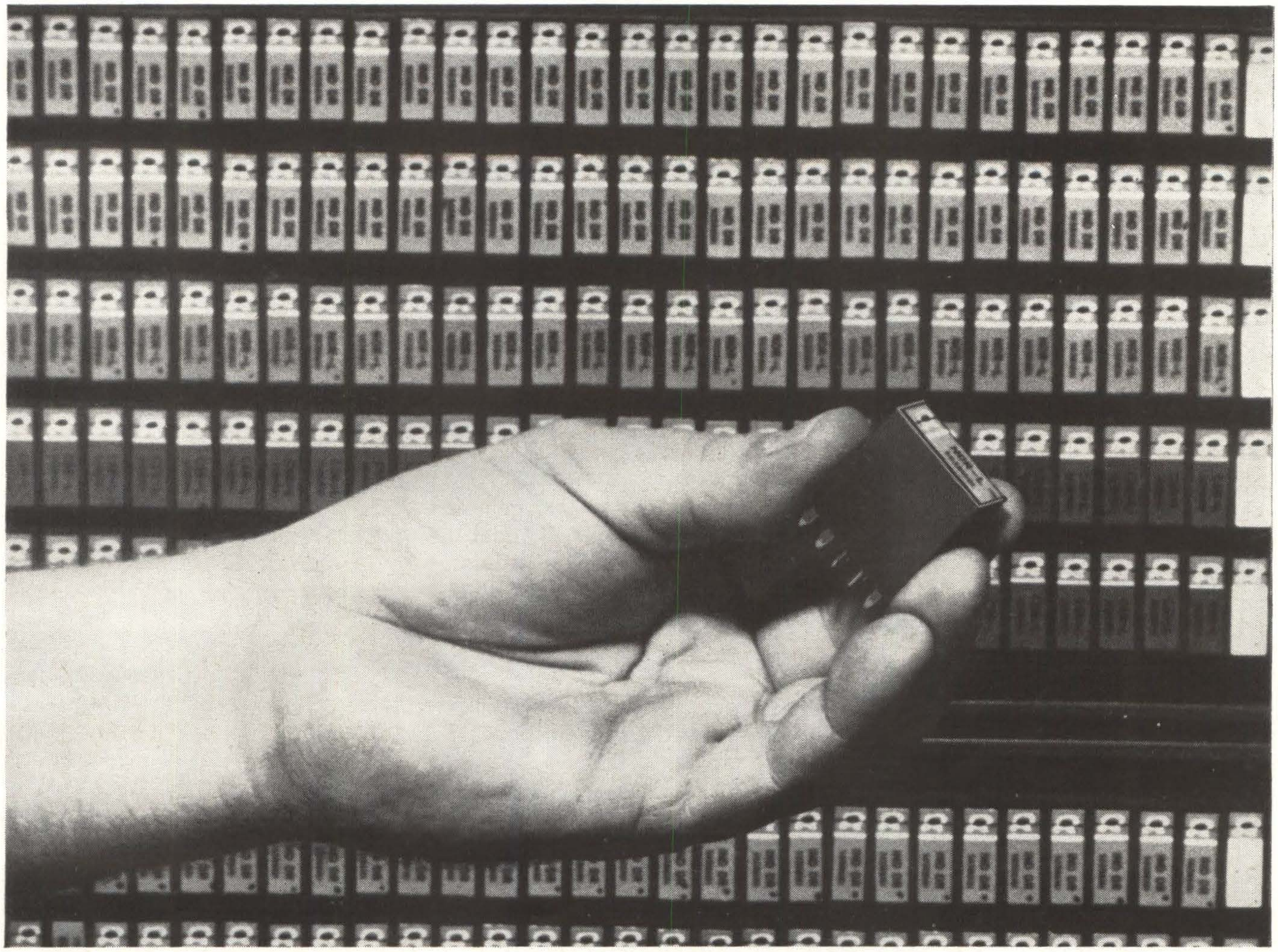


Power transducers cover from 1 w to 5 kw

A line of power transducers, based on the Hall effect, cover full-scale ranges from 1 w to 5 kw. The Hall effect can measure power because it is a true electrical multiplier. Providing a d-c voltage proportional to true power, these rugged, solid-state transducers are designed to meet specifications for most power-control systems, metering and recording applications. Single or three-phase models, covering frequencies up to 10 kc, are available in a variety of enclosures and terminations.
Scientific Columbus, Inc., 1035 W. Third Ave., Columbus, Ohio. **[353]**

Flame photometer with digital readout

A digital-readout instrument is announced for measurement of sodium and potassium in serum, urine or other biological samples. Model 143 flame photometer provides simple calibration, quick analysis, no serial



Simplify Digital Design

Radiation Logic Modules are packaged for flexibility, reliability, high-density mounting

There's no need for design compromise when you specify Radiation Logic Modules. They can be used in any configuration, type or number compatible with your digital system requirements. They can be mounted in vertical or horizontal drawers, in standard 19" racks, or on breadboards... fixed or removable.

Radiation Logic Modules are supplied from stock in standard as well as special-purpose types. Two sets of fully compatible resistor-transistor logic circuitry are available. They cover bit rates up to 200 kc, and rates to 1 Mc. More than a dozen types include: 4-input NOR—Counter Shift Register—Power Inverter—Emitter Follower—Complementary Driver—Differential—Filter (Decoupler).

RELIABILITY Superior engineering and rigid component selection assure highest reliability: based on extensive tests, MTBF for low-speed NOR Modules exceeds 2,940,000 hours! The units are also packaged for rugged use. Construction consists of welded circuitry molded in epoxy and mounted with high-density module connectors on cast aluminum frames. The resulting positive-contact units measure only 0.4" x 1" x 1.1" with a 0.25" pin protrusion.

ECONOMY Each module represents a fraction of the entire digital system. Each is designed for easy interrogation. Change or replacement is as simple as plugging in another unit. Thus, expensive downtime is reduced, costly benchwork completely eliminated.

APPLICATIONS ASSISTANCE Radiation offers the services of its engineering staff in the application of digital logic modules, or in helping solve your unique data problems. Write or phone for technical data sheets. Radiation Incorporated, Products Division, Department EL-09, Melbourne, Florida. Telephone: (305) 723-1511.

RADIATION
INCORPORATED

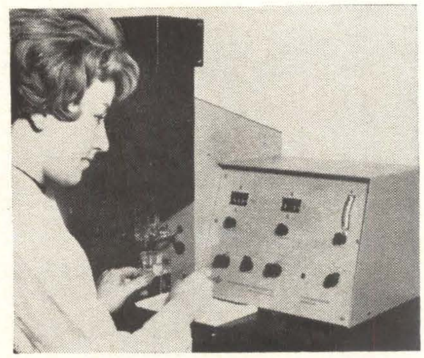
PRICE LIST—DIGITAL MODULES

Low initial cost is another attractive feature of Radiation Digital Logic Modules. Contact Radiation for unit prices on greater quantities than indicated below:

Part Number	Description	Unit Price
503815G1	NOR—Medium Speed	$ 10.38
503816G1	NOR—Low Speed	6.40
503818G1	Power Inverter—Low Speed	5.95
503818G2	Power Inverter—Medium Speed	10.69
503819G1	CSR—Low Speed	8.82
503819G2	CSR—Medium Speed	11.66
503819G3	CSR—Medium Speed	37.65
503820G1	MSMV "B" Side	7.74
503821G1	Diff (MSMV "A" Side)	9.68
503834G1	Filter (Decoupler)	7.55
503860G1	Compl. Driver—Low Speed	12.55
505694G1	Diode Gate	11.40
505703G1	D/A Converter	14.20
505704G1	Indicator Driver	14.15
506030G1	CSR-M1	21.20
507318G1	Emitter Follower—Low Speed	7.29
507318G2	Emitter Follower—Medium Speed	12.11
508334G1-G8	Octal Patch	4.20
508335G1-G2	Jumper Patch	4.84
508367G1	5 Volt Reference	196.20
508517G1	Module, Special Component	13.62
509050G1	Indicator Driver (Negative Coincident Input)	15.15

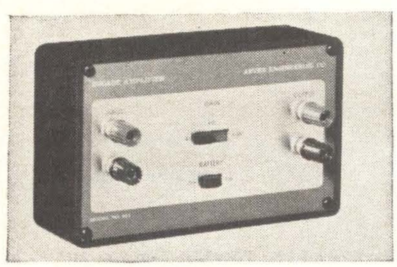
Specifications and prices subject to change without notice due to technological advances. Delivery, discount schedules and additional pricing information available upon request.

Circle 147 on reader service card



dilutions or computations and optimum reproducibility from a sample as small as one microliter. With only one dilution necessary, calibration becomes a simple procedure accomplished in about 30 seconds with no reiterative steps or serial dilutions. Once calibrated, the instrument permits samples to be read at the rate of one every five seconds. Since the final answers are presented automatically as large legible numbers, computation errors are eliminated. Model 143 provides such a high degree of reproducibility that typical coefficients of variation for both sodium and potassium are no greater than 0.3%.

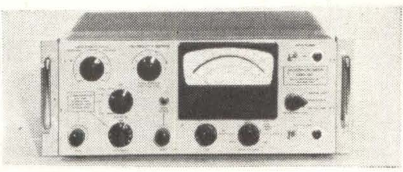
Instrumentation Laboratory Inc., 9 Galen St., Watertown Square, Boston, 72. [354]



Low noise, distortion in decade amplifiers

A series of all-transistor decade amplifiers, with frequency responses from below 5 cps to 1 Mc, have voltage gains of 1, 10 or 100. High-gain silicon transistors in the input stages insure temperature-stable, low-level operating points, and provide extremely low-noise performance. Equivalent input noise is less than 2.5 μv, and harmonic distortion is under 1%. The high-input and low-output impedances offer a convenient way to isolate critical circuits from undesirable loads. Applications include examination of low-level signals direct from the playback heads of tape recorders and standardization of termination impedance between sections of complex filter networks. Signals above ground reference can be amplified because the series 851 units operate on their own internal battery supplies. In addition, battery operation insures freedom from power-supply hum.

Arvee Engineering Co., 11263 Washington Blvd., Culver City, Calif. [355]

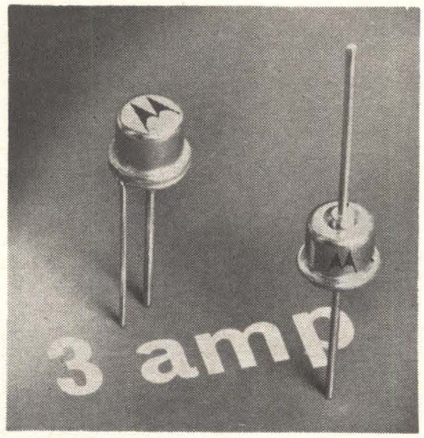


D-c microphotometer with fast rise time

A new d-c microphotometer has been developed for making picolumen light measurements with exceptionally short rise time and high stability. A variety of detachable probes [not shown] are offered for visible, infrared and ultraviolet, all of which use multiplier phototubes as transducers. Model 380 is suitable for laboratory uses and as an automatic inspection device for shape or color on production lines. Rise time is 0.5 millisec in most ranges and 1 millisec in the 1-millimicroampere range. Seven switchable low-pass filters are used to permit reducing the speed if fast rise is not desired. The d-c amplifier drifts less than 2% in 4 days. It is calibrated permanently in microamperes within 1.5%, and has 9 ranges from 10^{-5} amp to 10^{-9} amp. Equipment is included for zero suppression up to 100 times full scale. A 6-in. meter and a 3-ma recorder jack are the outputs. The integral h-v power supply is adjustable from – 500 v to – 1,800 v, and regulated within ± 0.1%. Price is $945 plus the cost of the probe selected.

Grace Electronics, Inc., 4380 Warner Road, Cleveland. 44105. [356]

New Semiconductors



Lead-mount rectifiers rated at 3 amperes

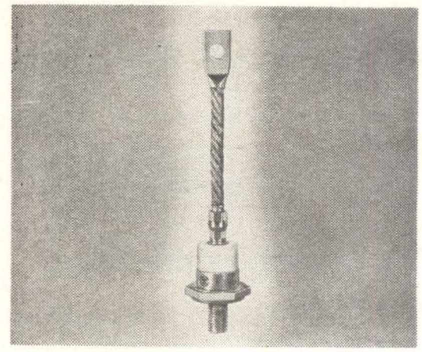
A new series of rectifiers is available in lead-mount packages. Rated at 3 amps forward current with 300-amp surge handling capacity, the MR1030 series are priced 50% to 70% lower than conventional rectifiers in the same current range, according to the manufacturer. These devices are especially suited for circuit board use in 1 to 3-amp applications that previously required the larger stud-mount package. The series includes seven devices in either axial-lead or single-ended packages with peak repetitive reverse-voltage ratings from 50 to 600 v. Reverse polarity units are available. Temperature operating range is $-65°C$ to $+175°C$. The unusual current handling characteristics are said to be achieved through an increased semiconductor junction area combined with a slight increase in lead diameter for optimized heat dissipation.

Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix, Ariz. **[331]**

Silicon transistors for uhf-tv tuners

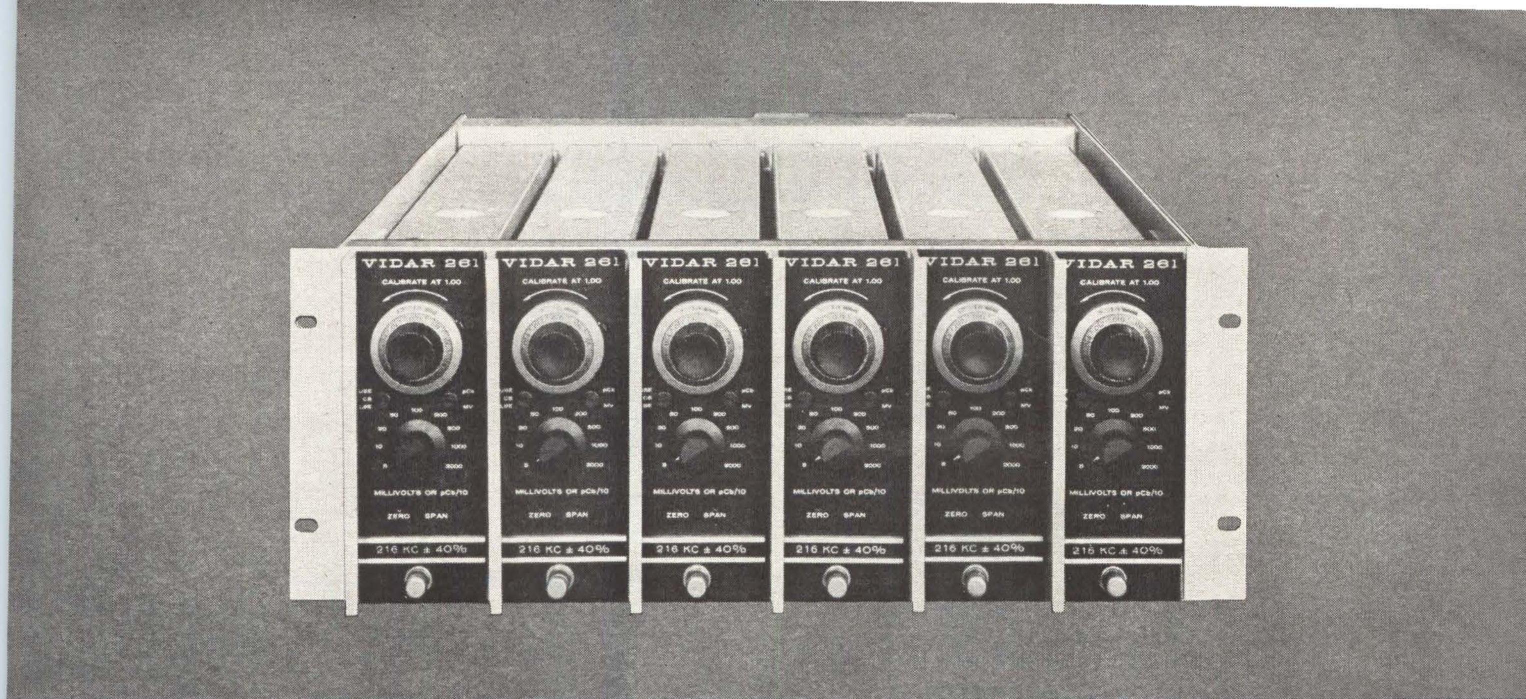
A line of high-gain, silicon planar transistors is designed for use as local oscillators in uhf-tv tuners. A typical device is the SE3002, with 8 mw power output at 930 Mc. At 200 Mc this device has the following specifications: a power gain of 12 db minimum with a collector current of 6 ma and collector-to-base voltage of 12 v. At a frequency of 60 Mc, the SE3002 has a typical noise figure of 4 db with 1 ma of collector current, collector-to-emitter voltage of 6 v, and a source resistance of 400 ohms. Leakage current is guaranteed less than 0.5 μa at 15 v collector-to-base.

Fairchild Semiconductor, a division of Fairchild Camera & Instrument Corp., 545 Whisman Road, Mountain View, Calif. **[332]**

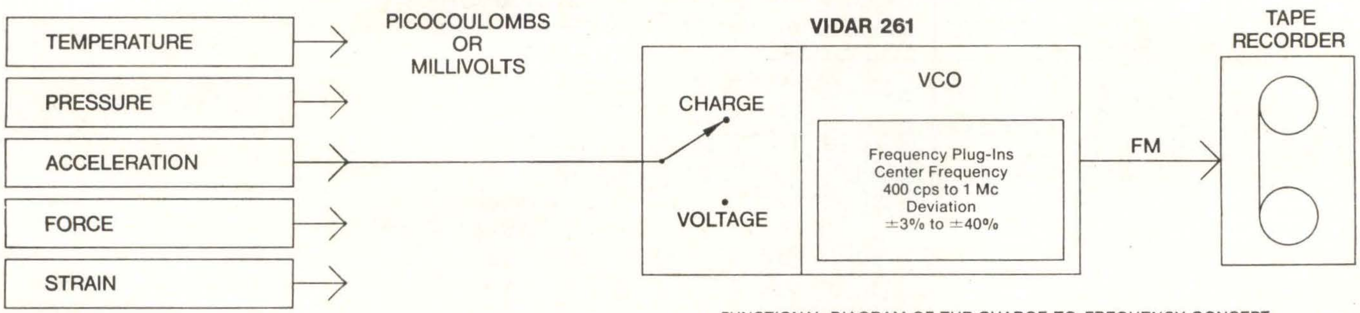


Rectifier diodes withstand severe use

Medium-power silicon rectifier diodes (type 402 JEDEC series 1N1183A) are designed for heavy industrial service involving cyclic loading and widely varying operating conditions. Principal applications are in d-c power supplies, inverters, welding controls, converters, motor controls, and frequency changers. The diodes are rated 40 amps with low reverse-leakage current, but can be used at currents up to 70 amps with proper cooling. Maximum one-cycle surge current under load is 1,000 amps peak; maximum reverse-voltage ratings are up to 1,000 v peak. Units have a junction operating temperature range from $-65°$ to $+200°C$. These rectifier diodes have hermetic seals and fused, double-diffused, hard-solder construction to insure dependability under fluctuating load currents and tough duty cycles that can cause soft-soldered junctions to fail. They have all-welded cases to withstand thermal



CHARGE-TO-FREQUENCY OR VOLTAGE-TO-FREQUENCY: WITH THE FLICK OF A SWITCH, THIS NEW CONVERTER DOES EITHER. FREQUENCY PLUG-INS AVAILABLE FOR ALL IRIG, CONSTANT BANDWIDTH, & FM TAPE FREQUENCIES.



FUNCTIONAL DIAGRAM OF THE CHARGE-TO-FREQUENCY CONCEPT

If you work with piezo-electric and other transducers with high output impedances, you are probably well aware of the problems associated with gathering data from these sources. Almost any amount of capacitance introduces RC roll-off. With the Vidar 261 operating in the charge mode, the voltage drop across the input circuit and the line capacity are kept at zero. Because no charge is stored, RC attenuation of high frequency data is prevented.

In the voltage mode, the Vidar 261 works directly from low-output transducers such as strain gage bridges, thermocouples, and biomedical sensors. True floating input with guard shielding assures immunity to ac or dc common-mode voltages in spite of source unbalances. High input impedance eliminates source loading errors.

The Vidar 261, with its wide range of possible center carriers and deviations, is ideally suited for both FM multiplex systems and straight FM recording. Because of its high sensitivity, no preamplifiers are needed. Fast response and quick overload recovery also allow the Vidar 261 to be used in commutated systems.

Brief Specifications

(Charge mode) Full scale sensitivities: 50 to 50,000 pico coulombs. Frequency response: 10 cps to 20 kc.

(Voltage mode) Full scale sensitivity: 5 millivolts to 5 volts. Input impedance: 1000 megohms per volt.

(Common to both modes) Common mode rejection: >170 db at dc, 130 db at 60 cps. Non-Linearity: <0.015%. Drift: <0.1% per week. Overload recovery time: Within 1% after 1 millisecond following 1,000% overload. Size: 7" high x 2¾" wide with up to six individual units in a standard Vidar rack housing. Price $1,100.

For more information drop us a line or circle the number below. We're located at 77 Ortega Avenue, Mountain View, California. Phone: 415-961-1000.

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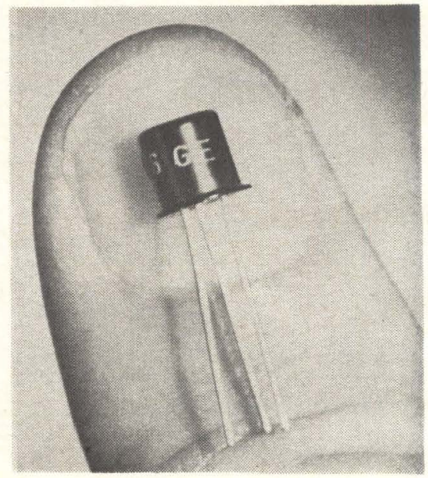
VIDAR

Circle 151 on reader service card

New Semiconductors

stresses, eliminating leakage or moisture penetration. The new diodes are available from stock as individual units or in various assembled configurations. Prices start at $1.71 each in quantities of 100 or more.

Westinghouse Semiconductor Division, Youngwood, Pa. **[333]**

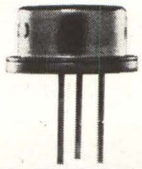


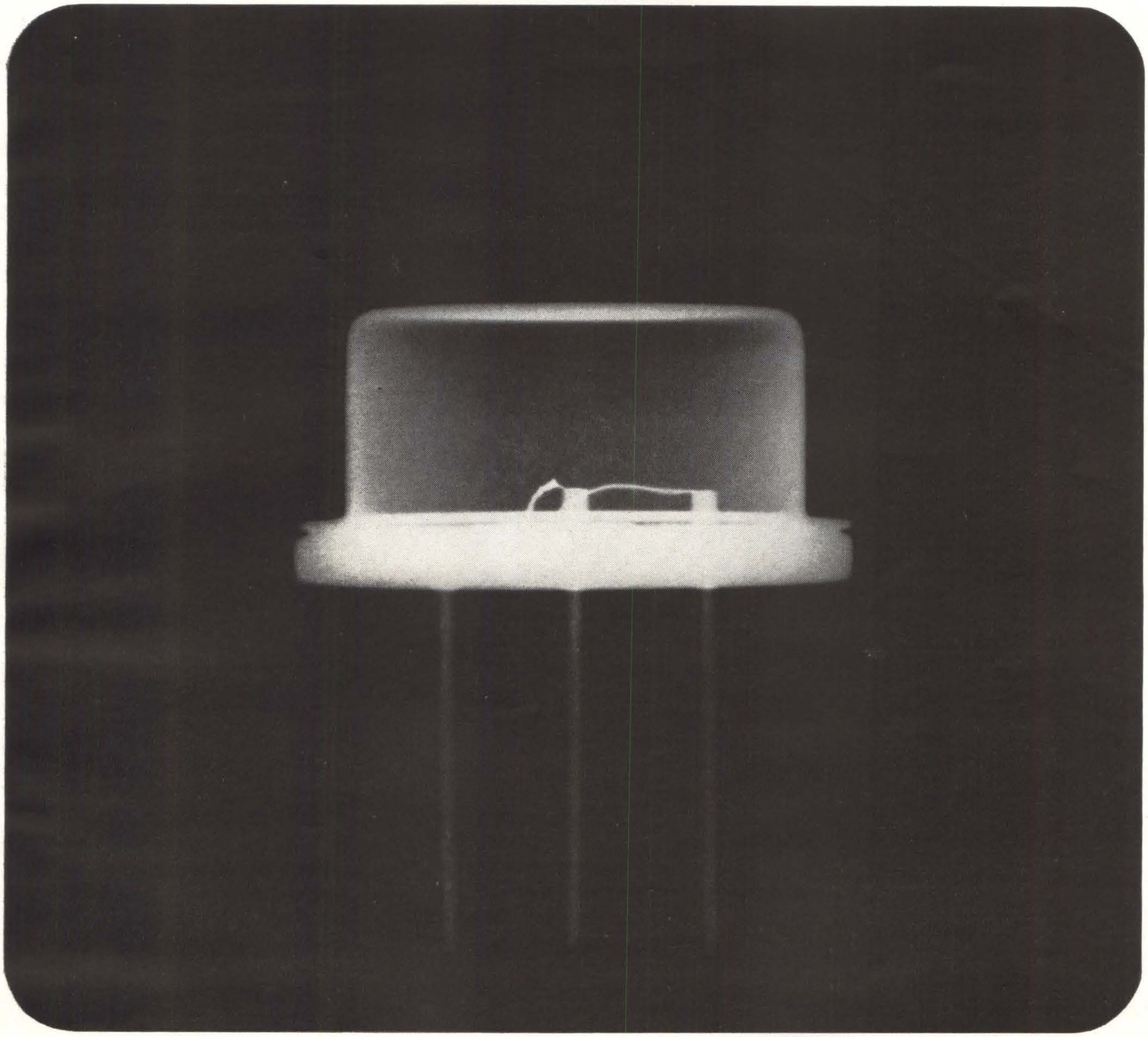
Miniature scr's offer long life

A family of low-current, TO-18-packaged, miniature silicon controlled rectifiers offers proved reliability and long life. The space-saving devices are light in weight and permit improved packing density of active components and simplified circuitry through use of pnpn structure. Applications are primarily military and industrial, including timing circuits, squib switches, ring counters, threshold detectors, relay drivers and shift registers. Peak forward current is 0.5 amp rms. Peak forward voltage ranges up to 200 v. Maximum junction temperature is 150°C. The new scr's feature a low holding current of 3 ma for the 2N877-881 and 5 ma for the 2N885-889. Gate sensitivity is 200 μa max for the former series and 20 μa for the latter series. Prices in lots from 100 to 999 range from $6.70 to $20 for the 2N877-81 and from $7.50 to $24 for the 2N885-89.

