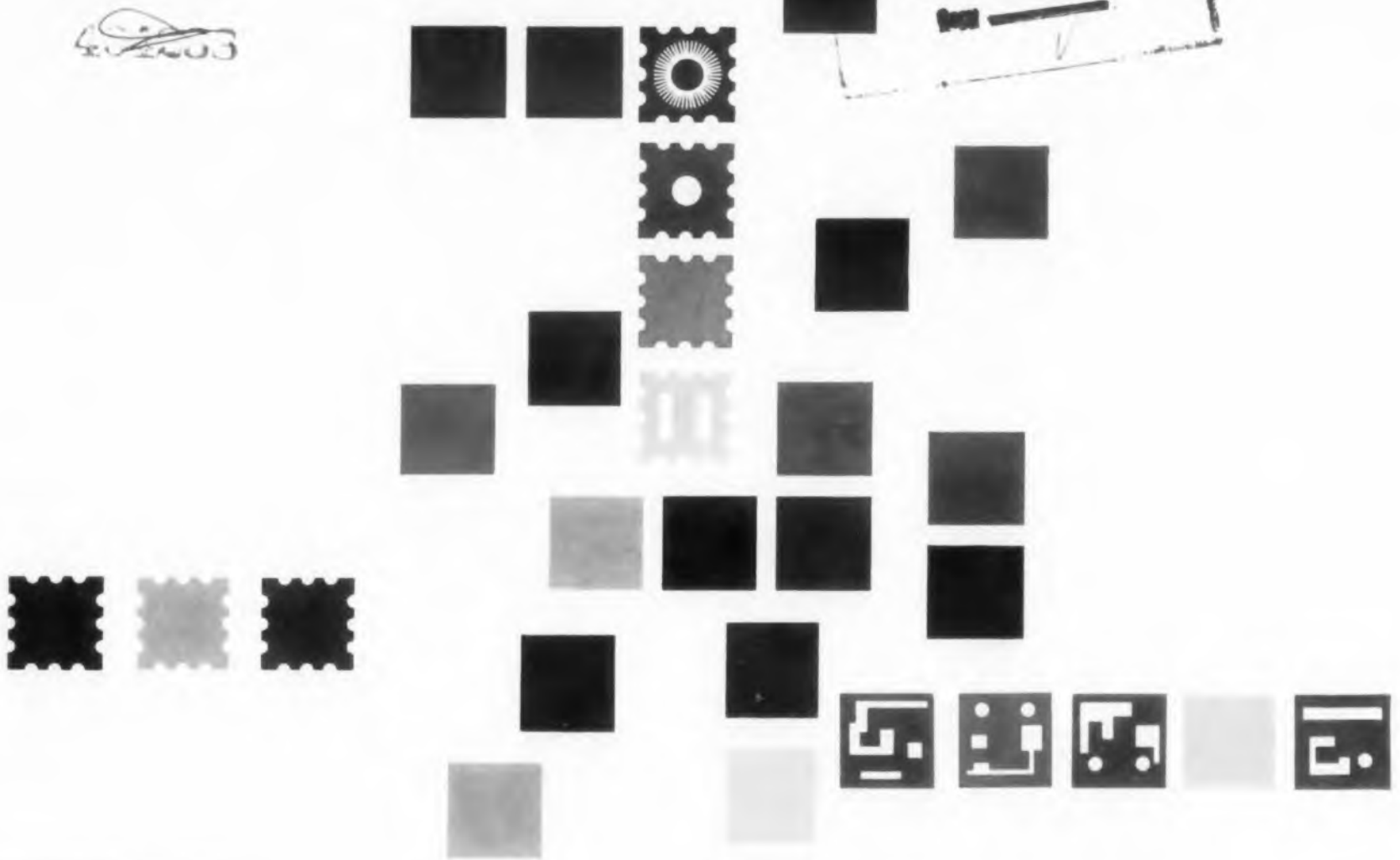
April 15, 1959

# ELECTRONIC DESIGN

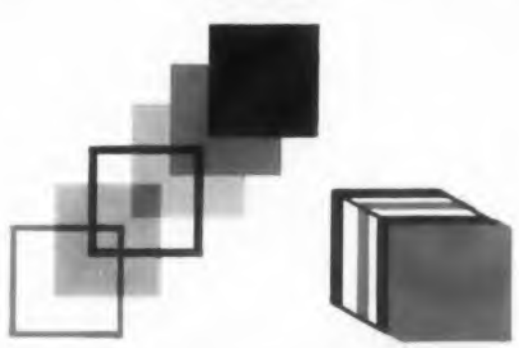
APRIL 29, 1959





An *ELECTRONIC DESIGN* Staff Report:

## MICROELECTRONICS... a new concept in packaging



## HIGHLIGHTS OF ISSUE

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# BEHIND THE NEWS

## Electronics Assists in Picking Astronauts

THE FINAL seven candidates for Project Mercury were evaluated and selected with the help of electronic transducers. Known as Mercury astronauts, one of the candidates will be chosen in about two years to probe outer space in a manned satellite.

To pick the seven final candidates from a field of 32, the volunteers were put through a rigorous battery of physiological and psychological tests. During many of the tests various electronic transducers were used to detect the men's bodily reactions. General areas of concern were the men's nervous, respiratory and circulatory systems.

During the tests cardiograms of heart muscle contraction were made. Heart stroke and sounds were also studied. To determine the response of the nerves they were stimulated electrically. And tracings of electric currents produced by the brain were made.

Other tests included making audiograms with and without background noises, and voice tape recordings. Electronic devices were used to measure blood pressure, breathing and air volume rate, and skin temperature and resistance.

These tests went on for seven and a half days and three evenings at the Lovelace Clinic in Albuquerque, N.M. See ELECTRONIC DESIGN, Mar. 4, page 20, for data on devices that may be used in these tests.

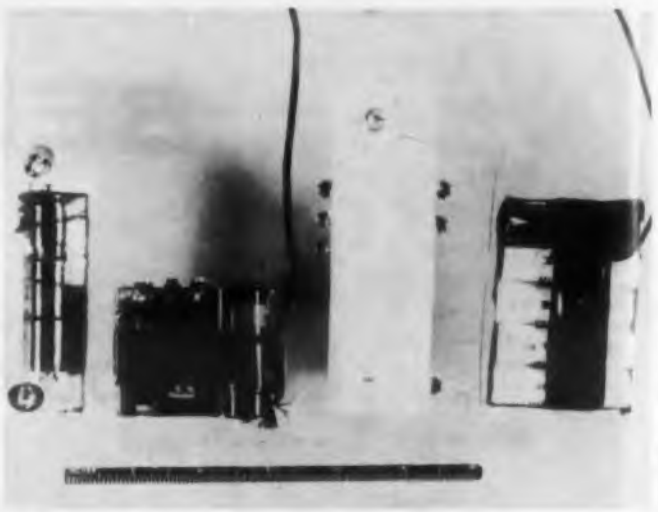
### Medical Data Sent While Astronaut Orbits

While the chosen astronaut orbits the earth he will be rigged with medical electronic equipment that will telemeter his physiological conditions to ground stations. Estimating the value of medical electronic equipment used during flight, one

**Complete shore-based receiving unit** (above), developed by the U. S. Navy Medical Dept., will permit a constant watch on the physical condition of animal and human occupants of space vehicles. The technique will also enable isolated medical practitioners who need the services of medical specialists located at distant points to transmit all essential data to the specialists by telephone. If a consultant is not available at the time of the call, data can be recorded on magnetic tape for later playback.

**Electrodes** are being attached to a Navy officer (left) in a new technique which will permit a constant watch on the space man's blood pressure, temperature, breath sounds, heart sounds and brain waves. Electrocardiograms are superimposed on carrier waves and transmitted over world-wide radio and telephone circuits.

## BEHIND THE NEWS



**This subminiature electrocardiogram** equipment is being used in experiments conducted for space travel. It was designed for use on ambulatory or exercising patients as a portable electrocardiograph and will enable medical researchers to collect important medical data as man responds to space. From left to right is: electrocardiogram amplifier; transformers; fm oscillator; dry cell batteries.

knowledgeable person said: "If he ever gets in trouble we'll probably know about it before he does."

The National Aeronautics and Space Administration is directing Project Mercury. It will pick and launch one of the seven astronauts into space. The astronaut will circle the earth two or three times at an approximate altitude of 125 miles in a one-ton capsule. Plans are for the satellite to splash-land somewhere in the Atlantic Ocean.

### Space Medicine Interests Navy Too

While the names of the seven Mercury astronauts and data on how they were selected was being released in Washington, D.C., a conclave in San Francisco watched a closed-circuit TV presentation of "Medicine Prepares For The Space Age."

At the meeting many of the medical problems and peculiarities of man's coming flights into space were outlined by Captain Norman L. Barr, USN, Director of Astronautics Div. Dr. Barr has developed systems for gathering physiological information from pilots in air and from animal and human occupants of earth orbiting vehicles. The equipment used in these systems permits transmission of electrocardiograms, electroencephalograms, body temperature and other physiological measurements. Some of the Navy's recent activities in Medical Electronics are shown in the accompanying photographs. ■ ■

## Channeling Millimeter Waves Big Challenge

Being so short, millimeter waves are not only difficult to generate but hard to control—and they remain so, as concluded by those who attended the three day symposium on millimeter waves earlier this month in New York. However the fruits of millimeter wave application continue to tantalize many engineers and scientists, mainly because of the great number of messages that can be transmitted on a single transmission line. It was estimated that at least three hundred thousand telephone messages could be sent at once on a transcontinental transmission line. In addition to radio, telephone and television applications, millimeter waves should prove useful in determining the densities of hot ionized gases created by atomic reactions and calculating the atomic weights of nuclei.

### Getting Strong Signal is Problem

However a number of problems will have to be resolved before millimeter waves can be successfully harnessed. Because of the small tube size needed to generate such waves, it is difficult to obtain a sufficiently high signal level. The problem is one of generation and detection. Second, an efficient means of transmitting the waves must be achieved with minimal losses. Presently waves are transmitted along rectangular or circular waveguides. Because of their low signal power, millimeter waves can not be transmitted readily through the atmosphere, since the elements absorb much of their energy. However in space-platform applications, millimeter waves can be efficiently used for communication because of the rarefied atmosphere.

At the present time 4 mm generation is possible but no one has successfully made for commercial use 1 and 2 mm devices.

### Expect To Transmit TV

Despite the problems that confront the millimeter-wave engineer and scientist, they showed little pessimism at the symposium. All eventually expect to achieve their goals in the not too distant future. One of the possibilities they envision is the ability to handle several hundred television channels at once on a transmission line. This is possible because of the great frequency range of millimeter waves. The spectrum is greater than the combined ranges of radio, television and radar.

Held from April 1st to the 3rd, the symposium was cosponsored by the Office of Naval Research and the Air Force Office of Scientific Research and arranged by the Polytechnic Institute of Brooklyn in conjunction with the Institute of Radio Engineers.

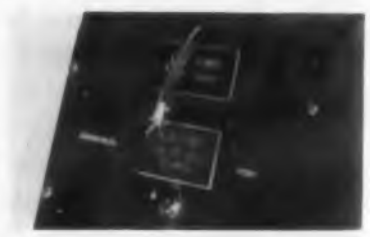
BEHIND THE NEWS

# Can "Power Saver" Alleviate World's Power Shortage

The United States consumed 567 billion kilowatt-hours of electricity last year. This figure will surely skyrocket in the next few years. To meet this problem, engineers at Texas Instruments' Industrial Instrumentation Division in Houston and at the Semiconductor Components Division in Dallas developed the unique "Power Saver" shown in action in the accompanying photos.

What's really unique about this great achievement is that it didn't cost the government a cent. There was no research and development contract—no cost plus fixed fee. The TI engineers did all the necessary work on this project at home—during off hours.

The "Power Saver" operates on Murphy's Law, which deals with the obstinacy of inanimate objects. The sign over the power switch reads: Caution—Do Not Turn On Switch. When the operator turns it on (he always does), a mechanical arm emerges, turns off the switch, then withdraws.





## U.S. to Play Major Role in Paris Computer Conference

Strong world-wide position of U.S. computer technology has been confirmed in the final program plans for the forthcoming global computer conference sponsored by the United Nations organization in Paris, June 15-20. The formal technical program will feature 23 of 55 papers from United States computer experts.

More than 2500 scientists, engineers, and mathematicians meeting at the Western Joint Computer Conference, March 2-6, heard the first official details of the program just finalized in Paris by consultants to UNESCO from the thirteen participating nations. It also was the first public announcement of the high honors accorded to certain leading computer specialists from the United States in appointing them to official positions for the global event.

A special new session has been added to the formal program which will explore "Computer Techniques of the Future." It was also disclosed that U. S. manufacturers of computer and data control systems would have considerable exhibit space in AUTO-MATH 59, a major equipment exhibit held in conjunction with the conference.

## Electronic Instrument Inside Concrete Mixer

Electronics is helping builders make better concrete. An electronic instrument to measure the water content of damp sand, with an error of only a fifth of one per cent, has been produced by Shaw Moisture Meters, England.

The measuring probe of the "Sandmaster" moisture meter is fixed inside the sand hopper of a concrete-making machine. The gage is located where the operator can see it easily and tell at a glance how much water to add.

The moisture content of the sand is measured by the ease or difficulty with which an electric current passes through it at a frequency of 100 mc.

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## BEHIND THE NEWS

### "Hotshot" Wind Tunnel

A new 40-in. "hotshot" wind tunnel now being built by Boeing will give the company its seventh operating wind tunnel and the largest privately owned hypersonic tunnel in the country.

Shown is an 8-in. pilot model which has been in operation since mid-1958. This "hotshot" tunnel—often called an "electric-arc-discharge wind tunnel"—gives Boeing testing capabilities in the Mach 10 to 27 range.

A "hotshot" tunnel consists of a capacitor bank for storing electrical energy, an arc-discharge chamber for containing high pressure—high temperature air, a nozzle, a test section to hold the model and a vacuum system for lowering the pressure in the test section. A plastic diaphragm maintains the pressure differential between the arc chamber and the test section until the moment of test.

In a typical test run, the capacitor bank is charged to capacity and compressed air is forced into the arc chamber. When an arc is struck, the air in the arc chamber becomes ionized. This high temperature—high pressure plasma rupture the plastic diaphragm and permits a high-energy shock wave to rush through the nozzle and into the test section. The shock wave is followed by a hypersonic flow of air.

Although the actual test lasts only about 1/25th of a second, ultra-high-speed oscillograph recorders can record data at 160 inches of paper per second on 36 channels.

The new hypersonic tunnel, as well as this pilot model, will enable the testing of models up to satellite Mach numbers.

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## Soviets Claim "World's Most Powerful" Computing Machine

A computing machine the Russians call "the most powerful in the world" is solving scientific puzzles at Kiev University, while another "unique" computer is working out problems of efficient exploitation of Soviet oil fields.

The Kiev computer, a differential analyzer, is described by a Russian writer as "incorporating 24 integrators and characterized by a high degree of automation in all of its units."

The solver of oil-field problems is said to illustrate Soviet mastery in series production of "specialized analog computers capable of investigating dynamic systems and other processes described by differential equations of the order 6 to 32."

The "matrix-type electrointegrator" has a matrix of resistors and capacitors at 20,000 points, a feature said to make it "a unique machine of this class."

One is a universal digital computer which will figure complex scientific and engineering problems at a rate of 20,000 operations per second. Its circuit will contain a series of storage units, one for internal storage of 2047 numbers, one for intermediate storage for 4096 numbers, and a third for external storage of 100,000 numbers.

The Russians describe the second machine as one of the first small-size universal digital computers with circuits using transistors, ferrites, and miniature tubes. Circuits of its control and arithmetic units incorporate transistors and semiconductor diodes.

The computer is designed to operate at a speed of 2000 to 2500 single-address operations a second. Internal ferrite storage will be 2048 forty-column binary digits of 4096 commands. External storage will consist of two magnetic tape units, each holding 70,000 forty-column digits.

## Japanese Interpreter

An experimental electronic computer which can translate English into Japanese has been successfully produced at the Industrial Technology Institute's Electric Laboratory in Tokyo.

The new invention, the first such machine ever made in Japan, was described by Dr. Shigeru Takahashi at the meeting of the Telecommunication Academy's Electronic Computer Research Committee at Osaka University's Department of Technology. The translating machine, christened "Yamato," was completed last December by Dr. Takahashi with collaboration of five other electronic specialists in the electric laboratory.

"Yamato" can translate first year junior high school English to Japanese.

BEHIND THE NEWS

# New Field Effect Semiconductor Tetrode Is Almost "Universal" Component

FUNCTIONS of a transformer, gyrator, isolator, non-distorting modulator, or short-circuit stable negative resistance can be duplicated by a new four-terminal semiconductor device developed by Bell Telephone Laboratories. Labeled a "field-effect tetrode," the device has no analog, either in electron tubes or previous transistors.

### Construction

The tetrode, Fig. 2, is composed of a disc of semiconductor with a diffused junction. A circular trench is cut and etched into each face of the disc, to within 1 mil of the junction on either side. Two leads are then attached to each face, one inside the trench, the other outside. When a voltage is applied across the junction, the thickness of the depletion layer adjacent to it is increased or decreased, depending on the direction of the biasing voltage. This in turn increases or decreases the resistance of each "channel" between the bottom of the trench and the junction.

### Unusual Applications

Depending on the polarity of the biasing voltage, the tetrode will function either as a transformer or a gyrator. As a transformer, it has a very decided size advantage for low frequency use, although it does not afford dc isolation. As a gyrator, it should be of considerable circuit interest. (A gyrator is a non-reciprocal four terminal network which behaves similarly to a transformer, while exhibiting a 180 deg difference in phase shift depending on the direction of transmission.) One important gyrator function is impedance inversion. For example, it should be possible to use the new device to convert the reactance of a miniature capacitor into that of a high-Q inductor.

If the device is biased properly, it will


**Fig. 1.** Inventors R. M. Warner Jr. and H. A. Stone, Jr. inspect model of field-effect tetrode

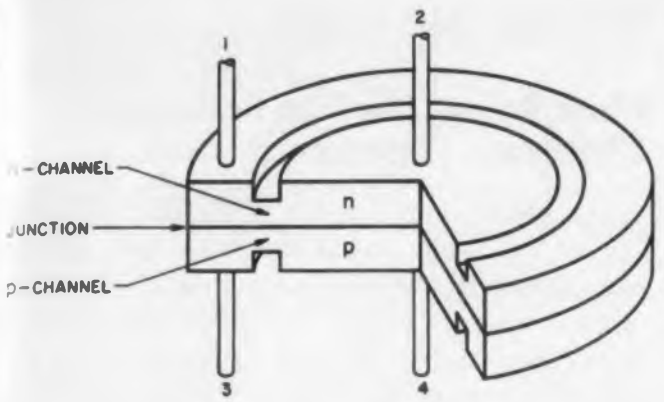


**Fig. 2.** Note circular trench etched into face of upper and lower section of field effect tetrode.

function as an isolator, allowing passage of alternating current in one direction only.

### Distortionless Modulator

According to its inventors, H. A. Stone, Jr. and R. M. Warner, Jr., one of the most important applications for the new device may be as a distortionless modulator, or electronically controlled resistor for large signals. In this use, a relatively low frequency control-voltage varies the width of the depletion layer, and thus the resistance of the device. Simple capacitors act as high-pass filters to isolate the control-voltage from the signal, if the frequency ratio is maintained at a high level. The signal voltage does not appear across the junction and has no effect on the depletion layer. Therefore, it can be magnitudes higher than the control voltage, without being distorted by self-modulation. For the same reason, it is not limited by junction capacitance.

### Stable Negative Resistance

If a direct connection is made between the inner lead on one face and the outer lead on the other, the device will function as a two-terminal a-c short-circuit stable negative resistance. In the experimental models produced at Bell Laboratories, this performance has been achieved over a range of about 30 to 250 v, at 0.6 to 0.1 ma, in a boron-doped silicon crystal with a phosphorous diffused junction.

While the practical development of the field effect tetrode is still in a very early stage, it shows potential characteristics in a single device which previously either could not be obtained at all, or only through extensive circuitry. ■ ■

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# BEHIND THE NEWS

## Moon Relay Link Ties Pentagon to 50th State Outpost

Communications between Washington and Pearl Harbor will make use of the moon as a passive relay station in the coming year. After nine years of research work by the Naval Research Labs., a feasible system for reflecting radio and radar signals off the moon has been developed. Known as the Communication Moon Relay Project, the system theoretically could handle all military communications between Washington and the military command center of the Pacific.

Two and one-half seconds will be required for the uhf signals to complete the trip to the moon and back; about 4500 miles lie between Washington and Pearl Harbor. Signals will be transmitted from 84 ft. diam. parabolic antennas at Annapolis, Md., and received by similar antennas at Cheltingham, Md., about 15 miles from Washington. Two similar stations will be located at Wakiawa and Opana in the Pacific.

The fact that the moon must be in sight of both links poses the obvious limitation to the system. Radio contact can vary from four to fourteen hours daily depending on the orbit of the moon. This disadvantage is outweighed, say Navy officials, by the improved reliability of message transmission. Noise interference and ionosphere-caused blackouts will not mar system operation.

In addition, the system is virtually jam-proof—an important military consideration. In order to jam the moon circuit, an enemy would require a station located within several miles of the main sites. Theoretically, the enemy could bounce signals off the moon at the same frequency, but this attempt could easily be thwarted by switching frequency at predetermined intervals.

## Ultra-High Speed Flash

Flash X-ray equipment for use in recording explosion processes and measuring the speed of hyper-velocity objects has been announced by Zenith Radio Research Corporation. Utilizing a newly developed air-core pulse transformer and special "triggering" circuits, the equipment performs with a degree of reliability and accuracy which has never before been achieved by flash X-ray systems.

Unlike other flash X-ray equipment in which capacitors apply the full accelerating voltage directly to the flash X-ray tube, Zenith's equipment stores the energy at a relatively low potential. The pulse transformer, steps it up to the required peak accelerating voltage only when the tube's operation is desired. Full accelerating voltage is within the range of 60-120 kv.

# NEWS BRIEFS . . .

• • • **LONG DISTANCE COMMUNICATION** employing man-made clouds which reflect radio signals has been patented by Henri Busignies, president of the ITT Laboratories of International Telephone and Telegraph Corporation. The system utilizes clouds of metallic chaff or ionized materials off which the radio signals, transmitted from earth, are reflected back to earth at distant points and picked up by radio receivers. The materials are sent aloft by various methods such as guns, aircraft including guided missiles, balloons, and rockets. They also can be expelled as ionized gas in the exhaust of aircraft such as rockets.

• • • **MANUFACTURERS OF PERMANENT MAGNETS** recently organized the Permanent Magnet Producers' Association, a national trade association designed to promote the progress and development of this industry. The basic program for the PMPA is to expand the program of magnet standardization with respect to magnetic and physical properties for the benefit of industries utilizing permanent magnets. In addition, it will collect and disseminate reliable technical information, from domestic and foreign sources, as an aid for the designer using permanent magnets.

Headquarters for the PMPA have been established at 27 East Monroe Street, Chicago 3, Ill.

• • • **ESTABLISHMENT OF THE NUCLEAR INSTRUMENTATION ASSOCIATION** has been jointly announced by a group of prominent nuclear instrument manufacturers. Creation resulted from the increased importance of nucleonics and nuclear instrumentation within the field of electronics.

Purpose of the Nuclear Instrumentation Association is to give industry support to research, development and production in the U. S. The new national trade organization will be expanded to represent major manufacturing segments of the nucleonics industry.

• • • **A NEW METHOD IN THE THEORY OF SUPERCONDUCTIVITY** by N. N. Bogolubov, V. V. Tolmachev, and D. V. Shirkov, will be published in April by Consultants Bureau, Inc., 227 W. 17th St., New York 11, N.Y. The book, a complete English translation of the recent Russian work, will be cloth bound and priced at $5.75.

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# WASHINGTON REPORT

**Ephraim Kahn**

## New Concept in R & D Planning

Present concepts of research and development would be vastly changed if the military adopt a proposal that has been suggested by Dr. William H. Martin, Director of R & D for the Army. As he sees it, R & D should continue through the first stage of the production cycle. If major production changes are needed, they should be worked into the design before the pilot run has been completed.

### Leadtime Could be Halved

Furthermore, Dr. Martin believes that the agency sponsoring the development program should be held responsible for all work until the "bugs" have been worked out of any new device. Object of this extensive change in R & D responsibility is to shorten leadtime to about four years from the eight now customary.

Increased automation must necessarily go along with the greater complexity of modern weapons. States Dr. Martin: "This applies especially in the microminiaturization of electronic components, where the designs of the device to be made by automatic machinery have to be compatible and concurrent with the designs of this machinery, and consequently must be able to react on each other."

Industry support for this change in R & D concept is solicited. The Army, for example, wants and needs "more organizations which are proficient in both development and production and whose management has the concept and the experience of handling as a prime contractor the over-all job from the systems point of view."

Some aspects of Dr. Martin's plan for R & D acceleration are bound to create a stir in Congress. The Armed Services have, in the past, come in for sharp criticism from both the House and Senate Small Business Committees for alleged over-emphasis on the use of negotiated contracts in military buying—particularly those involving larger firms. Nevertheless, Dr. Martin implies that competitive bidding is not appropriate for new and untried products that are still basically in the development stage. It is only after this period is over that the military is "ready to break into the systems concept of responsibility by the primary contractor and 'peel off' direct purchasing of some of the supporting equipment.

As Dr. Martin sees it, the four-year development cycle would require the services of a "project manager," and provision for funds for the entire cycle would have to be made at the time the program was set up. Though these are "objectives and not regulations to be applied to every project regardless of its magnitude or urgency," he believes that they "should be valid for the more important projects."