General Electric Co., Rectifier Components Department, Auburn, N.Y. **[334]**

Looks good, doesn't it?





...but, look at it <u>this</u> way to be <u>sure</u>!

Appearances *can* be deceiving. Often a tiny defect can escape most methods of detection. That's why so many companies depend on Ansco Industrial X-ray films to make the final check on their components.

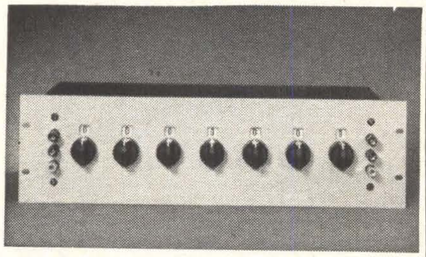
No method of non-destructive inspection shows up tiny imperfections, (especially in tiny components), more clearly or quickly than a radiograph on Ansco Superay® 'H-D' X-ray film.

This Class I film is especially designed for high definition radiography. It has an ultra-fine grain and very high contrast and provides the ultimate in image quality. Although used primarily with low voltage techniques, Superay 'H-D' maintains its high definition characteristics and image quality throughout the full KvP range.

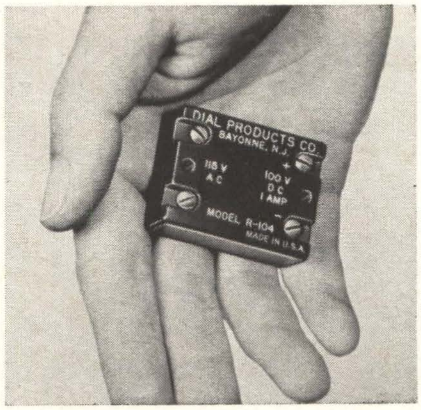
Ask your Ansco X-ray Products Representative how Ansco Industrial X-ray films and chemicals can be of significant value in your inspection procedures. He's always at your service.

gaf ANSCO

X-RAY PRODUCTS OF
GENERAL ANILINE & FILM CORPORATION
140 WEST 51ST STREET NEW YORK 10020



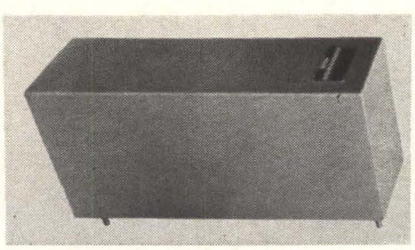
New Subassemblies and Systems



Miniature power supply is hermetically sealed

This power supply, measuring ½ in. by 1⅜ in. by 1¾ in., has built-in reverse-voltage transient protection and line-surge protection. Input voltage for model R-104 is 115 v; output voltage, 100 v; output current, 1000 ma; peak inverse voltage, 1200 v; surge current, one cycle, 45 amps max; operating temperature, −65°C to 125°C. Components of this supply are hermetically sealed against moisture and severe environmental conditions, and the unit is designed to provide reliable service in military and commercial applications. Model R-104 is a reliable source of direct current for clutches, brakes, solenoids, machine tools and motors.

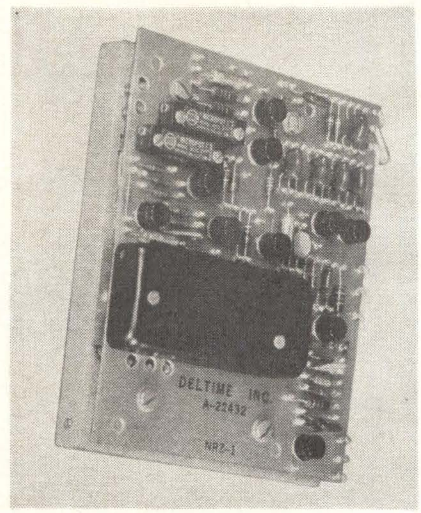
Dial Products Co., 21 Cottage Place, Bayonne, N.J. 07002. **[371]**



Crystal filter designed for carrier systems

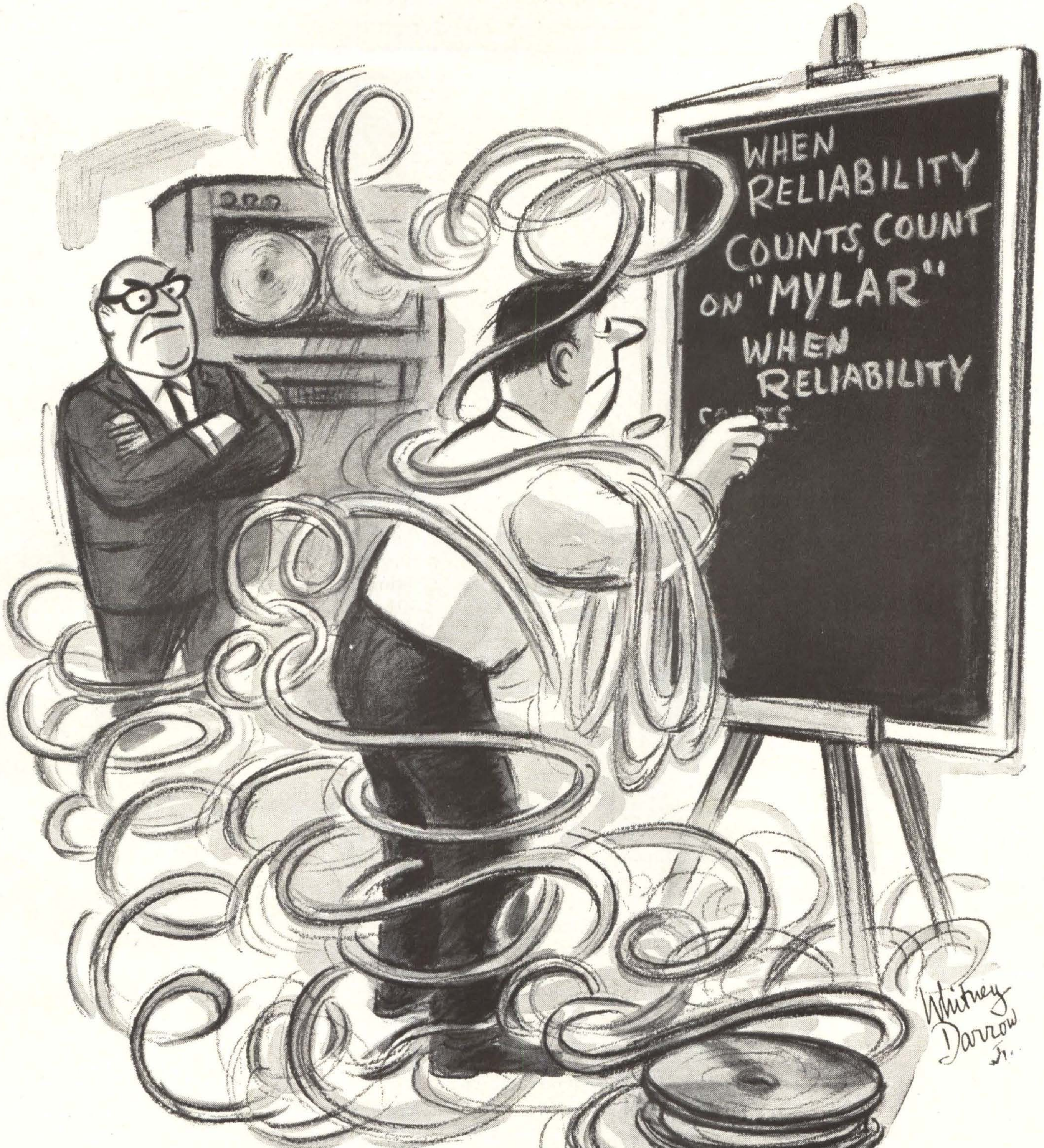
Designed for use in carrier communication systems, model A-24 crystal filter has a high rejection over a narrow bandwidth around 60 kc. Bandwidth at 3-db rejection is 60 cps maximum, 16 cps minimum at 80 db and 6 cps minimum at 100 db. Passband is 12 kc to 59.970 kc and 60.030 kc to 1,010 kc. Peak-to-peak ripple is 3 db maximum. Insertion loss, measured at peak passband response, is 4 db maximum. Both source and load impedance, unbalanced, are 75 ohms. Operating temperature range is from 40° to 100°F. Case size measures 10⅜ by 3⅜ by $4\frac{29}{32}$ in. high.

Systems, Inc., 2400 Diversified Way, Orlando, Fla. **[372]**



Digital circuit module for delay line use

A unity gain non-return-to-zero digital circuit module is available for magnetostrictive delay line application. The nrz-1 circuit module provides storage of up to 10,000 bits of binary information in nrz form, at a 2 Mc/bit rate when combined with a 5,000-μsec delay line and an external logic controlled recirculating loop. Complementary nrz input logic is required. Input and output nrz logic levels are 0 and −9 v. Input rise and fall time requirements are 0.070 μsec and 0.150 μsec respectively. Output rise time is 0.075 μsec and fall time is 0.050 μsec. Complementary nrz output logic is identical to input logic but delayed by delay time of delay line. The nrz-1 is de-



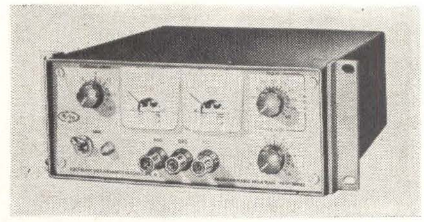
It would be difficult to conceive of anyone but the rawest novice not knowing the advantages of tapes of "Mylar"*. After all, for ten years "Mylar" has been far and away the first choice for EDP work. Good reasons, too. "Mylar" is strong (a tensile strength of 20,000 psi), stable (unaffected by temperature or humidity changes) and durable (can't dry out or become brittle with age.) There's no need to write it 50 times . . . just once: When reliability counts, count on "Mylar". *Du Pont's registered trademark for its polyester film.

DU PONT
REG. U. S. PAT. OFF.
Better Things for Better Living . . . through Chemistry

only DU PONT makes
MYLAR®
POLYESTER FILM

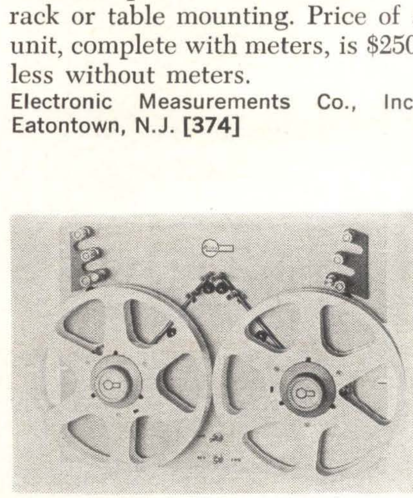
Circle 155 on reader service card

signed for operation from 0°C to +55°C and measures only $5\frac{5}{16}$ in. by 4⅜ in. by ⅞ in. over-all.
Deltime Inc., 608 Fayette Ave., Mamaroneck, N.Y. **[373]**



Power supplies offer programable operation

The new series PRO power supplies feature constant voltage with current control for automatic E/I crossover. Other features include programable remote-sensing, series and parallel operation, front and rear terminals, calibrated controls and main and vernier controls. Voltage ranges are 0 to 20, 0 to 40, 0 to 60 and 0 to 100 with current ranges up to 0 to 4 amps, depending upon model. Regulation is 0.04%. The units measure only 3½ in. high by 9½ in. wide by 12 in. deep. Removable mounting brackets provide for either half-rack or table mounting. Price of a unit, complete with meters, is \$250; less without meters.
Electronic Measurements Co., Inc., Eatontown, N.J. **[374]**



Punched-tape spooler with 10½-in. reels

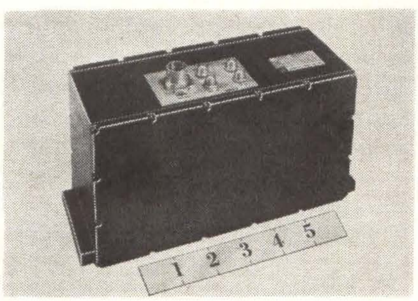
A tape spooler with 10½-in. diameter reels is being introduced. Model RS-502-10½ is offered with reel overhang on a 14-in. high panel and without reel overhang on a 21-in.-high panel. New features that extend the application and operation range include high-speed, bidirectional rewind at 20 in. per sec, self-adjusting electric brakes, no-tape and broken-tape sensing, and electronic noise suppression. The spooler is priced at $1,495 with reel overhang, and at $1,550 without reel overhang.

Rheem Electronics, 5250 W. El Segundo Blvd., Hawthorne, Calif. 90251. **[375]**

Flip-flop module operates at 100 kc

A new cordwood flip-flop circuit module can operate over a wide range of voltages outside of the design center. The all-purpose device, known as CM-12, operates at 100 kc, and may be used as a general-purpose divider flip-flop. Operating temperature range of the unit is —15°C to +65°C, and the storage temperature range is —35° C to +100°C. Dimensions are 1.25 in. by 1 in. by 0.600 in. Price is $4.97 per unit in quantities of 1,000.