### Possible Approaches

Guidelines for putting this proposal into practice would include:

- Adequate basic research and development programs to provide a reservoir of new concepts, knowledge, and components, and that each project be backed by a well-drawn plan prior to its authorization.
- Development cycle end only after acceptable and tested items have been produced in the course of the first production run.
- Responsibility by a single contractor for development, preparation for production, initial production, and support materials.
- Maximum stress be placed on the Qualitative Military Characteristics of the product throughout the development cycle, with the R & D agency primarily responsible for seeing to it that QMC are properly adjusted to available technology, economical quality production, reliability, and timely availability.
- Close relations with the contractor and the development agency be maintained by the logistics and user agencies to insure that their interests are properly effective in the development of the design.
- Designation, by the development agency, of an employee as project manager, responsible for the progress of the venture and for coordinating the participation of other government agencies.
- No more than a four year lead-time be planned from inception of a project to operational availability of its end-product, and that the availability of funds be geared to this rate of progress.

## EIA Group to Visit USSR

Ray C. Ellis, Vice President of Raytheon Manufacturing Co. and Chairman of the International Department of the Electronic Industries Association (EIA) will head a six-man delegation of American electronics specialists leaving shortly for a three-week visit to the USSR. The group will meet with its Soviet counterpart and visit electronics laboratories and plants.

This is the time of our annual subscription renewal.

# EDITORIAL

## Not a Breakthrough But a Revolution

There is a revolution going on in the components industry. Microcircuitry, or more generally, microelectronics, is no longer simply a blue-sky topic for luncheon speakers. The cover story of the last issue of ELECTRONIC DESIGN and special report in this issue, "Microelectronics . . . a new concept in Packaging", bears witness to the fact.

It is not easy to describe the transformation going on but the 18 pages that follow will give you an "operational definition" in the P. W. Bridgman sense. A study of the report will show the work of not one or two government labs but the results of at least 60 organizations. If you were at the IRE National Convention, you saw the Army's micro-modules at the RCA booth and the solid circuits at the Texas Instrument booth—the same solid circuits predicted as coming but at least five years away.

RCA's micro-modules are for sale. Texas Instrument says theirs will be available shortly. This means that in two years operational equipment using microelectronics will be available. Since at least 85% of today's electronics equipment can be built the micro-module way, today's engineer is witnessing the beginning of a revolution.

Whether the conversion will take depends on a number of factors. There will be of course widespread passive resistance if the owners of production machinery do not invest in new machinery. Currently, the components portion of the electronics industry, excluding tubes and transistors, produces products having a value of only $1.3 billion, but the practices of this small group determine the form factor of the product of a $7.9 million original equipment market.

There will be changes, therefore, only as production machinery for the new techniques is funded. We see this coming. The stakes are worth it: smaller size, greater reliability, lower costs. If the military finances but one company, the rest will follow as no one can afford not to be prepared to share in the new market. If components manufacturers do not rise to the challenge, weapon system contractors will take the lead. Once they do, the revolution will come to pass. Since microelectronics by automation is economical, producers can control not only the military market but the consumer and industrial market as well. Microelectronics products produced by automation will be cheaper than the coolie-labor products and the world market, too, will belong to the victors.

James G. Kupfer

# How To Determine Circuit Response With Two Time Constants

**The simplifying assumption is perhaps one of the most useful tools in the design engineer's arsenal. But it can be a treacherous one.**

**"Let us assume a step input," is one of the most popular of these tools. It is extremely convenient, but unless used carefully, it can lead to unexpected circuit response.**

**Richard Muller, a Fellow of the National Science Foundation, shows when the assumption is "safe," and what "safer" assumptions can be made when necessary.**

**Richard S. Muller**
Hughes Aircraft Co.
Culver City, Calif.

THOUGH no real waveforms can have zero rise time, practical calculations of network response usually assume that driving waveforms are square. This approximation is often valid, often not. When the approximation leads to troublesome errors, it is profitable to consider simplifications which may permit more accurate calculations while still avoiding the laborious, exact approach.

The step response of a single time constant network consists of a single exponential term which can be easily manipulated to yield an explicit solution for time. But if the driving waveform is rounded so it has a finite rise time, the response equation has two exponential terms. The driving wave's rise time contributes the second time constant.

In this case, an explicit solution for time is not attainable. An exact approach demands a laborious graphical technique.

### A Transistor's Step Response

To illustrate the problem, consider a network which has a transformed response to a step input which takes the form

$$\frac{A}{s(s+D)}$$

Such an equation is, for example, characteristic of the transistor step response derived by Easely.[1] In the common emitter configuration, for instance, the form of the equation is

$$I_c = \frac{A\ I_{b1}}{s(s+D)}$$

where $I_{b1}$ is the magnitude of the base current step and $I_c$ is the output (collector) current.

If the driving waveform is not square, but rounded as by capacitive shunting, it is likely to be of the form

$$I_b = I_{b1}\ (1 - \epsilon^{-Gt})$$

instead of the simple step $I = I_{b1}$.

Such a driving waveform would yield a transformed response equation of the form

$$I_c = I_{b1}\left[\frac{A}{s(s+D)} - \frac{A}{(s+G)\ (s+D)}\right]$$

since

$$L[I_b(t)] = \frac{1}{s} - \frac{1}{(s+G)}\ I_{b1}$$

which implies that

$$I_c = I_{b1}\left\{\left[\frac{A}{D}\ (1 - \epsilon^{-Dt})\right] - \left[\left(\frac{A}{D-G}\right)(\epsilon^{-Gt} - \epsilon^{-Dt})\right]\right\} \quad (1)$$

Eq (1) is the type under consideration. The first term is the step response of a network with a single time constant $1/D$. The second is due to the finite rise time of the driving waveform. As its time constant $1/G$ approaches zero, the rise time of the driving wave approaches zero and the output approaches the step response.

### How Accurate Is The Single Time Constant Approximation

The important question that arises with this example is "What is the relative magnitude of $G$ with respect to $D$, which would allow considering the step response alone with negligible error?" If one thinks in terms of time constants, the consideration is of the ratio of the circuit time constant $1/D$, to the driving waveform's time constant $1/G$.

For negligible error, the second term in Eq (1) must be negligible compared with the first. If, for example, the ratio of these two terms is set at 0.1, it should be interesting to see what restriction this places on the magnitude of $G$ with respect to $D$.

Accordingly, set

$$\left(\frac{D}{D-G}\right)\frac{(\epsilon^{-Gt} - \epsilon^{-Dt}}{(1 - \epsilon^{-Dt})} < 0.1 \quad (2)$$

Probably $G$ will have to be significantly larger than $D$ to make $\epsilon^{-Gt} \ll \epsilon^{-Dt}$ at all but very small $t$'s.

Hence, the effective requirement is

$$\left(\frac{D}{G-D}\right)\left(\frac{1}{\epsilon^{Dt} - 1}\right) < 0.1$$

which leads to

$$\epsilon^{Dt} > \frac{9D + G}{G - D} \tag{3}$$

Eq (3) gives a quantitative statement to the evident fact, that as consideration is extended to smaller and smaller response times, the approximation demands greater and greater disparity in the exponential time constants. The expression also indicates that the error decreases with time since the inequality becomes easier to fulfill with increasing $t$.

At this juncture, the designer must decide in what time range his interest lies. Then, using Eq (3), he can determine the required $G$ to $D$ ratio.

Continuing with the example of transistor step response equations, and specifying that response times of interest will be less than 1/2 the time constant of the dominant exponential, insert $t = 1/2 \times 1/D$ in Eq (3).

Thus

$$\epsilon^{1/2} > \frac{9D + G}{G - D}$$

which leads to a required $G = 16.4\,D$. If the 10 per cent error point had been set at $t = 1/D$, the required $G$ would be 6.25 $D$. These values justify the neglect of $\epsilon^{-Gt}$ when compared with $\epsilon^{-Dt}$ in Eq (2).

From this example, it is evident that a large deviation of one time constant from another may be necessary to permit neglect of the effect of one with respect to the effect of the other. In this instance, recognition of the finite rise time of the forcing function is necessary unless this wave is characterized by an exponential with about 1/15 the rise time of the response.

### Two Time Constant Consideration

When the first order approximation becomes too inaccurate, some recognition of both time constants becomes imperative.

It is helpful to examine plots of the actual response of the system of Eq (1) for different ratios of the two time constants. A careful inspection may point out a simplified approach that would bypass graphical techniques and yield a readily calculable explicit solution for response time.

Fig. 1 is a family of such curves for various values of $G$. As $G$ approaches $D$, the response approaches the form

$$\frac{I_e}{I_b}(t) = \frac{A}{D}\left(1 - \epsilon^{-Dt} - Dt\,\epsilon^{-Dt}\right)$$

From this graph, a second plot, more useful to the circuit designer, may be obtained.

If the time lag between the step response and the actual response is plotted, (Fig. 2) as a function of the amplitude, an interesting fact appears. For $G/D$ ratios of three or more, the time deviation of the actual response from the step response rapidly approaches a constant, independent of the response amplitude.

As $G$ becomes greater than $D$, the term in $\epsilon^{-Gt}$ rapidly tends to become negligible compared with $\epsilon^{-Dt}$. Hence, the correction term to the step response approaches

$$-\frac{A}{G - D}\,\epsilon^{-Dt} \tag{4}$$

Now, for any given amplitude $C$, the step response equation determines a value $t'$ as follows:

$$t' = \frac{1}{D}\,ln\left(\frac{A}{A - DC}\right) \tag{5}$$

Using the correction approximation of Eq (4),

**Fig. 1.** The actual response of a system compared with the estimated response assuming a square driving waveform for various ratios of system time constants $1/D$ to driving-wave time constants $1/G$.

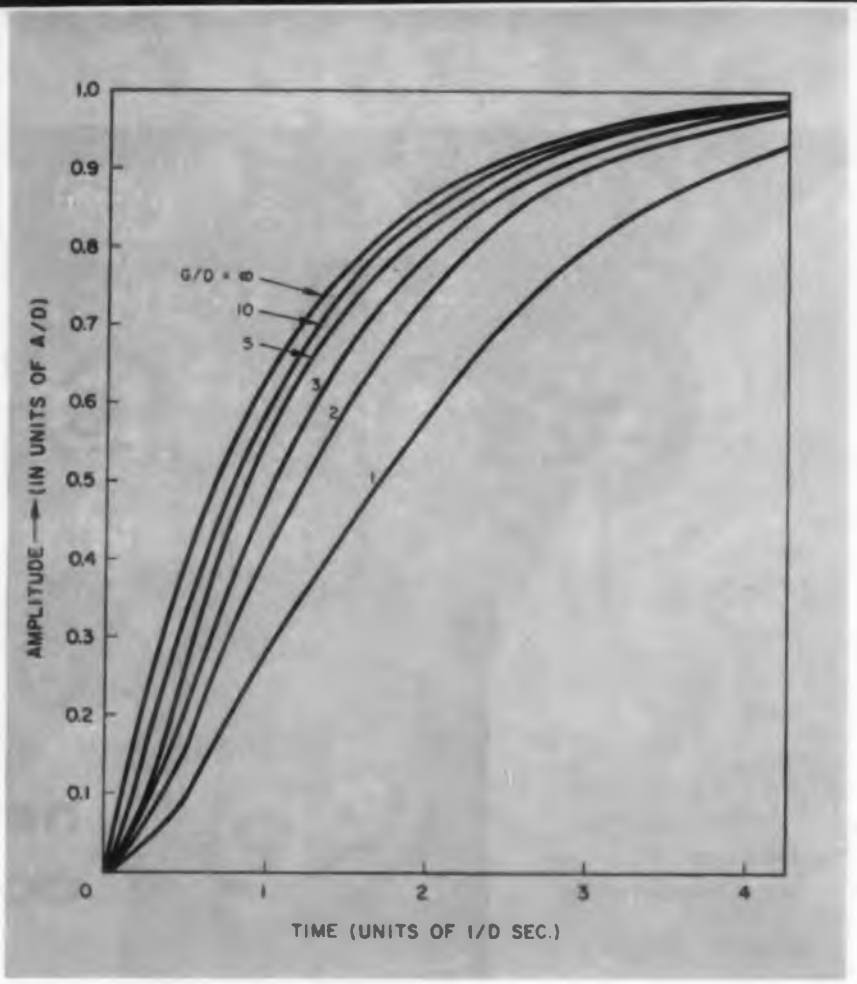
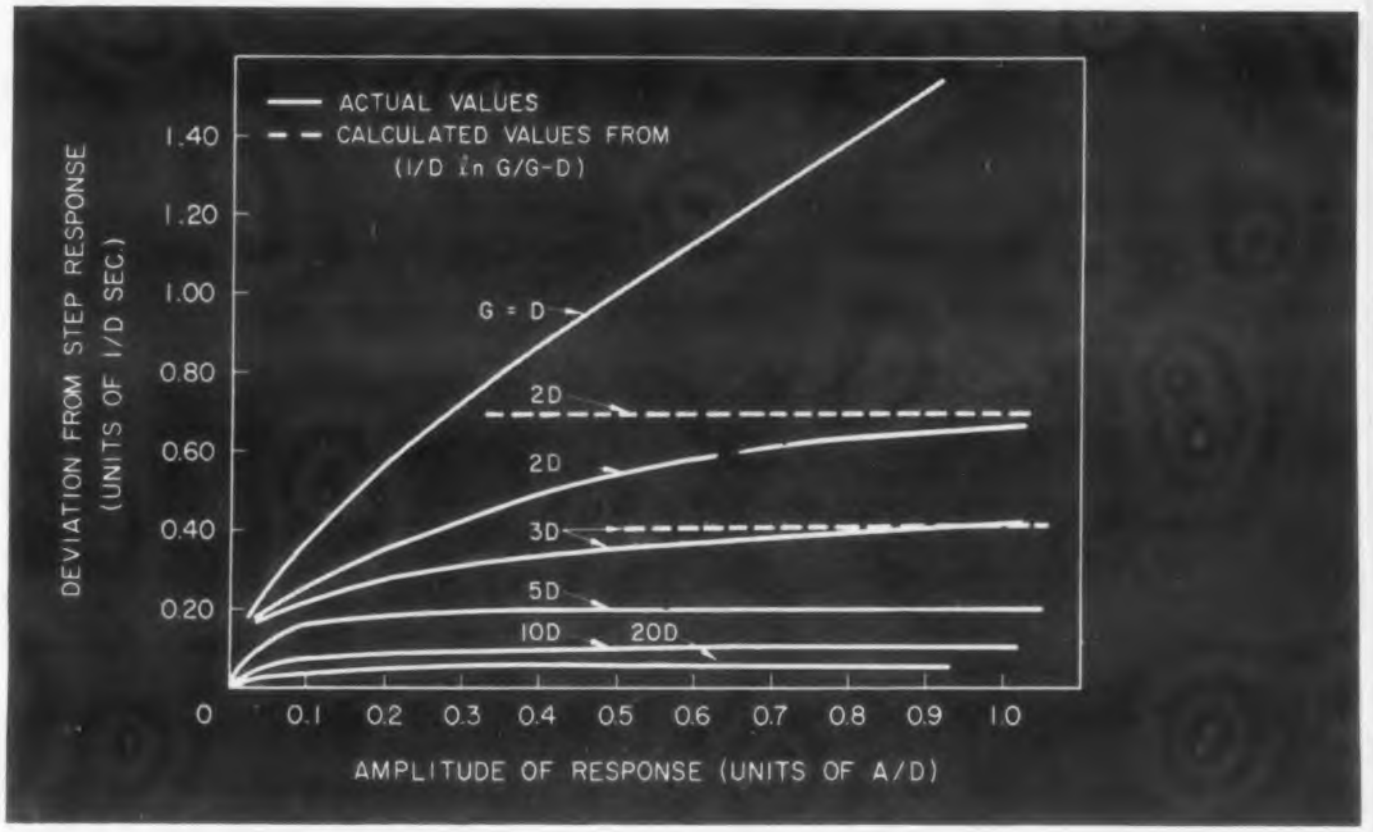