Electra Mfg. Co., Independence, Kansas 67301. **[376]**



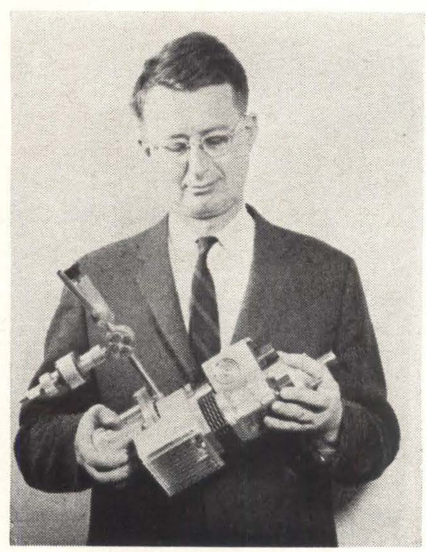
Inertia compensated recorder-reproducer

A new inertia compensated, magnetic tape recorder-reproducer is announced. Model 005 is immune to the forces of acceleration (100 g), vibration and shock, because the tape transport operates in an inert fluid which matches the density of the tape. Data is recorded on a continuous loop of tape and played back after a preset time delay. Typical applications include recording of data during communications blackout for reproduction when communications are restored. Tape speeds are available at 30, 15, 7½, 3¾ and 1⅞ ips. Frequency response is flat from 300 cps to 100 kc at 30 ips. Pcm data may be recorded at 1,200 bits per inch. Wow and flutter are 1% rms maximum. Delay time is 1 to 80 sec at 30 ips. Input power is 28 v d-c at 0.7 amp maximum. Weight is less than 7¾ lb. A solid state switch will allow the model 005 to be commanded to change its record, playback, erase cycle to repeated playback until a new comand to return to the normal cycle is received.

College Hill Industries, Inc., Warwick Industrial Drive, Warwick, R.I. **[377]**

Helium refrigerator cools paramps

A miniature helium refrigerator has been developed to operate in conjunction with the ground-terminal signal receivers for communications satellites. Its function is to cool parametric amplifiers to approximately —390°F, thereby reducing thermal noise within the receiver system and permitting useful reception and amplification of signals which would otherwise be lost. Designed and developed for ruggedness and reliability, the model 502 represents one of a family of units operating between —455°F and —320°F which can, among other cryogenic applications, improve the



signal reception of distant-star-finding radio telescopes as well as communication satellites.
Cryonetics Corp., Burlington, Mass. **[378]**

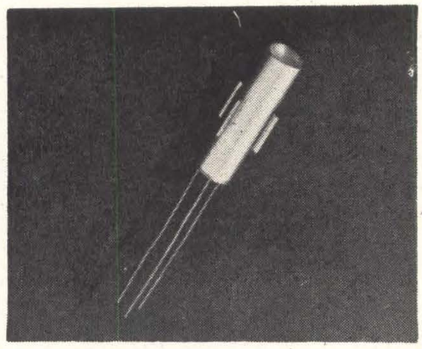
Indicator device for toggle switches

Designated as 13LT1, a new indicator device for toggle switches is intended for use in aircraft and spacecraft consoles, commercial equipment, and requirement calling for positive toggle-switch control and vivid status indication. It can be used with a wide array of 2- and 3-position toggles. Legends can be applied easily. It fits 15/32-in. diameter bushings, can be assembled without tools, and needs no power for color display. The toggle-indicator device provides a clearly visible color legend display that signals the toggle-switch control status. As the toggle lever is pushed to an extreme position, it triggers a flag that indicates actuation has taken place. Throwing the toggle lever to the other extreme position will trigger another flag, at the same time releasing the previously actuated flag. Colored with fluorescent hues, these flags are visible several yards from the panel. This enables the operator to observe the panel from a distance and to recognize the control status of individual stations or a row of stations, even though he may not be able to determine the exact position of the toggle levers.
Micro Switch, Freeport, Ill. **[379]**

Indicator light uses transistors

The Transindicator, a neon indicator light using transistors, offers the operational advantages of a single, hermetically sealed package containing all the necessary circuit components for positive and negative turn-on and turn-off. It is available in various mechanical configurations. These include clip-mounted types for printed-circuit boards, front and rear panel-mount adapter types, and complete standard or special printed-circuit board assemblies. The compact

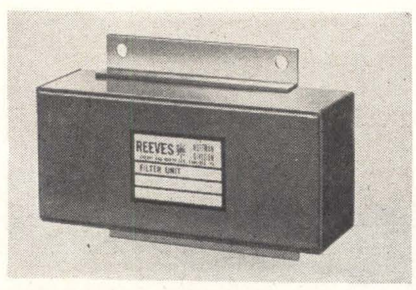
New Subassemblies



Transindicator can be mounted on ⅜-in. centers with maximum height above circuit card of 0.390 in. which is compatible with conventional p-c board spacing.
Transitron Electronic Corp., 168 Albion St., Wakefield, Mass. **[380]**

Crystal filters meet DCA specifications

A set of four crystal filters is designed to meet the Defense Communications Agency specification 175-2A for a 175-kc ssb multiplex communications system. The filters provide a combination of extremely high selectivity, low ripple, and a relatively high 70-db ultimate attenuation. Channel B_2 filter has a center frequency of 1745.405 kc; upper 1.0-db frequency, 1746.745 kc minimum; lower 1.0-db frequency, 1744.065 kc maximum; upper 60-db frequency, 1746.970 kc



maximum; lower 60-db frequency, 1743.680 kc minimum. Channel B_1 filter's center frequency is 1748.355 kc; upper 1.0-db frequency, 1749.-745 kc minimum; lower 1.0-db frequency, 1746.965 kc maximum; lower 60-db frequency, 1746.740 kc minimum; attenuation at 1750.000 kc, 55 db minimum. Channel A_1

filter's center frequency is 1751.645 kc; upper 1.0-db frequency, 1753.-035 kc minimum; lower 1.0-db frequency, 1750.255 kc maximum; upper 60-db frequency, 1753.260 kc maximum; attenuation at 1750.000 kc, 55 db minimum. Channel A_2 filter has a center frequency of 1754.595 kc; upper 1.0-db frequency, 1755.935 kc minimum; lower 1.0-db frequency, 1753.255 kc maximum; upper 60-db frequency, 1756.320 kc maximum; lower 60-db frequency, 1753.030 kc minimum. Ripple is held to ± 0.5 db max on all four filters. Attenuation skirts project to 70 db. This attenuation level is maintained for ± 60 kc from the center frequencies of the individual filters. Insertion loss is 6 db max with reference to average passband response. Each filter is in a hermetically sealed case 2 in. wide, 4½ in. long and 1⅜ in. high, excluding coax connectors.

Reeves-Hoffman Division of Dynamics Corp. of America, Cherry & North Sts., Carlisle, Pa. [381]

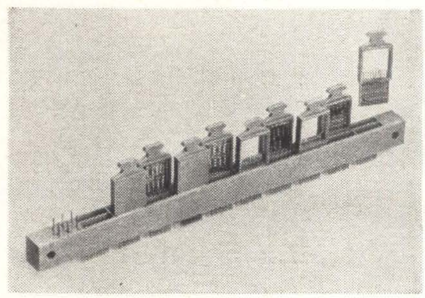
Digital modules for ground systems

A new digital building-block design approach to ground systems incorporates integrated circuits. The manufacturer says the new system design offers increased reliability, high-speed performance, greater noise immunity, and dependable operation over wide environmental extremes, and a significant reduction in system cost and space requirements. Each module of the system measures 1.4 by 0.8 by 1.4 in. and weighs less than one ounce. The modules each contain two or more integrated circuits to perform logic and such complex functions as sequential counting, decade counting, shifting, storing, adding, subtracting, comparing and code converting. The modules also can accommodate cordwood and other special circuit techniques using discrete components, where required. The modules plug into standard 17 by 18-in. panels which are rack-mounted in a cabinet, like pages in a book. Each page can be either hand-wired or automatically wired into the system configuration desired and will accommodate up to 190 logic modules. Use of silicon

New Subassemblies

planar integrated circuits make possible systems with operating frequencies from d-c to 5 Mc over a temperature range of 0°C to 75°C, using only 5 volts d-c. A single rack of logic modules will replace up to six racks which now use standard printed-circuit card techniques, the firm says. The new modular line can be used to design ground support equipment for space communications, data acquisition, data processing, and both military and commercial system checkouts.

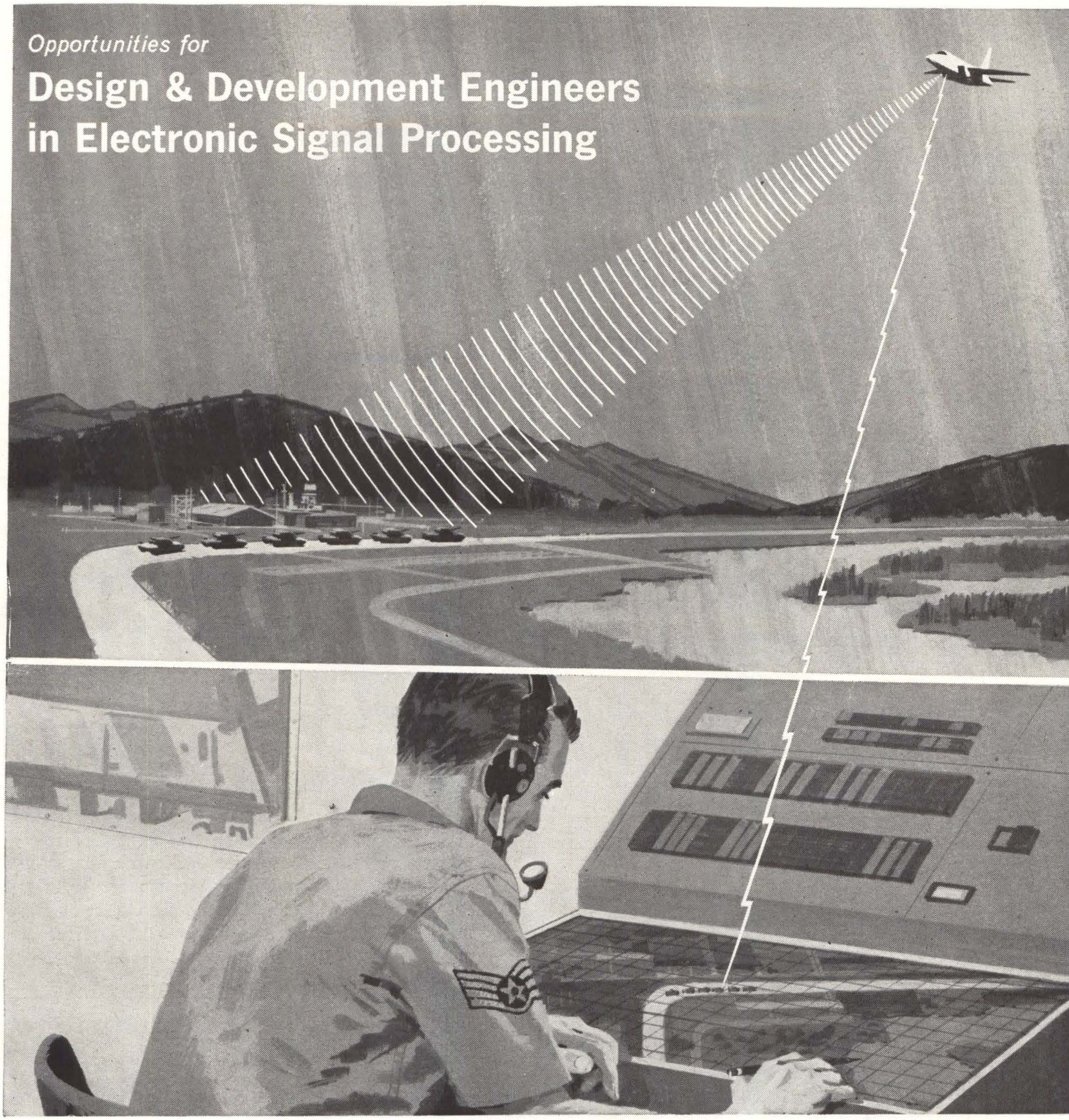
Philco Corp., Western Development Laboratories, 3825 Fabian Way, Palo Alto, Calif. **[382]**



Diode matrix assembly in modular design

This diode matrix assembly is designed for p-c boards, memory frames, and other electrical/electronic applications. A 0.050-in., modular-design connector that accepts diode matrix circuits, axial lead components, flat circuits and substrate-type circuits, the assembly consists of plugs or cells that are plugged into a compartmentalized strip. The strip can be mounted to p-c boards and memory frames, or soldered to wires by means of tines protruding from its bottom. Each module cell that is inserted in the strip contains twenty 0.050-in. cell contacts. Components are assembled in the cell prior to insertion in the strip, and cell modules can be extracted and inserted from the strip by hand to accommodate circuit changes, repairs and maintenance. Strip lengths can be increased or decreased as required.

AMP Inc., Harrisburg, Pa. **[383]**



Design and development activities in the field of Electronic Signal Processing are rapidly expanding today at HUGHES Aerospace Divisions.