**Fig. 2.** Deviations of actual network response from step input response.



the true response is closely approximated by

$$C = \frac{A}{D}\left[1 - \frac{G}{G-D}\,\epsilon^{-Dt}\right]$$

which yields

$$t = \frac{1}{D}\left[ln\left(\frac{A}{A-DC}\right) + ln\left(\frac{G}{G-D}\right)\right] \quad (6)$$

Hence, the time added to the step response approaches the difference between Eq (6) and Eq (5), or

$$\frac{1}{D}\,ln\left(\frac{G}{G-D}\right) \quad (7)$$

The dotted family of curves on Fig. 2 is calculated from this equation. For $G = 5D$ and higher, at amplitudes greater than two tenths of the final value, they nearly overlay the true curves. Even for $G = 2D$, the calculated curve, which is the true curve's asymptote, is a fair correction above about half the final amplitude.

### Simplified Calculations

This fact simplifies calculations for the two time constant case a great deal. It allows consideration of the second exponential via a simple additive term to the explicit solution for time, achieved by considering one time constant equal to zero.

Consider a specific application. From Easely's calculations (which add the effect of collector capacity to the transistor response equations, and were derived first by Ebers and Moll[2]), explicit solutions for "turn-on" and "turn-off" time were derived.

Since they are explicit for a single time constant, these same expressions can be modified by the correction term given in Eq (7) to account for a nonsquare input to a transistor amplifier. The following sample problem illustrates a typical design situation in which these observations apply.

### Sample Problem

It is desired to "turn on" a common emitter transistor with a current pulse which has a rise time (to $1/\epsilon$ of the final value) of 0.06 μsec.

What magnitude should the base current have to achieve a "turn on" time of 0.43 μsec, if the transistor has the following properties?

$f_{\alpha\,min} = 15.9$ mc ($\omega_{\alpha\,min} = 100 \times 10^6$)

$C_{c\,max} = 10\ \mu\mu f$

$r_{c\,min} = 200$ K

$\alpha_{o\,min} = 0.95$

The final current required is $I_{c1} = 10$ ma into a 1 K load $R_L$.

### Design Procedure

From the input wave rise time of 0.06 μsec, one may determine $G$. Thus

$$G = \frac{1}{t_r}\left[1 - ln\,(\epsilon - 1)\right]$$

$$= \frac{0.46}{0.06 \times 10^{-6}} = 7.67 \times 10^6$$

From Easely's paper

$$D = \frac{(1-\alpha_o+R_L/r_c)\,(\omega_\alpha)}{(1+R_L\,C_c\,\omega_\alpha)}$$

$$= \frac{(1-0.95+1/200)\,(100\times10^6)}{(1+10^3\times10\times10^{-12}\times100\times10^6)} = 2.75\times10^6$$

$$G = \frac{7.67}{2.75}\,D = 2.79\,D$$

Hence, the step response is $(1/D)$ ln $(2.79/1.79) = 0.44/D$ shorter than the actual response.

Since $1/D$ equals 0.364 μsec, the actual response is 0.44 x 0.364 = 0.16 μsec longer than the step response. Thus, for an overall "turn on" time of 0.43 μsec, the time to be inserted in the step response equation is 0.43–0.16, or 0.27 μsec. Thus, by Eq (3)

$$0.27 \times 10^{-6} = \left(\frac{2}{0.055 \times 100 \times 10^6}\right)$$

$$ln\left(\frac{I_{b1}}{I_{b1} - 0.9\,(10\times10^{-3})\left(\frac{0.055}{0.95}\right)}\right)$$

and the required base "turn on" current is

$$I_{b1} = \frac{2.1\,(0.521 \times 10^{-3})}{1.1} = 1.0\ \text{ma}$$

### Approximations Are "Safe"

The correction embodied in Eq (7) tends to be undefined as $G$ approaches $D$. This is to be expected since the approximation which leads to this term, through Eq (4), becomes further and further removed from reality. However, Fig. 2 shows that the correction term is quite accurate for values of $G$ three or four times the value of $D$, and may be helpful as a first order calculation for $G$ as small as two times the magnitude of $D$.

In any case, the correction term always exceeds the actual error. Hence, any design based on calculated response time will be on the "safe" side. ■■

#### References


1. The Effect of Collector Capacity on the Transient Response of Junction Transistors, J. W. Easely, *IRE Transactions on Electron Devices*, Vol. ED-4, No. 1, pg. 6.
2. Large Signal Behavior of Junction Transistors, J. J. Ebers and J. L. Moll, *Proc. IRE*, Vol. 42, Dec. 1954, pp. 1761-1772.

# Synchronous Motor starts, stops, reverses almost instantly

DESIGNED for electronic control systems, this synchronous motor can start, stop, and reverse itself almost instantly. The small, maintenance-free unit operates at constant speed and produces a high torque.

Applications of the motor, called Slo-Syn and made by The Superior Electric Co., Bristol, Conn., include: remote control systems; numerical control systems; and automatic machines and apparatus. It is an enclosed, permanent-magnet type synchronous ac motor.

### Electrical Characteristics

The motor combines a speed of 72 rpm with a 150 oz-in. torque. Speed is synchronous with line frequency and at 60 cps it remains at a constant 72 rpm without gear reduction. Because the motor is self-starting, no additional starting means are necessary.

Spinning the motor forward, instantly reversing or stopping it can be done with a single-pole, three-position switch since the unit has but three leads. The motor will start or stop in less than 0.025 sec, or about 1.5 cycles. Electrical or mechanical braking is not needed because it will stop in less than 5 deg of motor shaft rotation.

There is no excessive inrush current when the motor is turned on because the starting current is nearly identical to the operating current (0.3 amp max at 60 cps). The correct set of phase-shifting components is specified for nominal 60 cps duty. And with these components the motor will operate satisfactorily at any frequency between 40 and 70 cps. Rated for 50 C temperature rise at 40 C maximum


**Fig. 1.** This exploded view shows the various parts of the synchronous motor. No lubrication of the bearings is required for the life of the motor since the shaft is mounted on two prelubricated ball bearings.

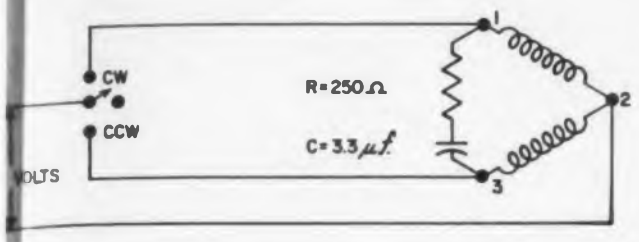



**Fig. 2.** This graph shows the motor's torque at various input voltages, 60 cps.

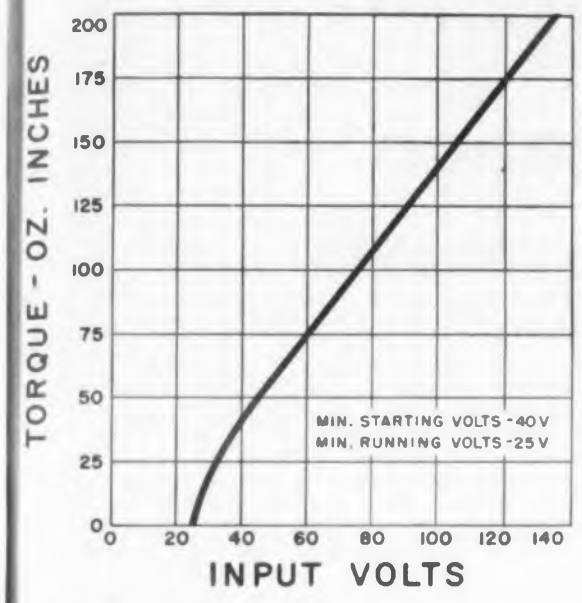



**Fig. 3.** A phase-shifting network, as shown, must be used to operate the motor when the power source is a single phase.

ambient under continuous operation, the unit weighs 6.5 lb.

### Physical Dimensions

Shaft diameter of the motor is 3/8 in. and its length is 1 x 3/16 in. The motor has a 4.25 in. diameter and a 4.75 in. depth.

When the synchronous motor is adapted for use as an incremental positioning device, dc electrical pulses are converted into either 200 or 400 precise increments for one revolution of the motor shaft. The motor will maintain its rated torque for any stepping position. And since no ratchets are used, each step is made instantly without slip or clatter.

A phase-shifting network, required when the motor operates from a single phase source, can be had in an enclosure that is mounted on the end of the motor.

For more information on this synchronous motor, turn to the Reader-Service card and circle **101**.

# Space Coordinate Transformation

## *Using High-Precision Resolvers*


**Gilbert H. Steinberg**

Reeves Instrument Corp.
Garden City, N. Y.



**Problems in space navigation require detection of the vehicle's attitude in reference to fixed space coordinates. This article shows how resolvers are combined to transform velocity vectors and angles from one coordinate system to another.**



**Gil Steinberg is manager for resolver and gyro products for Reeves. He's interested in educating engineers on the capabilities of resolvers in coordinate transformation and wrote this article as a step in that direction. Current and future trends, he says, indicate more and more use of "amplifierless" chains.**


MODERN computer techniques for navigation and guidance usually involve linear transformations of vectors and angular relationships between two or more coordinate systems. Many aircraft and ships are supplied with a central inertial space reference system to and from which all guidance and fire control data are referred. The most convenient and efficient method presently available for solving transformation is through the use of high precision resolver chains.