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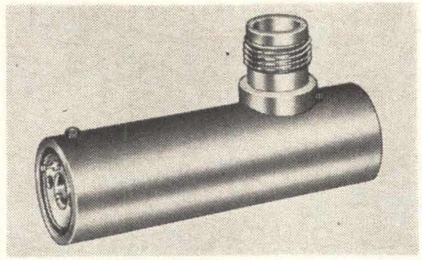
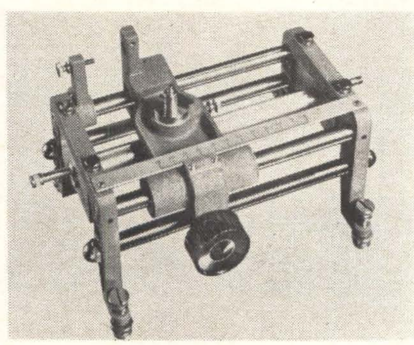


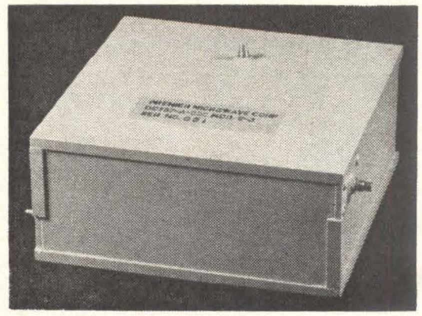
C-band c-w oscillator delivers high power

A C-band c-w oscillator has been developed with a power output of 100 mw minimum and 200 mw center range. Especially designed as a parametric amplifier pump, it can also be used as a local oscillator or a harmonic generator driver to produce X-band and K-band local oscillator sources. Manual tuning range of the type 9186-1019 is 5.4 to 5.9 Gc. Power input requirements are 175 v at 30 ma. Physical dimensions are ⅝ in. diameter by 2⅝ in. long, excluding projections; weight, 1¾ oz.
Trak Microwave Corp., Tampa, Fla. **[391]**



Co-ax slotted line covers a range of 2 to 18Gc

Covering the frequency range of 2 to 18 Gc, the model 20010 coaxial slotted line provides a means for accurate measurement of vswr and phase on miniature microwave components and 0.141-in. coaxial line. The slotted section is a miniature air-dielectric line with integral connectors, one plug and one jack, mounted permanently on the carriages. Probe travel is 10 cm. The probe is a special untuned device using a high-sensitivity diode having a flat frequency response. Price is $960.
Omni Spectra, Inc., 8844 Puritan Ave., Detroit, 48238. **[392]**



Variable attenuators for 350 to 380 Mc

Nanosecond speed, voltage-variable attenuators are designed for use as microwave amplitude modulators. The devices are basically phase and temperature stable. Frequency range is 350 to 380 Mc; insertion loss, 1.2 db max; attenuation, 70 db min.; vswr, 1.2 max; switching speed, 20 nsec; bias voltage, 0 to 20 v; bias current, 0 to 2.10 ma; size, 5 in. by 5 in. by 2¼ in. Units are priced at $1,250.
Premier Microwave Corp., 33 New Broad St., Port Chester, N.Y. **[393]**

Ferrite isolators reduce system size

Ferrite isolators have been designed to plug in stripline sub-systems simply, without the need for coaxial connectors. This feature allows more complete system continuity and offers significant reduction in size and weight for missile and space uses. A typical example

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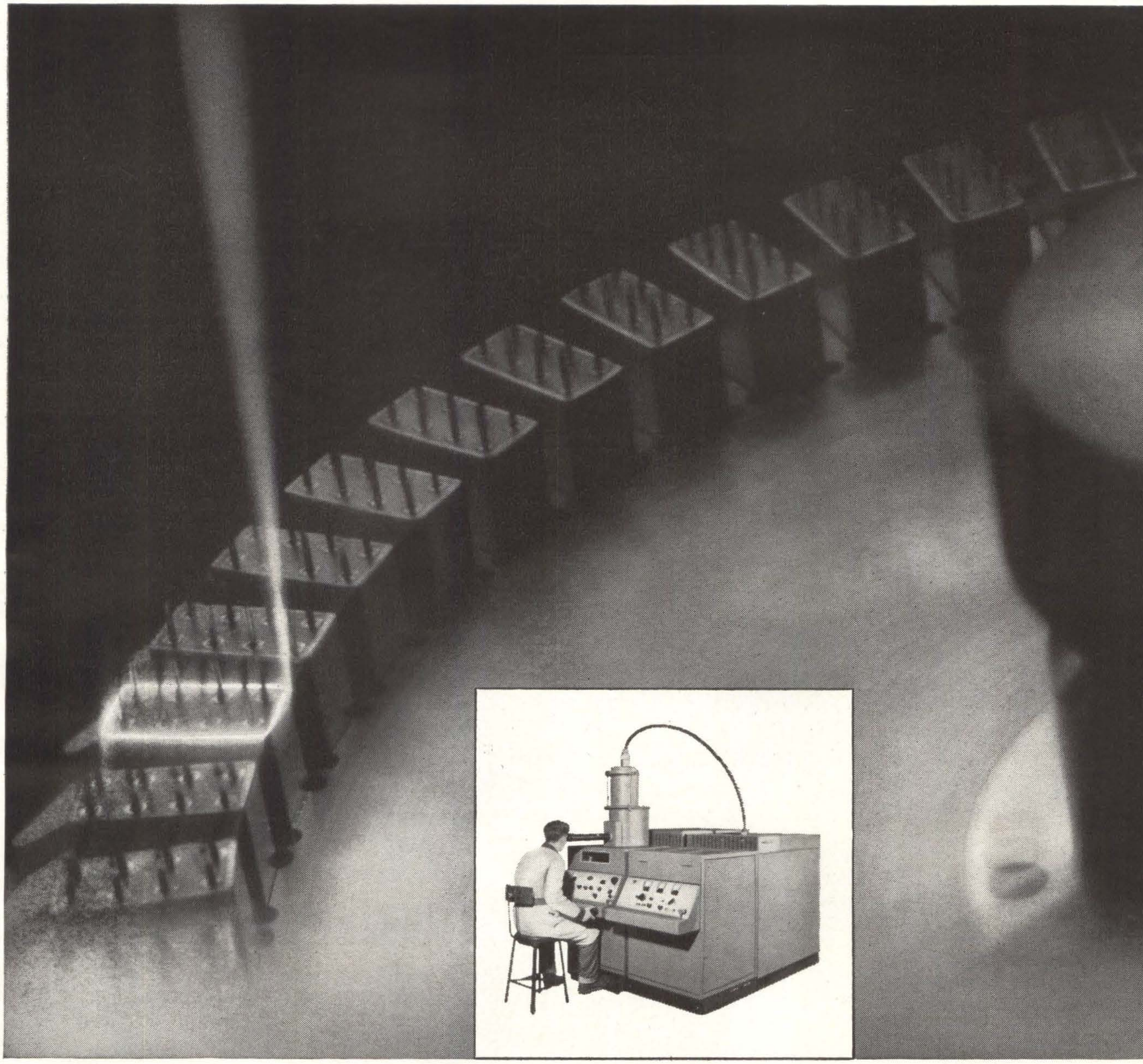


Why three leading relay manufacturers use the Hamilton Standard Electron Beam Welder to seal subminiature relays

The Hamilton Standard Electron Beam Welder can be programmed precisely enough to seal a crystal case type relay in a few seconds, with production rates up to 250 units an hour. It allows engineers to design for lowest weight and highest reliability, because the high energy density of the beam concentrates all the heat in a remarkably small area. Contamination is eliminated because electron beam welding takes place in a vacuum. Physical and electrical properties remain unchanged because electron beam welding involves very low heat input.

Filtors, Inc., General Electric (Waynesboro), and the Leach Relay Division have all found the Hamilton Standard Electron Beam machine an important tool in crystal case relay manufacture. Other companies have discovered its value in many different problems of microelectronic production. To find out how it can help **you,** send for bulletin. Write: Manager, Electron Beam Systems, Hamilton Standard, Windsor Locks, Connecticut.

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION • WINDSOR LOCKS, CONNECTICUT

New Microwave

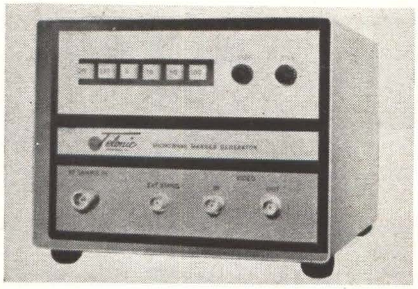
of this device is the model ICS-344 isolator which covers the 2.7 to 3.3 Gc range with the following specifications: isolation, 20 db minimum; insertion loss, 0.5 db maximum; vswr, 1.2 maximum; termination, ½ w integral.
Western Microwave Laboratories, 1045 DiGiulio Ave., Santa Clara, Calif. **[394]**

Triode oscillator is ferrite-tuned

Model ET-504 is a 260% sweep-width ceramic triode oscillator that can be electronically tuned from 500 Mc to 1,300 Mc. The tuning principle is the change in resonant characteristics of a ferrite-loaded cavity. This occurs when the ambient magnetic field is changed. The ET-504 is said to be superior to voltage-tuned magnetrons and backward-wave oscillators in size, stability, fine structure of its output spectrum and flatness of its power characteristic. In addition, it costs less in large quantities, requires only 150 v of plate potential, is rugged and meets demanding military environments. Specifications include: filament voltage, 6.3 to 7.3 v; filament current, 0.400 amp; cathode voltage, —150 v; cathode current, 60 ma max; power output (500 to 1,000 Mc), 75 mw typical; size, 3⅝ by 2 by 2¼ in.; weight, 2.2 lb.
Trak Electronics Co., 59 Danbury Rd, Wilton, Conn. **[395]**

Frequency marker covers 1 to 10 Gc

A highly accurate, solid-state frequency-marker generator can operate over a range of from 1 to 10 Gc. It is designed generally for use with a sweep oscillator or generator and an oscilloscope or X-Y recorder. It provides a precise frequency pip, every 5, 10, 50, or 100 Mc, enabling the operator to chart signal response with a degree of accuracy said to be heretofore attainable only with high-priced frequency counters. The new device



functions by sampling the unknown r-f from the sweep source and mixing this sample with harmonics produced from its own internal crystal oscillators. The mixer output is channeled to a low-noise video amplifier and then combined with the vertical input to the oscilloscope. Accuracy of the new instrument is specified 0.001%, a factor of 100 times better than most frequency meters, according to the manufacturer.

Telonic Engineering Co., 480 Mermaid St., Laguna Beach, Calif. **[396]**

Coaxial isolators occupy minimum space

Two new broadband coaxial isolators are magnetically shielded and have ¾-inch outside diameters. Model L19N is 10 inches long, weighs less than 11.5 oz. and provides a minimum of 15 db isolation, a maximum insertion loss of 1.0 db, and a maximum vswr of 1.20 over the frequency range of 1.0 to 2.0 Gc. Model S21N is 7.7 inches long, weighs less than 9.0 oz. and, over the frequency range of 2.0 to 4.0 Gc, provides a minimum of 15-db isolation, a maximum insertion loss of 1.0 db and a maximum vswr of 1.25.

E & M Laboratories, 7419 Greenbush Ave., North Hollywood, Calif. **[397]**

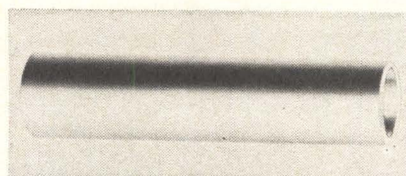
Symmetrical circulator for low-power uses

An X-band, four-port symmetrical circulator, model CL5595, is designed for low-power applications. It operates over a 250-Mc bandwidth in the frequency range 8.95 Gc to 9.45 Gc. Typical isolation and cross-coupling are greater than 20 db. Insertion loss is less than 0.4 db, and the input vswr is better

than 1.13. Weight is 13 oz. and physical dimensions are approximately 2½ by 2½ by 1⅝ in.
Mullard Overseas, Ltd., Torrington Pl., London W.C. 1, England. **[398]**

Coaxial bolometers for high frequencies

A group of high-frequency coaxial bolometers and thermistors, completely interchangeable with standard 1N26 and 1N53 crystals, has been announced. Held to the closest tolerances for precise attenuation and vswr measurements and for all pulse-modulation applications, these units fit all commercial barretter mounts and compatible waveguide detectors. The necessary square-law detection characteristic is provided by a microscopically thin, thoroughly cleaned Wollaston wire element axially located and soldered in place. Response error is less than 1% for power levels of 0.2 mw. Carefully finished coin-silver casings and dielectric bead supports hold loss down over the entire 12.4 to 90.0 Gc range.



Filmohm Corp., 48 W. 25th St., New York, 10010. **[399]**

Traveling-wave tubes have low distortion

Two new traveling-wave tubes feature low a-m/p-m conversion. The N1055 covers 5.8 to 7.2 Gc with a working power output of 10 w. The a-m/p-m conversion is typically 1.5° per db with a noise figure of 26 db. The N1056 covers 3.6 to 4.2 Gc with a working power output of 10 w. The a-m/p-m conversion is typically 1° per db with a noise figure of 25 db. These tubes comply

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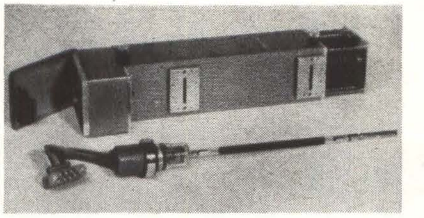
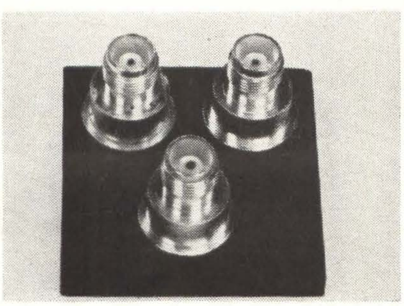


with the requirements of designers of multichannel microwave links, where their low a-m/p-m conversion and noise figure will enable cross-talk and distortion to be kept to a minimum. Both tubes are focused in ppm mounts.
Calvert Electronics, Inc., 220 E. 23rd St., New York, 10010. **[400]**

Power dividers cover 1 to 12 Gc

A series of stripline power dividers covers the 1- to 12-Gc spectrum in four small, lightweight units. They feature phase balance between outputs of $\pm 3°$ max, and output power balance of ± 0.3 db max. Type 06-33-03880 covers the 1 to 2-Gc band, has dimensions of 3 in. by 3 in. by 1.25 in. and weighs only 10 oz. The other units, which are even smaller and lighter, are 06-33-03890 (2-4 Gc); 06-33-03900 (4-8 Gc); and 06-33-03910 (8-12 Gc).