Simplified representation of a resolver, Fig. 2(a), shows essentially a rotatable transformer with two windings in space quadrature on both primary and secondary. Fig. 2(b) illustrates the standard schematic representation of a resolver. The output equations are:

$$C = A\cos\theta - B\sin\theta$$
$$D = B\cos\theta + A\sin\theta \qquad (1)$$

These equations describe a simple two dimen-

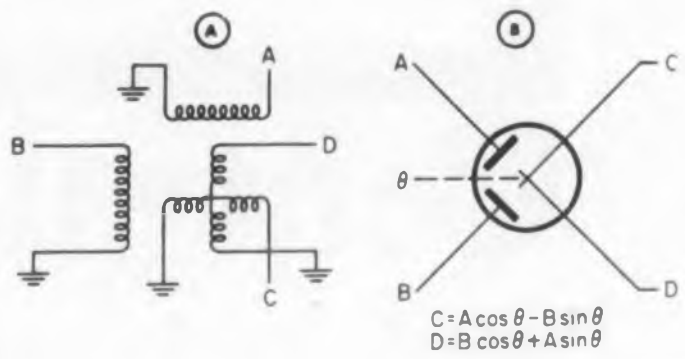



**Fig. 2.** Simplified circuit of resolver (a) and standard symbol (b).

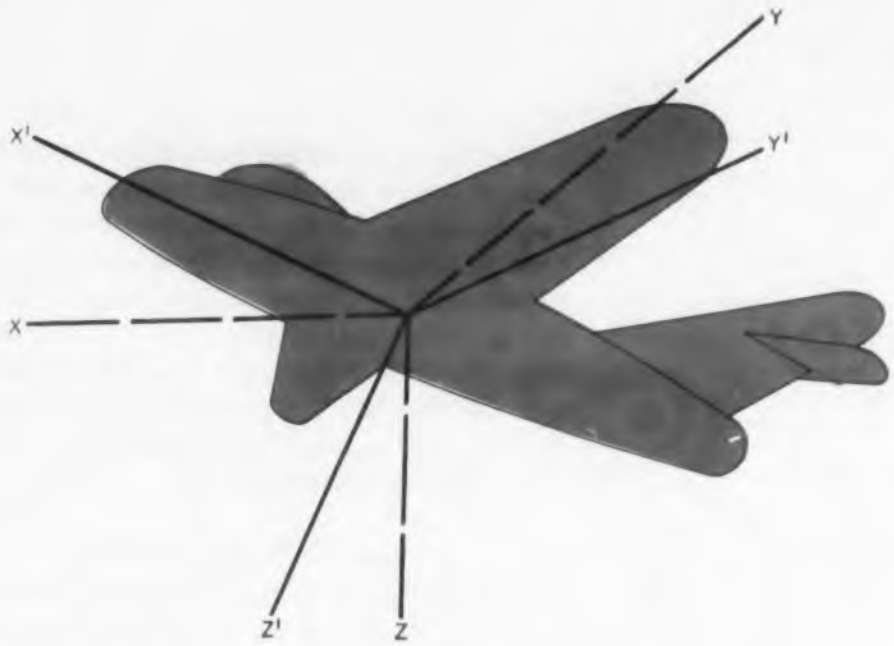



**Fig. 1.** Typical coordinate transformation problem *x*, *y* and *z* are fixed space coordinates; *x'*, *y'* and *z'* are aircraft coordinates.

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ional coordinate rotation. As shown in Fig. 3, *A* and *B* are the (*x*, *y*) components of the vector *V* in the original coordinate system and *C* and *D* are the (*x'*, *y'*) components in the new coordinate system, rotated through an angle θ with respect to the original coordinates. In matrix notation these equations can be represented as:

$$\begin{bmatrix} C \\ D \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix} \qquad (2)$$

Since both coordinate systems are orthogonal, the inverse of the transposition matrix is equal to the transposed matrix and therefore:

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} C \\ D \end{bmatrix} \qquad (3)$$

Equation (3) describes a coordinate rotation from the new coordinate system (*x'*, *y'*) back to the original system.

Equations 2 and 3 describe a coordinate rotation through one degree of freedom. This can be instrumented using only one resolver. The same basic techniques can be expanded to cover coordinate rotation through 3 degrees of freedom.

### Three Possible Rotations

Assume (Fig. 1) that the aircraft is in level flight; that is, the aircraft coordinates coincide with the space coordinates. Three coordinate ro-

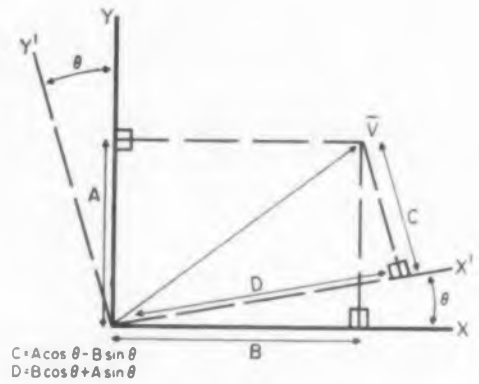



**Fig. 3.** Simple two-dimensional rotation.

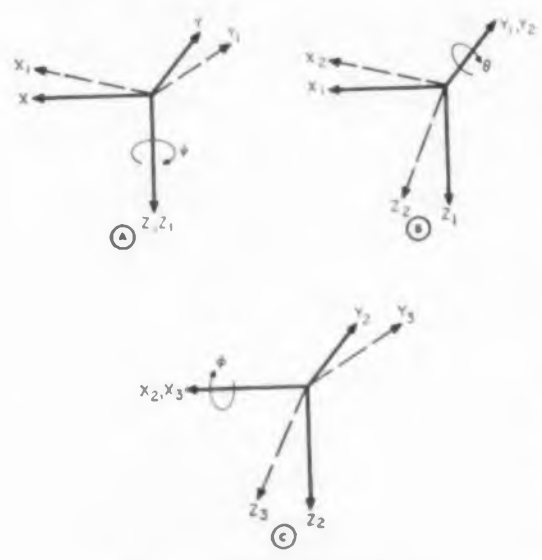



**Fig. 4.** Transformation from space coordinates to aircraft coordinates, around *z* axis (a), $y_1$ axis (b) and $x_2$ axis (c).

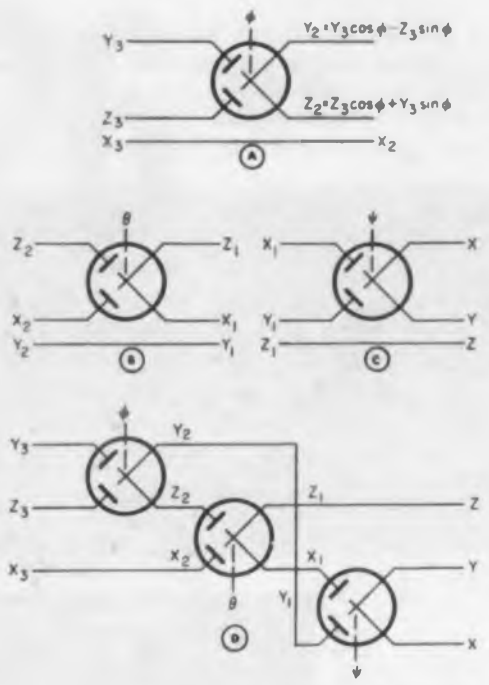


**Fig. 5.** To determine the vector in terms of space coordinates, three rotations are instrumented as in (a), (b) and (c), and tied together to complete the system (d).

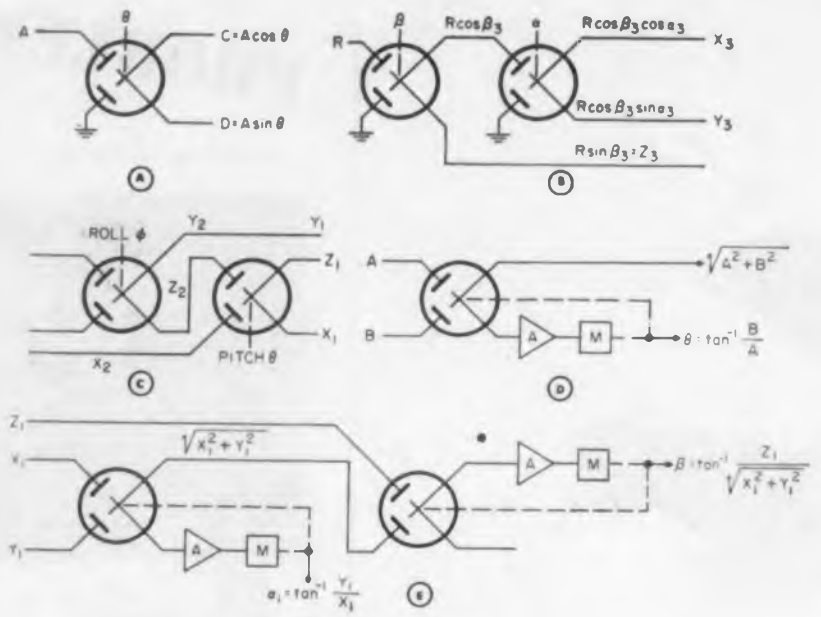


**Fig. 6.** Resolver with one input grounded (a); conversion from spherical coordinates to rectangular coordinates (c); transformation (d) from one rectangular coordinate system ($x_2$, $y_2$, $z_2$) to another ($x_1$, $y_1$, $z_1$); converting from rectangular coordinates to spherical coordinates (e).

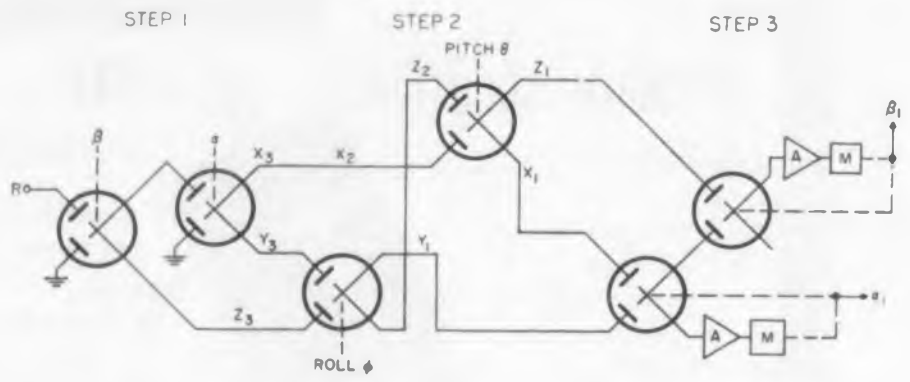


**Fig. 7.** Solution to antenna stabilization problem is instrumented like this.

tations are possible: (1) a rotation about the $z'$ axis (yaw), (2) rotation $\theta$ about the $y'$ axis (pitch), and (3) rotation $\phi$ about the $x'$ axis (roll). It is apparent that space coordinates can be transformed to aircraft coordinates through successive coordinate rotations about each of the three axes.

The converse is also true: aircraft coordinates can be transformed to space coordinates by three successive rotations about fixed axes. The order in which the rotations are made will determine the final form of the transformation equations. While any order is correct and will give the same final results, to be consistent with current practice in the aircraft industry the angles will be taken in the order $\psi$, $\theta$, $\phi$, when transforming from space coordinates to airplane coordinates. The reverse order $\phi$, $\theta$, $\psi$, is taken when transforming from aircraft coordinates to space coordinates.

First rotation, Fig. 4(a), is taken about the $z$ axis. The equations of this transformation are:

$$X_1 = X\cos\psi + y\sin\psi \qquad X = X_1\cos\psi - Y_1\sin\psi$$
$$Y_1 = Y\cos\psi - x\sin\psi \qquad Y = Y_1\cos\psi + X_1\sin\psi$$
$$Z_1 = Z \qquad Z = Z_1 \qquad (4)$$

Second rotation, Fig. 4(b), is taken about the $y_1$ axis. The equations of this transformation are:

$$x_2 = x_1\cos\theta + z_1\sin\theta \qquad x_1 = x_2\cos\theta + z_2\sin\theta$$
$$Y_2 = Y_1 \qquad Y_1 = Y_2$$
$$Z_2 = Z_1\cos\theta + X_1\sin\theta \qquad Z_1 = Z_2\cos\theta - X_2\sin\theta \qquad (5)$$

Third rotation, Fig. 4(c), is taken about the $x_2$ axis. The equations are:

$$X_3 = X_2 \qquad X_2 = X_3$$
$$Y_3 = Y_2\cos\phi + Z_1\sin\phi \qquad Y_2 = Y_3\cos\phi - Z_2\sin\phi$$
$$Z_3 = Z_2\cos\phi - Y_2\sin\phi \qquad Z_2 = Z_3\cos\phi + Y_3\sin\phi \qquad (6)$$

To illustrate the use of resolvers in this type of coordinate transformation let us assume we are given a vector ($x_3$, $y_3$, $z_3$) in the aircraft coordinate system. We are also given the angle information, which is supplied by gyros. We wish to determine the vector in terms of the space coordinates ($x$, $y$, $z$). This involves a successive rotation through the angles $\phi$, $\theta$, $\psi$. The first rotation is into the ($x_2$, $y_2$, $z_2$) coordinate system using the equations:

$$X_2 = X_3$$
$$Y_2 = Y_3\cos\phi - Z_3\sin\phi$$
$$Z_2 = Z_3\cos\phi + Y_3\sin\phi \qquad (7)$$

The $Y_2$, $Z_2$ equations are similar to the simple case of a two dimensional rotation. This is because each of the three rotations keeps one axis fixed. Therefore, we can instrument the set of Equations 7 as shown in Fig. 5(a). In like manner the other two rotations can be instrumented as shown in Fig. 5(b) and 5(c). All that remains is to tie together the proper terminals as shown in Fig. 5(d) and we have mechanized the complete solution to our problem.

### Convert Angular Systems

It is frequently necessary to transform angles, instead of vectors, from one coordinate system to another. A typical example of this type of transformation is an antenna stabilization problem. We have a target at bearing angle $\alpha_3$ and depression angle $\beta_3$ with respect to the aircraft coordinates and wish to stabilize the antenna with respect to the pitch and roll of the aircraft. Pitch and roll angles are supplied by a gyro reference system. We can stabilize the antenna by deriving angles $\alpha_1$, $\beta_1$, in the ($x$, $y$, $z$) coordinate system. $\alpha_1$ and $\beta_1$ are called respectively the antenna train and antenna depression angles. In this case we can neglect the yaw angle. In order to convert these angles we assume a vector $R$ with a bearing angle $\alpha_3$ and a depression angle $\beta_3$. Then:

$$X_3 = R\cos\beta_3\cos\alpha_3$$
$$Y_3 = R\cos\beta_3\sin\alpha_3$$
$$Z_3 = R\sin\beta_3$$

Also:

$$\alpha_3 = \tan^{-1}\frac{y_3}{x_3},\quad \beta_3 = \tan^{-1}\frac{z_3}{\sqrt{x^2+y^2}} \qquad (8)$$

And, in general:

$$\alpha_n = \tan^{-1}\frac{y_n}{x_n} \qquad (9)$$

$$\beta_n = \tan^{-1}\frac{z_n}{\sqrt{x_n^2+y_n^2}}$$

Using this analysis we break our problem into three steps:

(1) Given angles $\alpha_3$ and $\beta_3$ and a reference voltage $R$ we first instrument Equations (8) to put the problem in terms of the vector coordinates ($x_3$, $y_3$, $z_3$).

(2) The coordinates must be rotated back through

the roll and pitch angles to give us the coordinates $(x_1, y_1, z_1)$.

(3) Using Equations (9) we derive the antenna bearing angle $\alpha_1$ and the antenna train angle $\beta_1$.

To solve Equations (8), consider the output equations of a resolver with one input grounded, as shown in Fig. 6(a). The equations are:

$$C = A \cos \theta$$

$$D = A \sin \theta$$

By combining 2 resolvers with one input of each grounded, Fig. 6(b), we have solved Equation (8) as required in Step 1.

Step 2 is similar to the three axis problem except that we eliminate the yaw angle resolver. The schematic is shown in Fig. 6(c).

Step 3 involves finding the arc tangents using the coordinates derived in Step 2. This can be instrumented using the circuit shown in Fig. 6(d). The servo drives the rotor of the resolver until there is a zero output on the servo input winding. At this position the other winding has maximum coupling with the flux vector formed by the two inputs. Therefore, the outputs are $\theta = \tan^{-1} B/A$ and $\sqrt{A^2 + B}$ as shown. Using this technique we can instrument Step 3 as shown in Fig. 6(e).

Combining the proper terminals of Steps 1, 2 and 3, we have the solution as shown in Fig. 7.

Note from Fig. 7 that one of the outputs of the resolver which is driven to $\beta_1$ is $R$. A rough check of the accuracy of the chain could be made by comparing this $R$ voltage with the original reference voltage. Since lengths of vectors do not change during coordinate transformations these voltages should be equal.

### Practical Applications Vary

In actual system applications, the output of one resolver cannot be fed directly into a second resolver without introducing some loading errors into the system. The accepted method of avoiding these loading effects is through the use of isolation amplifiers, with one amplifier being used for each winding. When used in conjunction with resolvers having special feedback windings· compensation for temperature and frequency changes can also be made. Overall accuracies of better than 6 minutes have been achieved in chains when compensated resolvers and isolation amplifiers were employed.

By using special loading networks and thermistors in place of the amplifiers, resolver chains can be simplified. While this method has the virtue of convenience and simplified circuitry, it is gained at the expense of some loss in system accuracy. ■ ■

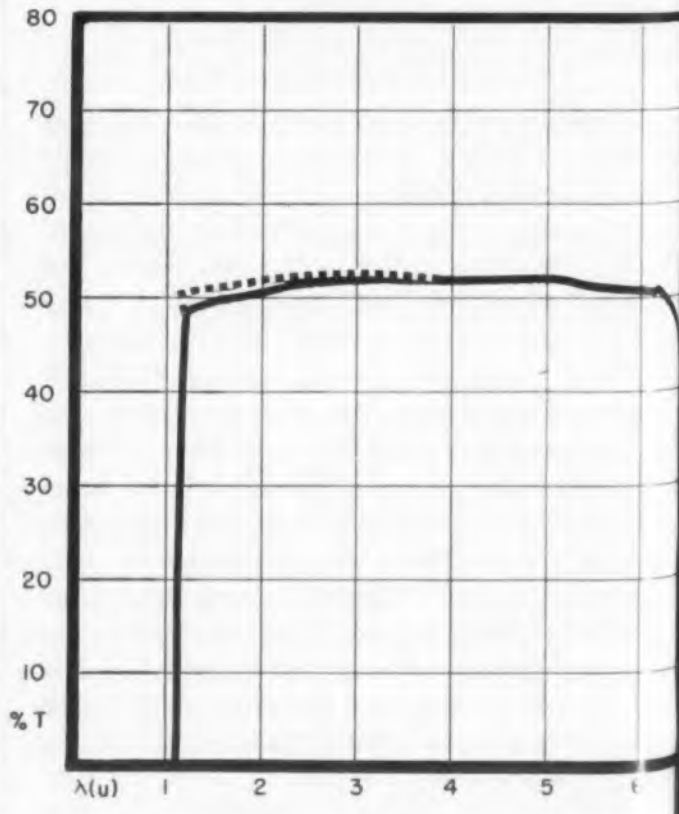
**Ballistically spherical castings** of polycrystalli silicon shown at the IRE Show. In the foreground i crude casting. After etching, the dome looks like one at the rear—note the mosaic polycrystal patte To right and left are polished domes.

# Cast Silicon I-R Domes

BLANKS, DOMES, flats and prisms of pu silicon for infrared systems are available production quantities. Cast from polycrystalli silicon instead of being ground, laboriously, fr a large single crystal, the new material sho optical transmission and scatter characteristics most identical to the single-crystal parts.

Manufactured by Hughes Products Semico ductor Division, Newport Beach, Calif., the pu polycrystalline material is cast and polished wi

**Fig. 1.** (below) Comparison of transmission and em sivity of cast polycrystalline and single-crystal silic over a 1-14 micron wavelength range.



very little waste of raw silicon. The design of infrared optics for military and commercial systems becomes considerably more economical than heretofore.

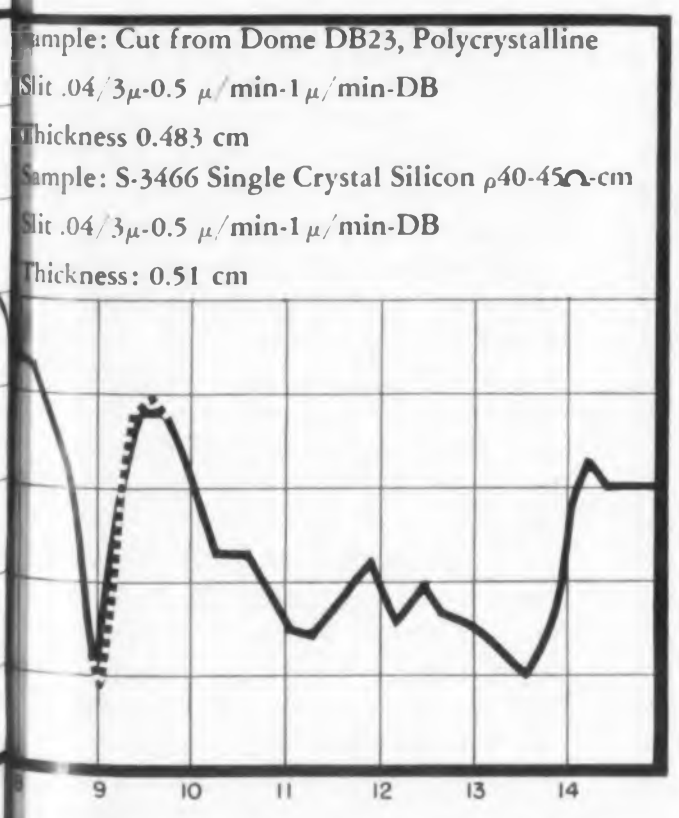
Casting, as a practical, in-production method for making infrared missile domes, was revealed for the first time at the IRE show in late March. The shiny, bluish domes shown above are ballistically spherical, pass infrared wavelengths, are opaque to light. In an infrared system an aspheric silicon lens would be protected by the dome, focus infrared radiation on a cooled or uncooled detector. Cooled detectors, which work in the three to five micron range, operate in an ambient on the order of 30 K and might consist of PbSe, InSb or GeAu. Environment ambient detectors work at 25 C, might consist of PbSe or PbTe.

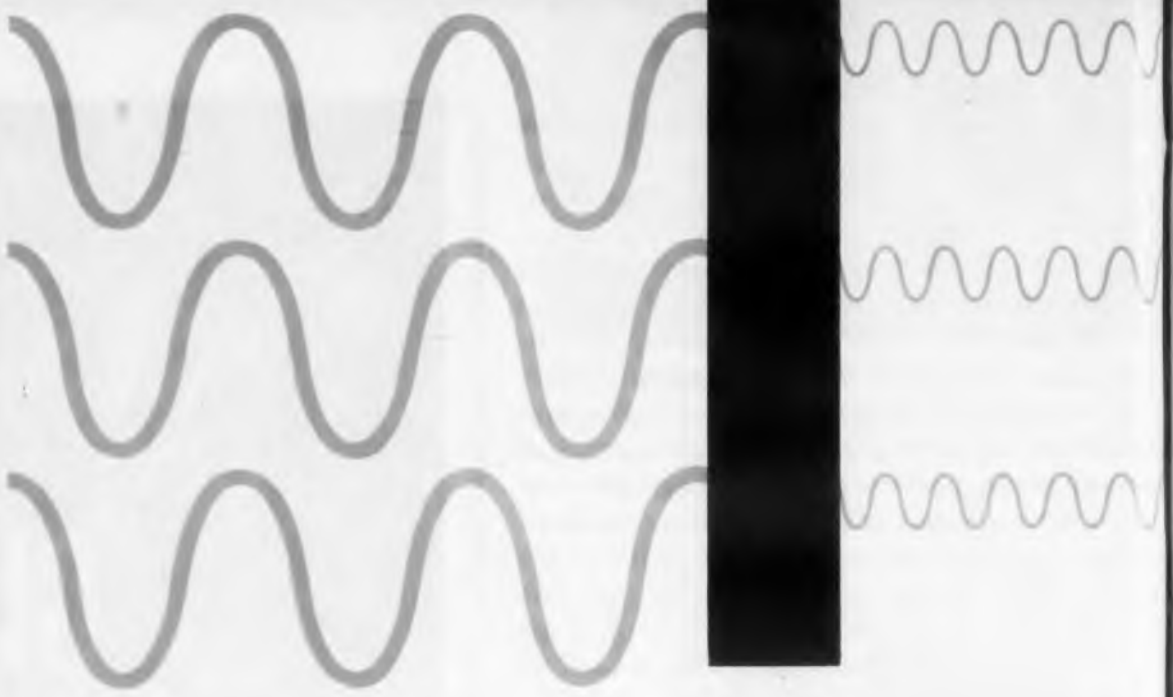
A comparison graph of transmission characteristics shows no significant difference between the cast material and grown single-crystal silicon. See Fig. 1.

Scattering was compared, again showed no significant difference, within the ±5 per cent accuracy of the test. In the test, a single crystal aspheric lens focused a collimated beam on a pinhole in front of a band-pass filter (3.0 to 4.2 micron) and a cooled PbSe detector. The beam, from an 800 K source, was chopped at 90 cps. Sample domes were placed in front of the lens.

Density of cast polycrystalline silicon is the same as single-crystal—it is apparently entirely free of voids. It has approximately 80 per cent of the breaking stress and modulus of elasticity of the single-crystal silicon.

For further information on cast polycrystalline silicon infrared components, turn to the Reader's-Service card and circle **102**.





# The New Look In Ripple Reduction


**Bernard Daien**
Kearfott Company, Inc.
Clifton, N. J.


**Engineers often use voltage regulators—not for regulation—but for ripple reduction. They pay for this in size, weight, and transistor dissipation. They don't have to.**

LARGE ripple reductions are possible with substantial weight and volume savings when transistors replace reactors.

The cascaded emitter follower shown in the figure offers lower impedance and better stability than many previous circuits that performed essentially the same function. The divider across the input provides a constant fraction of the supply voltage to the base of the driver transistor. A capacitor filters this base voltage, leaving only the dc component.