Standard TNC or other connectors can be provided in the configuration shown, or in line. The power dividers are priced at $90 each in small quantities.
Electronic Specialty Co., 5121 San Fernando Road, Los Angeles, Calif. **[401]**

Fixed-tuned r-f probe spans 400 Mc to 18 Gc

This fixed-tuned r-f probe, model 228, covers frequencies from 400 Mc to 18 Gc and features a replace-

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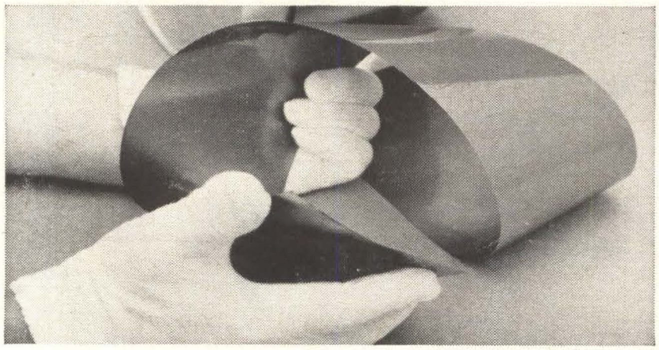

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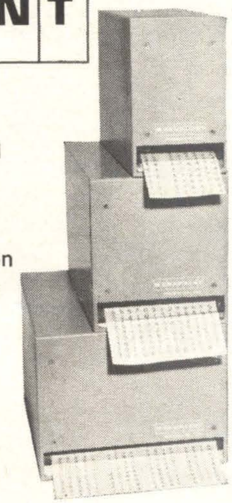

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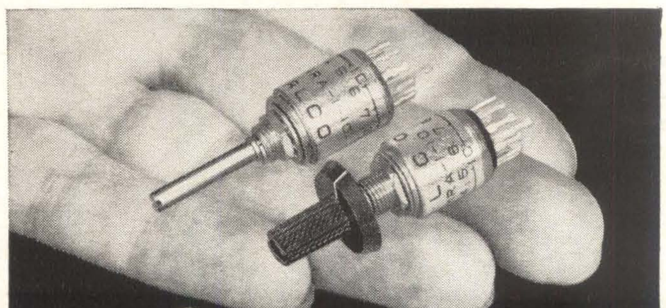

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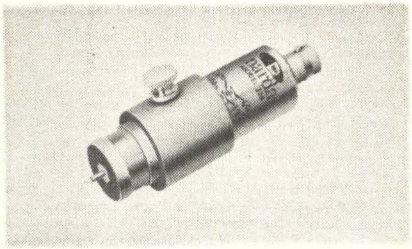
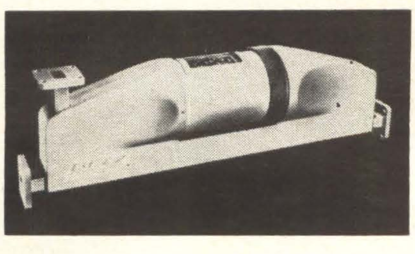


able crystal detector plus an optional bolometer. The probe is designed to operate with a standard ¾-in.-diameter slotted-line carriage. Its depth is adjustable to approximately ¼ in. and the setting can then be locked. Accurate scale readouts are permanently marked on the probe body to facilitate resettings. The fine wire probe tip is covered with a plastic shield to reduce the possibility of tip bends. The crystal detector element can be replaced by removing a BNC connector and then sliding out the crystal unit. Price of the model 228 with crystal model 822 is $55. The model N607 bolometer costs $20.

Narda Microwave Corp., Plainview, N.Y. [402]

Variable couplers use direct-reading dial

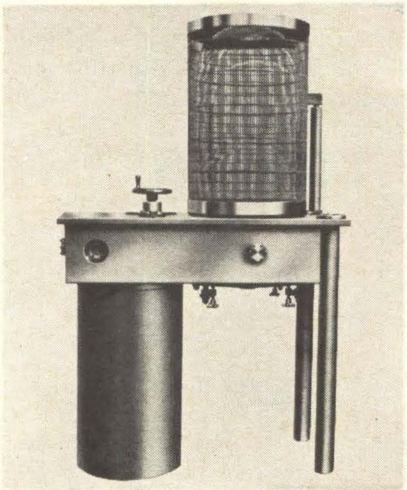
Eliminating the need for a large assortment of fixed value couplers, these Vari-Couplers facilitate system prototype and laboratory testing. Utilizing a direct-reading dial calibrated in db, selection of coupling from 5 to 50 db (model 501)



or 10 to 60 db (model 601) can be obtained quickly and accurately without removing the unit from waveguide lines. Unit price is $275.

Belz Industries, a division of El-Tronics, Inc., 140 Terminal Drive, Plainview, N.Y. [403]

New Production Equipment



Vacuum system offers rapid cycle

A versatile, rapid-cycling VacIon pumped system for coating or evaporation in research, engineering, and production has been introduced. The VI-3 pumps to 10^{-6} torr in 30 minutes, and the fastest of the optional versions reaches this pressure in 10 minutes. Base pressure is below 10^{-7} torr. The system meets the need for low-cost, clean vacuum, providing an alternative for those who, up to now, have had to consider diffusion-pumped systems for economic reasons. The heart of the functional design is the high-vacuum pumping system. A fully-enclosed 380 liter-per-sec Vac-Ion pump is said to provide the highest possible pumping speeds in the higher pressure region for faster cycling. Direct attachment of the pump to the baseplate chamber and the special valve minimizes conductance losses. Also included in the system is a high-speed titanium sublimation pump. An optional cryopump adds even more speed for condensable gases. Flexibility and a variety of feedthrough arrangements are provided by the rectangular baseplate chamber. Horizontal and vertical feedthrough ports include four on the sides and five directly below the bell jar. More can be added for special requirements.

Varian Associates, Vacuum Products Division, 611 Hansen Way, Palo Alto, Calif. **[421]**

Hand tool tightens cable ties and straps

A new pistol-type hand tool automatically tightens self-holding Ty-Rap cable ties and straps to the desired tension and in one simple motion cuts off the excess, flush with the tie. Tension of the Ty-Rap is easily adjustable on the tool. The tool, WT-199, accommodates three sizes of Ty-Raps which cover a wire bundle range from 0 to 4-in. diameter.

The Thomas & Betts Co., Elizabeth, N.J. **[422]**

New Materials

Room-temperature casting systems

A new series of room-temperature polyurethane casting systems is designed to improve the protection of electronic components and circuits. Using Polycin-U liquid isocyanate-terminated prepolymers and Polycin curing polyols (hardeners), the systems are suitable for potting, filling, embedding and encapsulating electronic parts. They offer low water absorption and shrinkage; good electrical properties; excellent abrasion, thermal shock and impact resistance; good heat and electrical stability and usefulness over a wide temperature range. The two-component, 100%-solids systems are said to have dielectric properties equal to or better than epoxy and styrene polyester casting compounds. They are readily used in transformers, power supplies, packaged modules, amplifiers, and computer circuiting, as well as for thin-film protective coatings on circuit boards and components.

The Baker Castor Oil Co., Bayonne, N.J. **[411]**

High-permeability magnetic alloy

Hipernik, a soft magnetic alloy of 50% nickel and 50% iron, exhibits an initial permeability of 10,000 to 15,000 and a maximum permeability of 100,000 to 200,000 with low hysteresis loss throughout the range of operating flux densities. The alloy's magnetic and mechanical properties make it ideal for applications in electronic transformers and inductors where high permeability and low core loss are required to meet performance and size specifications. Specific applications include electronic power transformers, isolation and impedance-matching transformers, servo devices, a-c and torque motors, solenoid cores of sensitive relays, and magnetic shielding. The material is available from stock in cold-rolled strip form in thicknesses from 0.006 to 0.110 in. and in widths from ¼ to 15 in. In the cold-rolled form, it is readily punched for laminations or can be slit into tape.

Westinghouse Materials Mfg. Division, Blairsville, Pa. **[412]**

Combination laminates for p-c boards

A line of combination laminated materials for printed-circuit boards is said to allow use of parallel gap welding techniques to fasten components to the boards. The materials combine a glass-fabric epoxy laminate with a cladding of nickel alloy, such as Kovar or Nichrome. Since leads on micromodules are made from the same alloy, parallel gap welding can be used to fasten components to the circuits. The combination material is being offered in a variety of thicknesses of base laminates and cladding. Sheets can be clad on one or both sides.

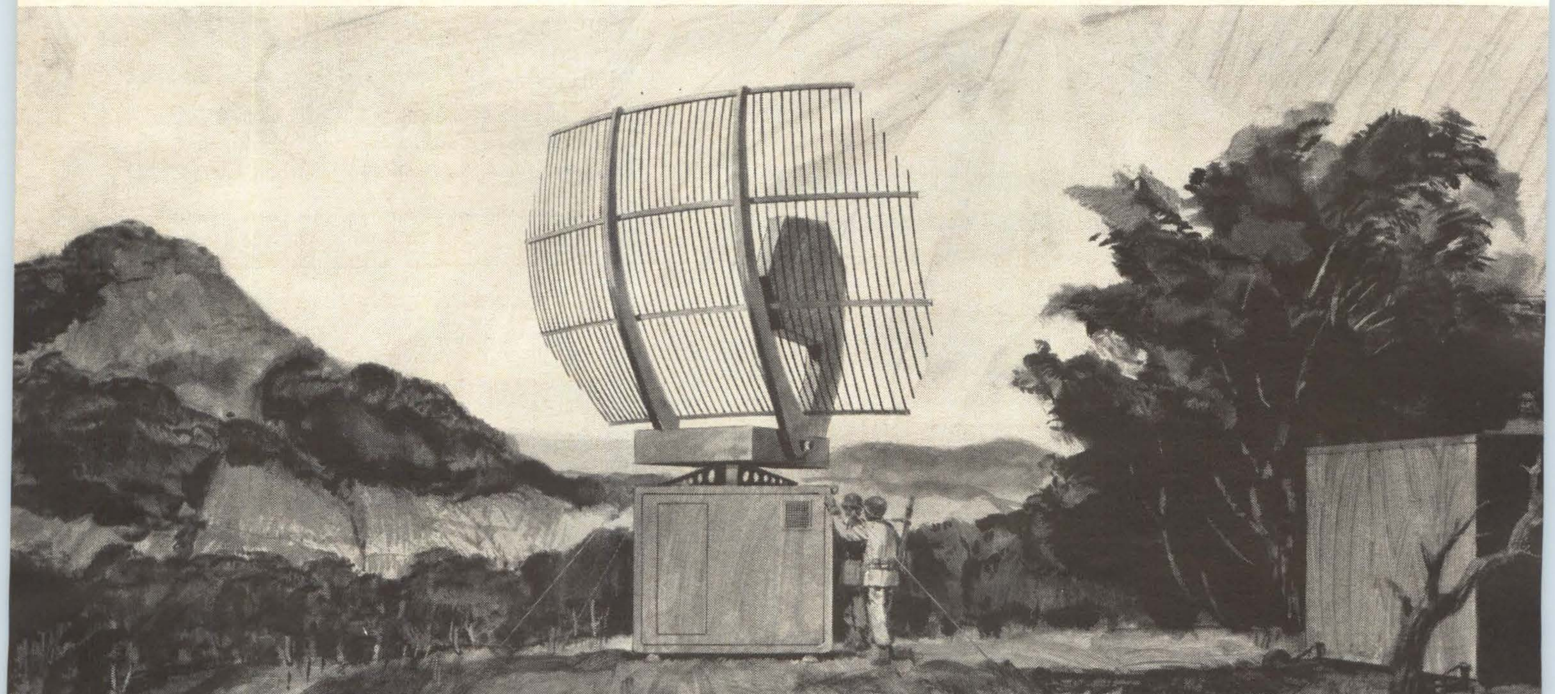
Synthane Corp., Oakes, Pa. **[413]**

Photo resist for semiconductors

Formulated to meet the requirements of semiconductor and microelectronic manufacturing, the AZ-1350 photo resist features resolution, edge acuity, multiple exposure capability, clean developing, and clean removal. The necessity for applying extremely thin coatings is eliminated because of superior resolution. Even with coatings as thick as 0.000070 in., which is 3 to 20 times thicker than conventional applications on semiconductor wafers, the AZ-1350 will reproduce lines and spacings smaller than ½ micron. AZ-1350 coatings have excellent adhesion to substrates. Edge acuity of the highest degree is said to be possible because the developer solution does not soften the unexposed image. Removal of the coatings is quick and complete by simple immersion in the aqueous AZ remover solution.