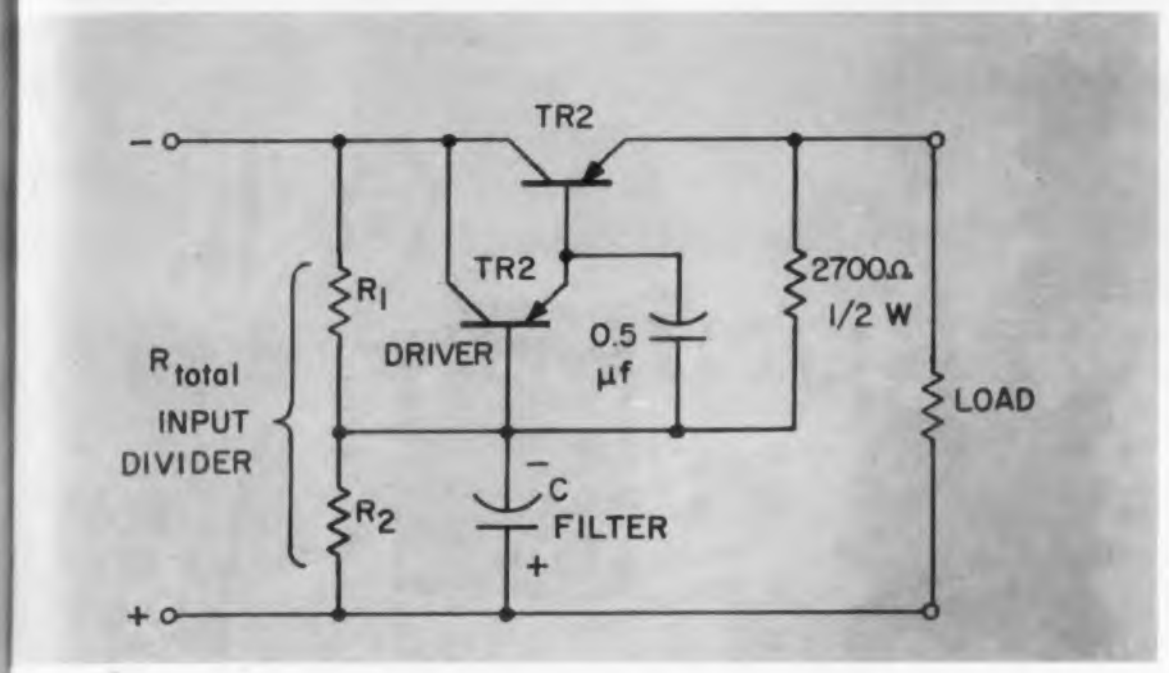
The output voltage depends on this filtered dc, and is relatively independent of the collector ripple.

Several important differences distinguish this circuit from the series voltage regulator, which it resembles.

- The output is a constant fraction of the dc input. Hence a change in input level appears at the output. This eliminates the rapid increase in transistor dissipation which occurs in the series regulator as the input rises and the transistor must absorb the difference between the rising input and the fixed output voltage. Since dissipation is reduced, the de-rippler handles heavy currents with a smaller heat sink, resulting in compact design.
- In the de-rippler the output is always less than the input. In a regulator, the input may fall below the fixed reference, in which case the circuit drops out of regulation and the output ripple rises sharply.

To prevent dropout, an *LC* filter must precede the regulator. It must have enough energy storage to maintain the input voltage during an undervoltage period. The ripple reducer does not drop out during undervoltage.

- Dc overvoltage will destroy a true reg-




**This circuit can knock down ripple** by a factor of 200. (*Tr 2* can be several transistors in parallel for high load currents.)

ulator long before it would even overload the ripple reducer. Since the de-rippler's output follows the input, it is quite difficult to develop sufficient voltage across the transistors to punch through.

### Quick Design Procedure

Values for the components in the figure are calculated as follows:

$$R_{total} = \frac{\beta_1 \beta_2 E_{in}}{10\, I}$$

$$R_1 \cong \frac{R_{total}\,(1 + 0.5\, E_r)}{1.1\, E_{in}}$$

where $E_r$ is the peak to peak input ripple, $E_{in}$ is the nominal dc input voltage, $\beta_1$ and $\beta_2$ are the dc beta's of transistors *1* and *2*, and *I* is the maximum load current.

The capacitor C is best chosen by substitution. Increasing its value will reduce the ripple till the desired reduction is obtained. Ripple reduction by factors of more than 200 are quite realistic.

The final step is to choose suitable transistors and heat sinks. The dissipation required of the transistors is approximated by the following expressions.

For transistor *1*

$$P_d = \frac{I\,(1.5 + 0.5\, E_r)}{\beta_2}$$

For transistor *2*

$$P_d = I\,(1.5 + 0.5\, E_r)$$

The maximum voltage across transistors should be held to about 1.5 plus the peak to peak input ripple.

The maximum voltage across transistors is

$$E_{max} \cong E_r + 1.5$$

### A Typical Design

A 28 v bench supply, operating from the 60 cycle line, had a 2.8 v peak to peak ripple. The ripple reducer had to provide a 24 v output with no more than 15 mv peak to peak ripple. Output current was 1 amp.

An equivalent filter would have required a 0.8 henry choke with a 4 ohm resistance. It would have weighed 2 lb. and taken up 2-1/2 x 3 x 2-1/2 in. In addition it would have required filter capacitors and mountings.

The de-rippler, in a can no larger than the choke alone, weighed 1-1/4 lb. Net saving was four cubic inches and one pound with no attempt at miniaturization.

### For Higher Temperatures

The formulas given here apply when the transistors are germanium. Where higher temperatures call for silicon transistors, which are less efficient, the dissipation and voltages will be somewhat higher. ■ ■

An *ELECTRONIC DESIGN* Staff Report:

# MICROELECTRONICS —

## a new concept in packaging

**Laurence D. Shergalis**
Associate Editor

**Less than two years ago, the flat-wafer concept of making ultraminiature electronic circuits was still in the laboratory. Since that time, with a boost from the Signal Corps and Diamond Ordnance Fuze Laboratories, the concept has developed rapidly. Industry is becoming more aware that a revolution in electronics packaging is taking place. To bring our readers up to date, *ELECTRONIC DESIGN* presents in this special report the latest techniques, processes and the current status of the work in microminiaturization.**

MICROMINIATURIZATION or microelectronics has never been clearly defined. But basically, it means making an electronic circuit as small as possible. Advantages of microcircuits are:

- Lower weight. They require little or no support and will withstand more g's.
- Better reliability. Microminature devices will perform through a wider temperature range at reliabilities about 50 per cent higher than standard units.
- Less space. Eliminating bulk and weight permits higher density packaging, thus permitting better systems for aircraft and missiles with greater fuel and payloads.

Assembly of electronics circuits has followed the classical method of hooking together a group of components with wires. Each resistor, capacitor, transformer, etc. is complete in itself and provided with leads, terminals or other forms of connecting devices.

These components are placed on a chassis and connected together with wires. More recently, they have been connected with printed wiring. But the classical form factor remains the same. For example, resistors are generally round with axial leads. Their general shape has not changed much in the past 40 pears.

New materials and methods of production have resulted in making these devices somewhat smaller (Fig. 1). This decrease in size has been called miniaturization. The common hearing aid is a good example. But the degree of miniaturization has been limited by the relatively poor utilization of space by these classically-shaped components.

With the advent of printed wiring, engineers began printing conductors, resistors and capacitors. Concentrated effort toward improving techniques of making these flat-type components and flat-type circuits has led to different approaches to microminiaturization.

### Two Basic Philosophies

One approach to the problem is concerned with putting an entire circuit on one small flat plate. The other approach is that of placing one component on an extremely small flat plate and combining these plates to form a circuit (Fig. 2).

Both of these philosophies have valid reasons for their existence and are not in competition with each other. Each has its advantages and disadvantages for particular applications.

Diamond Ordnance Fuze Laboratories, Washington, D. C. is one center of activity of work by the military in utilizing the concept of placing the entire circuit on one plate (Fig. 3). Their 2D program (2D for two-dimensional) is aimed at putting as much circuitry as possible on one flat plate. But the method is economical only where a great number of these plates bearing the identical circuit must be reproduced. It will not pay if a relatively small number of these units are to be produced. A great deal of independent research by private industry is also in progress.

To gain the advantage of economical production for almost any number of units, the U. S. Army Signal Corps has initiated an extensive research, design and development program based upon the concept of micro-modular construction. Here, Fig. 4, components are constructed on 0.3-in. sq wafers and assembled in standard-size modules of standard shapes. Each module is a complete circuit assembly. But they are generally larger than the 2D units.

Defense Electronic Products of RCA is leader contractor on this project for the Signal Corps. Their objective is to provide a production oriented microminiaturization concept. Over 25 companies are actively engaged in various phases of this pro-

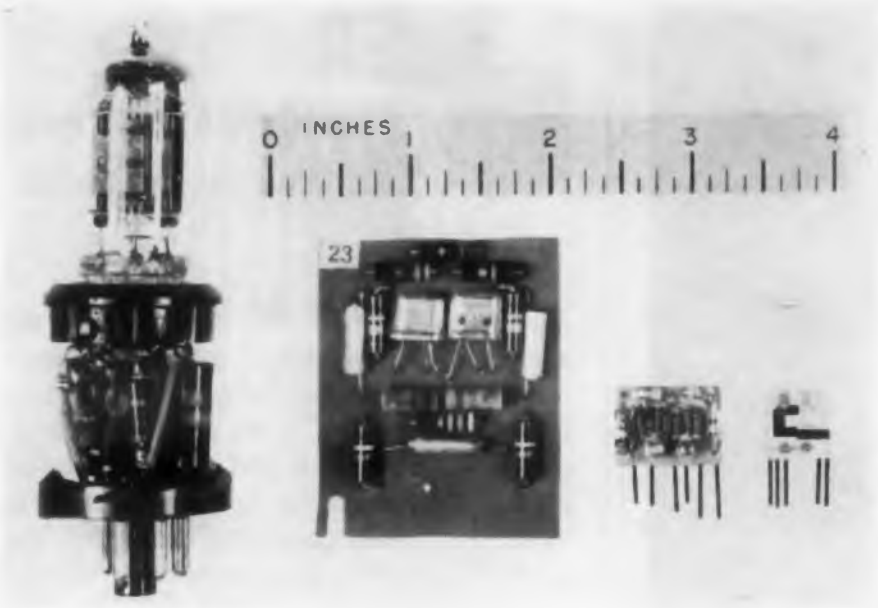



**Fig. 1.** Module using a standard miniature tube (left) compared to a transistor version (second from left), a "hearing aid" form of the same circuit (second from right) and the flat-wafer version (right).

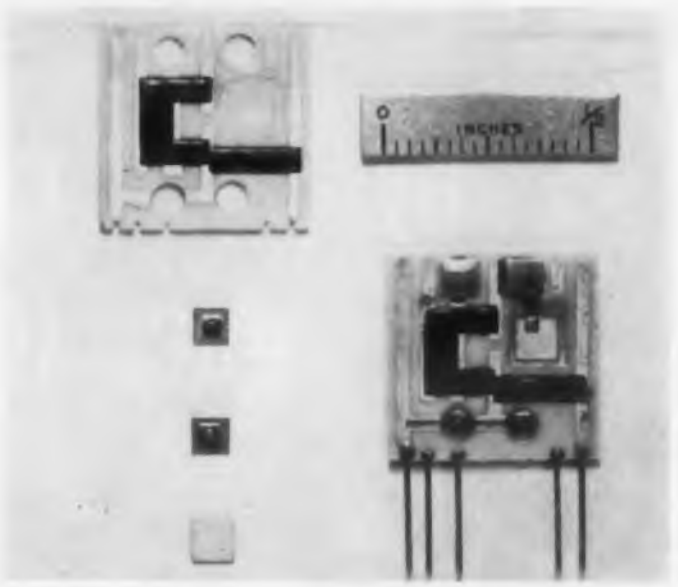



**Fig. 3.** Typical circuit assembly on one wafer using the DOFL approach. Complete module, lower right, has a component density of 2800 components per cu in.