Shipley Co., Walnut Park, Wellesley 81, Mass. **[414]**

Weight is the only thing missing...



from this new Westinghouse tactical radar system

Westinghouse has designed a tactical radar system so light it rides into combat in a single helicopter load, so simple it sets up in 30 minutes or less. Yet this lightweight unit has all of the sensing, coverage, range, height accuracy and performance of present systems weighing many times more.

Design of this new breed of radar draws on Westinghouse experience in developing the first successful, fully transportable, long range tactical radar and the first successful 3-D tactical radar.

Pioneering in micro-miniaturization (thin film and molecular circuitry), Westinghouse radar experts have applied these advanced techniques to today's proven systems, as well as to future designs.

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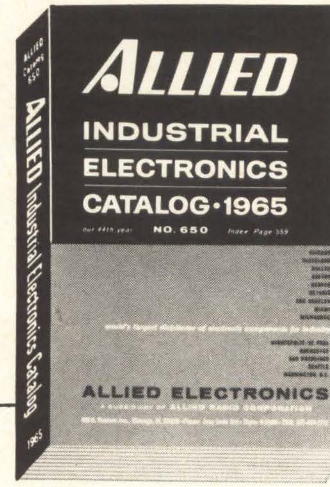

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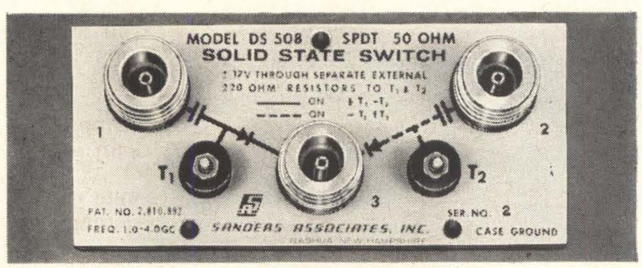

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New Literature

Clean rooms. Angelica Uniform Co., 700 Rosedale Ave., St. Louis, Mo. 63112. A new glossary, covering 74 definitions, deals with the terminology of environmentally controlled areas, the equipment used in clean rooms, and gives special emphasis to the fabrics and uniforms for personnel. Circle **451** on reader service card

D-c power modules. Electronic Research Associates, Inc., 67 Factory Place, Cedar Grove, N.J., offers a technical bulletin describing a line of d-c power modules for military and other rugged applications. **[452]**

Coaxial connectors. Microdot Inc., 220 Pasadena Ave., S. Pasadena, Calif. High-quality miniature coaxial connectors in all-crimp form are described in a two-page bulletin. **[453]**

Magnetic amplifiers. Airpax Electronics Inc., Fort Lauderdale, Fla. Bulletin 8E-1 describes PRS3, PRS4, and PRS5 d-c magnetic amplifiers used in control circuits and systems, instrumentation and measurement. **[454]**

Measuring instruments. Waveforms, Inc., 333 Sixth Ave., New York City, 10014. Characteristics of the company's oscillators, voltmeters, and transmission measuring sets are summarized on a single sheet. **[455]**

Motor tach generators. Avionic Division/John Oster Mfg. Co., One Main St., Racine, Wis. A designer's hand book describes a wide range of available motor tach generators and some of the many possible variations and gearheads. **[456]**

High-reliability semiconductors. Motorola Semiconductor Products, Inc., 5005 E. McDowell Rd., Phoenix, 8, Ariz., offers a brochure discussing the details of its Meg-A-Life II Assurance Program for high-reliability semiconductor devices. **[457]**

Weldable contacts. ITT Cannon Electric Inc., 3208 Humboldt St., Los Angeles, has available a brochure describing Weldcon weldable contacts. **[458]**

Transistor curve tracer. Aero Geo Astro Corp., 13624 Magnolia Ave., Corona, Calif., announces a specification sheet on the TVT-1 transistor curve tracer which is built as a plug-in unit for use with Tektronix and Hickok oscilloscopes. **[459]**

Filter-crystal test set. Systems Inc., 2400 Diversified Way, Orlando, Fla. A six-page technical bulletin describes a filter-crystal test set designed to measure parameters of high Q devices over a range of 750 kc to 50 Mc. **[460]**

Housings and accessories. Premier Metal Products Co., Inc., 337 Manida St., Bronx, N.Y. 10474, has issued a 64-page catalog No. 640 dealing with metal housings and accessories for the electronics industry. **[461]**

Silicon modules. Packard Bell Computer, 2700 South Fairview St., Santa Ana, Calif. Catalog SP-147B on silicon digital modules is now available. **[462]**

Synthesizers. Rhode & Schwarz, 111 Lexington Ave., Passaic, N. J. A 4-page catalog sheet provides complete technical data, block diagrams, applications, and operational theory for types 262 and 263 synthesizers. **[463]**

Digital voltmeters. Electronic Associates, Inc., West Long Branch, N.J. An 8-page illustrated brochure covers the series 6000/6001 all-solid-state digital voltmeters which operate at speeds of one conversion per millisecond. **[464]**

Steerable tracking antenna. Electronic Specialty Co., 4561 Colorado Blvd., Los Angeles, Calif., 90039. A 4-page, illustrated brochure describing a high-velocity, steerable telemetry antenna system for missile tracking is announced. **[465]**

Microwave system noise performance. Lenkurt Electric, San Carlos, Calif. Volume 13, No. 6 of the Demodulator contains the second part of a two-part article entitled "Noise Performance in Industrial Microwave Systems." **[466]**

Gold bonding wires. Sigmund Cohn Corp., 121 So. Columbus Ave., Mount Vernon, N. Y., has available a bulletin dealing primarily with the use of gold bonding wires in the manufacture of transistors and diodes. **[467]**

Accelerometers. Gulton Industries, 212 Durham Ave., Metuchen, N. J. Fact sheet ASI-101 covers a new line of Glennite subminiature, high-frequency accelerometers. **[468]**

Resistor test network kit. Corning Glass Works, Electronic Products Division, Raleigh, N. C. A kit of microcircuits designed for evaluation testing is described in bulletin CE-11.01. **[469]**

Heat dissipators. International Electronic Research Corp., 135 West Magnolia Blvd., Burbank, Calif, offers a test report on new low-priced, "staggered finger" heat dissipators for high-power semiconductors. **[470]**

Precision film resistors. EMC Technology, Inc., 1133 Arch St., Philadelphia, Pa., 19107. A 16-page booklet describes newly developed precision film resistors that exhibit bulk properties. **[471]**

Controlled power products. Sorensen, a unit of Raytheon Co., Richards Ave., South Norwalk, Conn., offers a 140-page controlled power catalog and handbook. **[472]**

Silicon diodes. Computer Diode Corp., 250 Garibaldi Ave., Lodi, N.J., has published a catalog on a complete line of silicon semiconductor diodes. **[473]**

Continued on page 179

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Epoxy tubing. Resdel Corp., P. O. Box 217, Rio Grande, N. J. A four-page bulletin describes the company's epoxy tubing for potting, encapsulation, insulation, and other uses. **[475]**

YIG filters. Microwave Physics Corp., 420 Kirby St., Garland, Texas 75040, has released a bulletin on its full line of octave bandwidth, electronically tuned YIG filters. **[476]**

Semiconductors. General Electric Co., Syracuse, N.Y. Applications and characteristic ratings for a line of more than 1,400 semiconductors are given in a new 40-page catalog. **[477]**

Telemetry ground system. Beckman Instruments, Inc., Systems Division, 2400 Harbor Blvd., Fullerton, Calif., has issued an 8-page brochure on the model 4400 pam/pdm telemetry ground system. **[478]**

Power amplifier. Leach Corp., 1123 Wilshire Blvd., Los Angeles 17, Calif. Bulletin TA-10664 contains technical data on the model TA-1000 solid-state, 10-watt r-f power amplifier. **[479]**

Accelerometer-amplifiers. Gulton Industries, Inc., 212 Durham Ave., Metuchen, N.J. A new series of subminiature, composite accelerometer-amplifiers are described in bulletin ASI-107. **[480]**

Rotating components. Avionic Division, John Oster Mfg. Co., One Main St., Racine, Wis. A designer's handbook describes a wide range of available synchros and some of the many possible unit variations. **[481]**

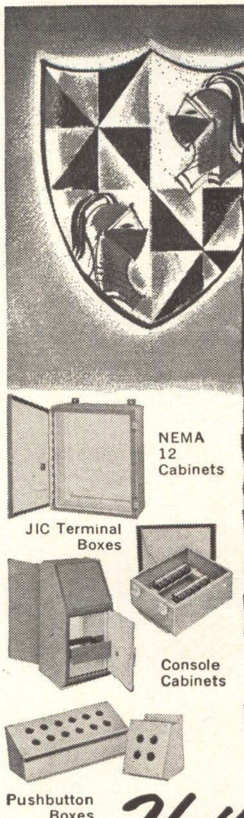
Resistor catalog. Dale Electronics, Inc., P.O. Box 488, Columbus, Neb. Catalog A is a 32-page book listing complete specifications for a full line of wirewound and film resistors. **[482]**

Ferrite memory cores. RCA Electronic Components and Devices, 64 "A" St., Needham Heights 94, Mass. A quick-reference guide summarizes pertinent data for the company's most widely used ferrite memory cores. **[483]**

Silicon transistors. Westinghouse Semiconductor Division, Youngwood, Pa. High quality npn silicon power transistors at germanium transistor prices are described in bulletin B-7960. **[484]**

Circuit board materials. Panelyte Industrial Division of Thiokol Chemical Corp., N. Enterprise Ave., Trenton, N. J., 08604, has published a brochure on epoxy-glass, copper-clad, multi-layer circuit board materials. **[485]**

Power signal sources. Sierra Electronic Division of Philco, 3885 Bohannon Drive, Menlo Park, Calif. A bulletin describes two all-solid-state signal sources that offer a choice of 190-600 Mc and 470-1,000 Mc coverages in power outputs beginning at 50 mw. **[486]**



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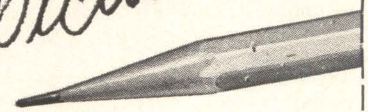

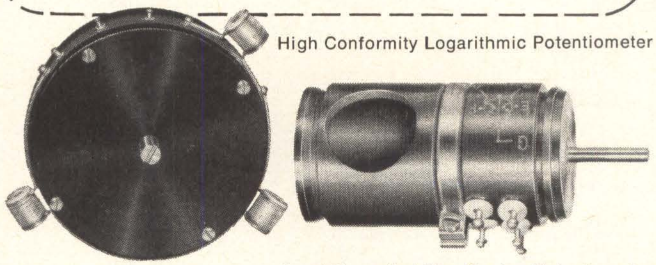

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New Books

Useful tables

Elphyma Tables. Compiled by
Erik Ingelstam and Stig Sjoberg.
John Wiley & Sons, Inc.,
New York, 1964, 100 pp., $3.50

Translated and imported from Sweden, this small volume packs an amazing amount of useful reference information, including logarithms, roots and powers, mathematical formulas, basic information from mechanics, physics, optics, radio and electricity and circuit nomograms.

The information is ingeniously arranged and appears to be much easier to locate quickly than in other reference books. One of the chief merits of the book is its compactness, in contrast to the bulky reference volumes usually found on engineers' shelves.

The information contained is entirely up-to-date; for instance, the omega-minus hyperon particle, discovered in February, 1964, is included in the table of subatomic particles. The authors were obviously conscious of the various systems of measurement in use throughout the world, so that English cgs, mks and metric figures are found with almost equal ease.

George V. Novotny
Advanced Technology Editor

Space electronics

Ion Propulsion for Space Flight.
Ernst Stuhlinger.
McGraw-Hill, Inc., New York, 1964
373 pp., $17.50.

Dr. Stuhlinger's book meets the reader's expectations of a work by one of the foremost authorities in the new field of electric propulsion. Its coverage of the subject is thorough without being excessively wordy; with historical background, proceeds through the analytics of operation and concludes with future applications.

The text strikes a balance between mathematical development and descriptive material. Certainly it fills a need in the available literature. For the engineer involved in this field, it will serve as a ready reference; for the person entering this field, the book provides the breadth necessary for an understanding of ion propulsion and its applications; and for one having a passing interest, selective readings give a basic appreciation of the subject.

Of particular interest to engineers in general should be the sections discussing the systems aspects of ion propulsions and describing exemplary space missions for ion engine systems. In the systems discussion, Stuhlinger does indeed point up the areas needing further development; in the description of space missions he presents a clear picture of the future roles of this new technology.

It is a credit to the author's objectivity that he makes no attempt to promote or advocate the actual use of ion propulsion space flights, which would involve vast effort and expenditure. One statement, in the closing chapters, stands out: "No attempt has been made here to offer reasons for the desirability of space missions. It is assumed that flight into space is desirable, and that it should be undertaken as soon as the necessary technology is available."

Besides ion propulsion, the type of electric propulsion described most fully is photon propulsion. This is unusual, because plasma-type propulsion has been more widely publicized.

The use of numerical examples throughout the text is valuable in giving a practical appreciation of the subject. The presentation on the flight mechanics of ion-propulsion spacecraft covers the engineering formulations of the more important cases with a sufficient amount of analytical treatment. Solutions are given to a wide variety of pertinent problems that concern the propulsion specialist.

The author's style is extremely readable. However, the reader must be prepared to participate in order to follow the analytical developments presented. Each section contains a rather complete bibliography; however, many of the referenced papers are not readily available in the open literature.

Lawrence E. Golden
and T. Todd Reboul
Radio Corp. of America

Technical Abstracts

Adaptive memories

A magnetic variable-gain components for large adaptive networks.*
J.B. Angell and R.C. Woodbury,
Solid State Electronics Laboratory,
Stanford University, Stanford, Calif.

Large-capacity, trainable systems require large numbers of adaptive (variable-gain-with-memory) elements. The total cost of such elements is exorbitant unless an economical, integrated-device technique can be used. In addition, the cost of switching circuitry is high if the adaptive elements must be switched individually for the training and readout cycles. This paper describes a new device that holds promise of easing these difficulties.

One method of alleviating the problem of individual component switching, previously devised by H. S. Crafts, depends on a switching-field threshold in the device. Crafts found this characteristic exhibited by his two-core magnetic adaptive component, which was developed several years ago. The square-loop cores are driven with a sinusoidal current that results in a second-harmonic output proportional to the remanent state.

Adaption or change of the remanent state will not occur unless the sinusoidal driving field is present in addition to an appropriately chosen d-c field. This adaption constitutes the threshold characteristic, and it enabled Mr. Crafts to devise a coincident selection scheme that would eliminate much of the switching circuitry.

Certain ferromagnetic-tape cores, sinusoidally driven in the longitudinal direction, possess a second harmonic in the flux response by virtue of certain nonlinear properties of residual domains. A more direct way of producing a second harmonic proportional to remanence is to apply the a-c field at right angles to the magnetization and sense directions. One method of accomplishing this is to pass alternating current along the magnetic material itself. This technique is employed by the device described.

The experimental structure consists of a two-tape sandwich that has been sectioned into separate components with spot-welded seams and squares at equal intervals along the running direction of the tape. Only one conductor passes through each section, and it serves to carry both the sense and adaption signals. This same conductor passes through all other tapes if an array is used. As stated above, the a-c drive signal flows along the tape itself. It is believed that this structure can be integrated in such a way as to bring about a large reduction in cost per component.

Photoelectric array

A microelectronic reading aid for the blind.* J.G. Linvill,
Solid State Electronics Laboratory,
Stanford University, Stanford, Calif.

A blind person can, with his fingertips, "read" a dynamically embossed version of printed material viewed by a photoelectric device coupled to an electromechanical device.

The photoelectric part includes a rectangular array of photoconductors on which the image of a part of a page is focused. The electromechanical part consists of an array of piezoelectric reeds having a one-to-one correspondence to the photoconductors.

The reeds corresponding to the dark cells vibrate in flexure; those corresponding to the lighted cells do not. The tips of vibrating reeds are sensed by the reader's finger. Thus he obtains a dynamically embossed version of the printed material.

A primitive version of the device was constructed, using a 7/8-by-1 1/8-inch array of photoconductors connected to an array of piezoelectric reeds. This version provided an embossed form of characters presented to it.

Subsequently, a more precise piezoelectric-reed array of 96 elements was made and connected to a computer that Dr. James Bliss and his colleagues at the Stanford Research Institute (SRI) can use to simulate the printed material and photoelectric sensing part of the reader. A blind subject has read the embossed output of Roman capital letters at more than 25 words a minute.

Gambling Adaline

Bootstrap learning.* B. Widrow,
Solid State Electronics Laboratory,
Stanford University, Stanford, Calif.

Adaptive logic elements (Adalines) are usually trained to respond to pattern inputs by supplying both input patterns and the associated desired binary response (decisions). This procedure involves learning with a teacher.

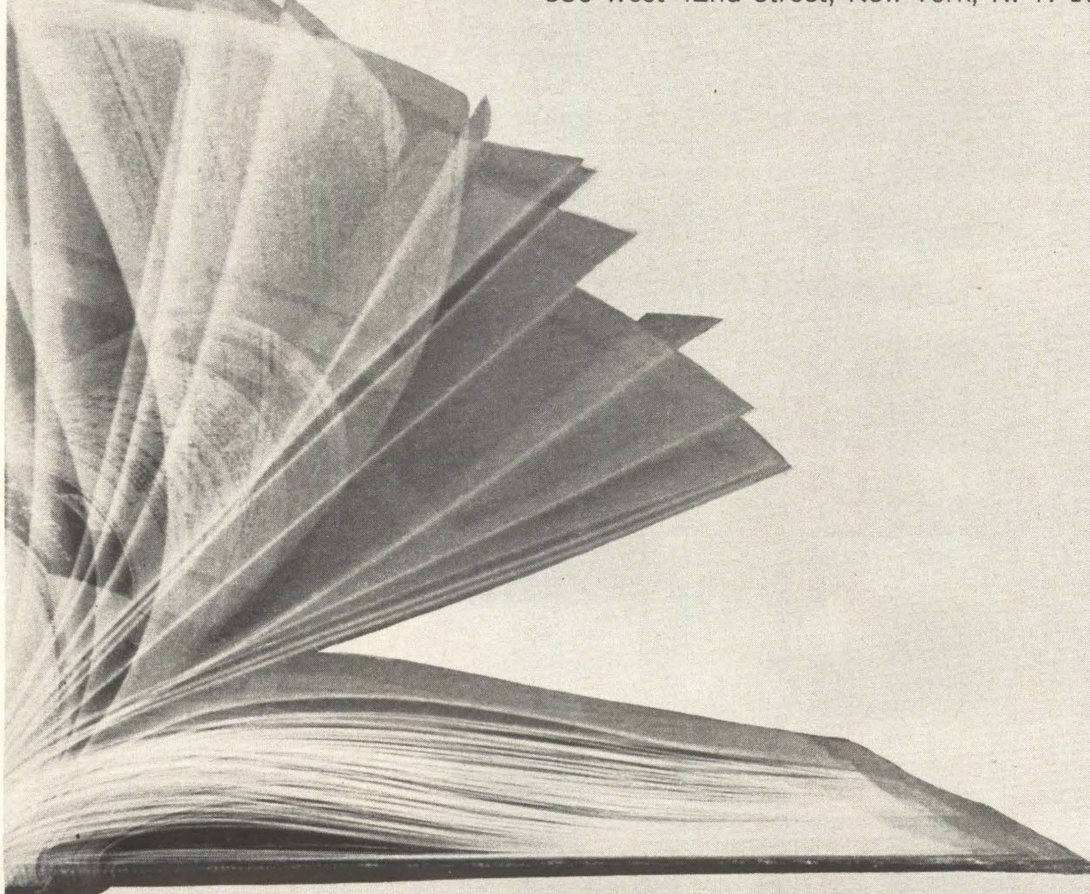
Often the desired responses to specific input patterns are not supplied, but the quality of performance based on a series or combination of decisions is known. If response quality is better than average, adaption can be effected by assuming that actual responses are the true desired responses. On the other hand, if performance quality is low, the active process will take the desired responses to be opposite to the actual responses. This is learning with a critic. Deriving the desired responses from the actual responses will be called "bootstrap adaption."

These principles have been applied to the game of blackjack, or 21. A single Adaline can learn to play with close to optimal strategy after several hundred games, without being told how to play or what the object of play is. When the Adaline player wins, it is adapted assuming that the decisions made were optimal. When the Adaline loses, the responses are assumed to have been the worst possible. The pattern and responses from the previous game are stored for adaption purposes pending the outcome of the game.

Bootstrap adaption requires the critic or performance evaluator to have much less knowledge than that required of the teacher during the more conventional training processes. Adaptation is not always effected in the correct direction.

Bootstrap adaption may be applicable to a variety of situations.

*Presented at the Stanford Electronics Laboratories annual Contractor's Meeting, August 18, 19, Stanford, Calif.



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TO EMPLOYEES

Letters written offering Employment or applying for same are written with the hope of satisfying a current need. An answer, regardless of whether it is favorable or not, is usually expected.

MR. EMPLOYER, won't you remove the mystery about the status of an employee's application by acknowledging all applicants and not just the promising candidates.

MR. EMPLOYEE you, too, can help by acknowledging applications and job offers. This would encourage more companies to answer position wanted ads in this section. We make this suggestion in a spirit of helpful cooperation between employers and employees.

This section will be the more useful to all as a result of this consideration.

Classified Advertising Division
McGRAW-HILL, Inc.
330 West 42nd St., New York, N. Y. 10036

Electronics advertisers

September 7, 1964

Classified advertising

F.J. Eberle, Business Mgr.
[212]-971-2557

Classified advertisers index

■ For more information on complete product line see advertisement in the latest Electronics Buyers' Guide

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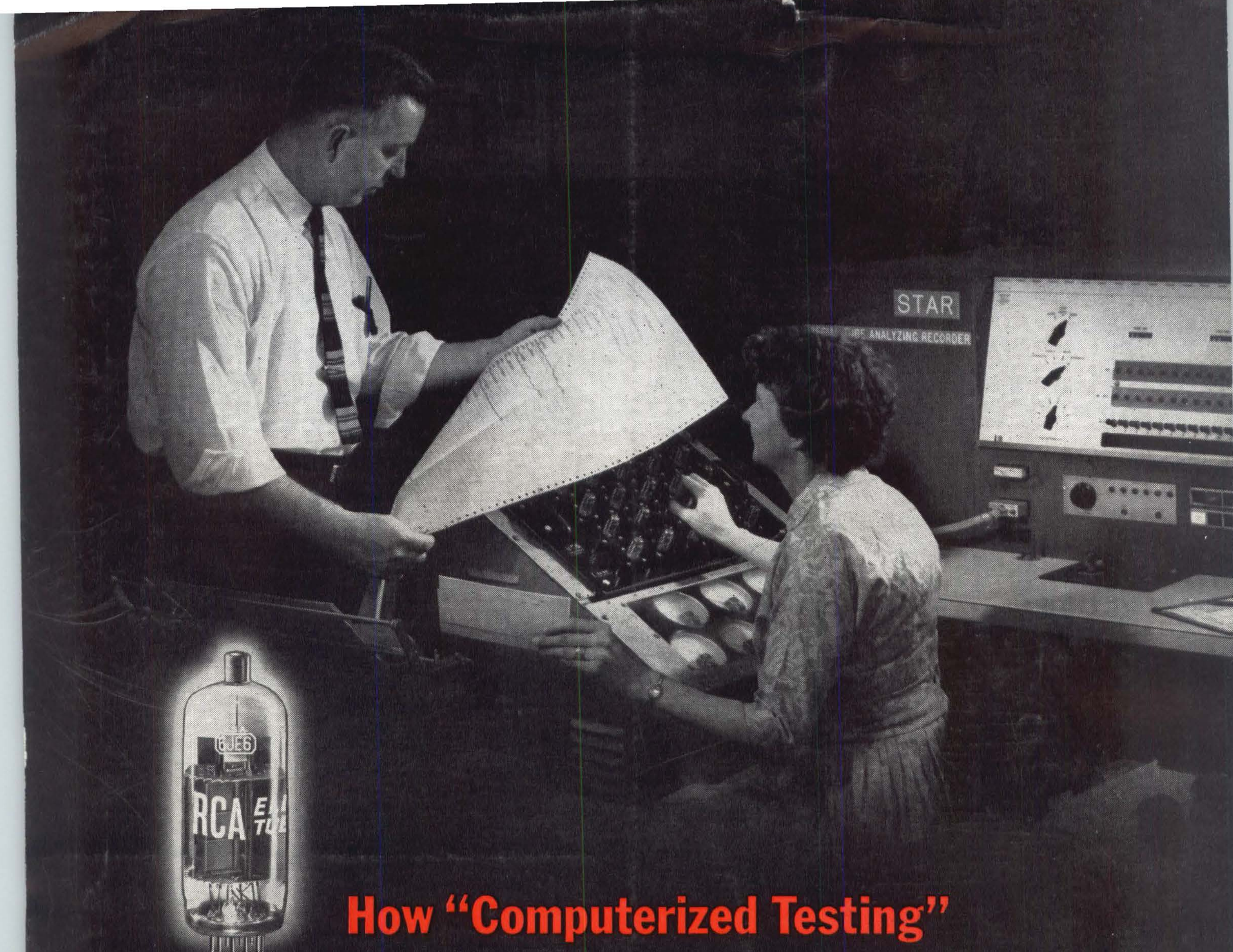

How "Computerized Testing" helps assure the reliability of RCA Receiving Tubes

This engineer is studying final test results of another production run of RCA Receiving Tubes. Nothing surprising here . . . except for one thing: the production run had been completed only hours before!

A few years ago, a thorough quality evaluation of a day's production run of a certain tube type took days, even weeks. But now, at RCA, it's done automatically, with computers, the same day.

Computers in conjunction with the Special Tube Analyzing Recorder (STAR) accumulate and store test data on every receiving tube type we make.

Sample tubes from the production lot are individually analyzed on STAR. As many as 60 tests may be made quickly and automatically on each tube depending on the type. Test results are recorded simultaneously on a test sheet and on punched cards. The computers compare the results with predetermined standards, make "accept" or "reject" decisions and then add the results to the historical record of the tube type.

Thus, in a mere half-hour of running time each night, a full day's receiving-tube output can be evaluated before it is released for shipment. Equally important, the test data for any day's production of a particular tube type together with the historical record for that tube type are on the desks of the production, quality-control and design engineers the following morning. With these data, the engineers can evaluate performance, analyze trends and quickly initiate any corrective measures necessary to assure the consistent quality of RCA Receiving Tubes.

"Computerized testing" is one more reason why you should specify RCA Receiving Tubes for all your requirements. For technical information on specific types, call your nearest RCA District Office or write Commercial Engineering, Section I19DE-1, RCA Electronic Components and Devices, Harrison, N. J.

RCA Electronic Components and Devices, Harrison, N. J.

RCA® **The Most Trusted Name in Electronics**