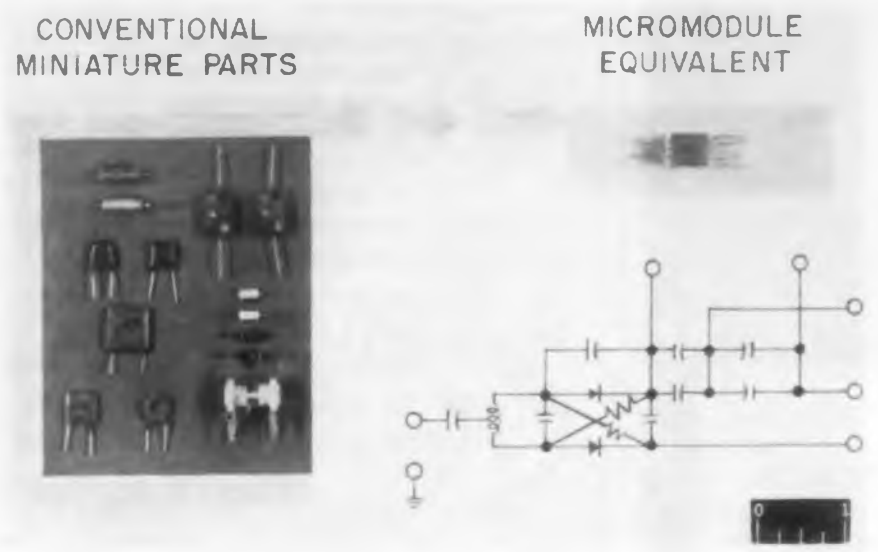



**Fig. 2.** Discriminator Micro-Module (right) contains the same number of components shown at the left.

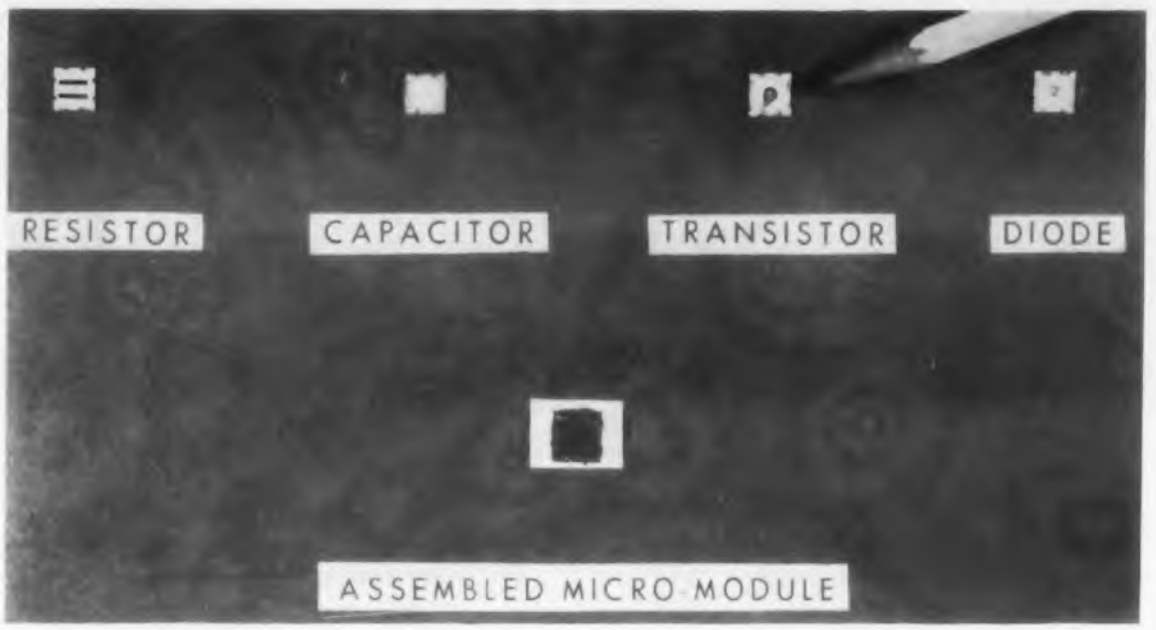
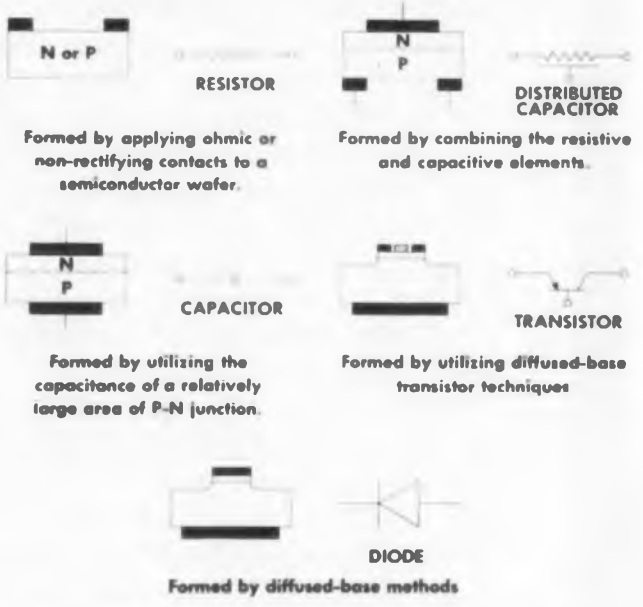



**Fig. 4.** Component parts of a typical micro-module.

## Ultramicroscopic Circuits




**Forms of Texas Instruments, Inc.** components that are integrated into solid circuits.

Last month Texas Instruments Inc. announced a major advance in microcircuitry. Complete working circuits have been made, each measuring less than 1/4 x 1/8 x 1/32-in. They have a theoretical packaging potential of over 25 million parts per cubic foot as compared to the Micro-Module's packing density of about 500,000 parts per cubic foot.

So far TI has succeeded in making development models incorporating only transistors, diodes, resistors and capacitors. Inductors still present a problem, however.

Two working circuits have been completed. One is a multivibrator circuit containing as integral parts the equivalent of 12 components—two transistors, two capacitors and eight resistors.

The other is a phase shift oscillator containing five resistors, three capacitors and one transistor.

All these components are integral parts of one piece of solid semiconductor material. Either silicon or germanium may be used. Manufacturing techniques used involved controlled masking, etching and diffusion.

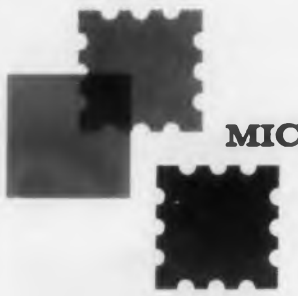
Greatest potential for these solid circuits is in applications where large numbers of repetitive circuits are required. The computer field would use units of this type to great advantage.

Samples or production units of the solid-circuit type will not be available for about a year, TI says. And then probably only a limited number of circuit types.

RCA announced last month their version of the solid circuit. Dr. Irving Wolff, vp, research, RCA Laboratories, said that their development of a computer logic circuit makes possible packaging densities up to 100 million parts per cubic foot. An important element in this development is the utilization of the uni-polar transistor.

Both active and passive elements can be built into a small piece of silicon as small as 0.000016 cubic in. To date, RCA has built only the computer logic circuit in this form. Investigation of other base materials such as gallium arsenide and indium phosphide is continuing.

RCA also recently announced the availability of their micro-modules (*ELECTRONIC DESIGN*, April 15, page 28). Sample quantities are available for sale to designers of military equipment.



## MICROELECTRONICS PROGRESS

gram with RCA and the Signal Corps with we over 100 others interested in participating.

As a result of the present micro-programs, th industry is expected to see increased use of digita equipment. In aircraft and missiles, the digital ap proach to instrumentation is becoming more com mon. This means packaging densities going up t a possible million components per cubic ft. An automatic machinery is being developed to handl the microcomponents which will result in greatl decreased production costs.

### Resistors

Several methods of making resistors are now i use. RCA, in their Micro-Module program hav prepared resistors using a duPont metal glas frit-ink. The properties of this new type ink pro vide a temperature coefficient of the order o 150 ppm/C.

Several inks have been used with resistivity fro 100 ohms per square to 35 K ohms per square Firing is done in a continuous belt tunnel kiln a about 1300 F.

Resistors of the type shown in Fig. 5 are bein used because they allow some adjustment. Resist elements of this type are being supplied by Corn ing Glass and have tin oxide as the resistive mate rial. Thus, resistors are available to the program with resistances ranging from 47 ohms to 100 K ohms.

Both Glass Products Co. and Mallory are sup plying tin oxide type resistors in the Micro-Module program. Weston Electrical Instrument Co. is sup plying 250 metal film resistor elements. The Weston process consists of metallizing the whole wafer first and then scribing the required resistor and dividing lines. Temperature coefficient of these units has been found to be less than 5 ppm/C. Value of the resistance changed about half a per cent during handling, but work is in progress to determine if this change can be pre vented by suitable coating.

Weston, now Daystrom-Weston Instrument Div. of Daystrom Inc., is making wafer-type re sistors commercially available in small quantities They expect to go into production in about months. Units now offered have resistance ran from 100 ohms to 1/4 megohm, with four resis on a wafer. Obviously these four can be connected in series. Power rating is 1/8 w at 70 C or 1/16 at 125 C. Later, units ranging from 10 ohms t

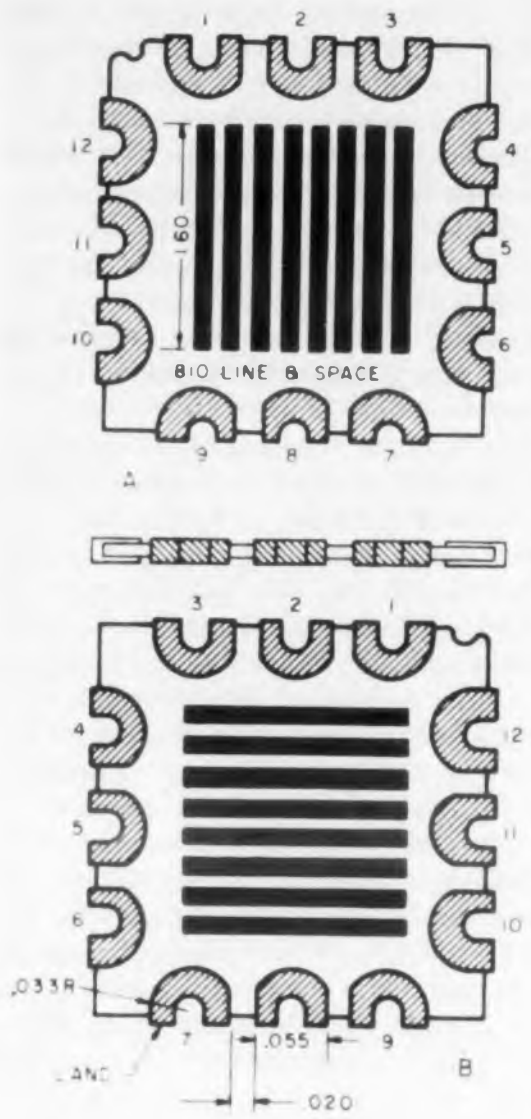



**Fig. 5.** How the resistor pattern is laid out on both sides of the micro-module wafer.

1 megohm will be available. These Weston units fulfill the requirements of MIL-R-10509C.

Allen Bradley and Chicago Telephone Supply Co. are also working on metal film resistors in conjunction with the program. Centralab is providing some carbon composition type resistors for evaluation.

Nichrome film resistors are also being made at RCA for the program. The metal film is applied by vacuum deposition through an organic film mask previously applied to the wafer. The organic film, Kodak photo resist, is applied as a solution by brushing, is air dried and then baked at 100 C for 15 minutes. The coated wafers are placed on a photographic plate having the resistive pattern design and exposed to an ultraviolet light. Then they are developed, the result being a positive photographic plate containing the open lines of the resistive pattern. The resistive film is deposited by vacuum deposition. Nichrome alloy (80 Ni:20 Cr) is deposited to give a resistive value of 50 ohms per square.

Resistor patterns are made from a drawing to determine line length and configuration based on the 50 ohms per square value. The design is then

produced on Mylar film using black photographic tape to form the proper configuration. Master patterns have been worked out to provide resistor values ranging from 1 ohm to 33 K ohms.

Problems have been encountered in obtaining fine lines using the photo resist. Feathery edges were noticed and these are believed to be a result of internal reflection of light in the glass wafers. Ceramics also show a similar lack of sharpness due to their rough surfaces.

**Tin oxide film resistors have** also been produced. Resistance values of 25 to 1000 ohms per square have been obtained. Coatings prepared on glass plates were found to be easily reproducible. Steatite and Fotoceram are also being used as substrate material.

Practical resistors of platinum-gold alloy have been produced by the Royal Radar Establishment, England. They are in production and are reported to have excellent temperature characteristics. An alloy of 80 per cent gold and 20 per cent platinum gives a resistivity of 60 microhms per cm in a thickness of 100 Angstroms. Temperature coefficient is 0.025 per cent. An alloy of 60/40 gold-platinum has been found to have a resistivity of 75 microhms per cm in the same thickness with a temperature coefficient of 0.06 per cent.

This same group is also engaged in making high resistance units from films of nickel chromium. Problems have arisen in making the extremely fine lines required. Meanwhile, engineers at the Royal Radar Establishment are continuing their search for alloys offering much higher resistance. This group has been engaged in work similar to that of the Diamond Ordnance Fuze Labs. They report that their work in making actual resistors can be adapted to making an entire circuit. The necessary resolution required for units of this type can be obtained by photomechanical processes.

Recent research at Bell Telephone Laboratories promises some interesting results in this area using the old technique of cathode metal sputtering. In this process, ionized gas molecules bombard a cathode, dislodging atoms of metal which then redeposit on nearby surfaces.

A plate of the metal to be deposited is used as a cathode. The substrate on which the film is to be deposited is placed near it. After evacuation, argon or other suitable gas is introduced and maintained at a pressure of about 40 microns. When a voltage is applied, ionized atoms of gas bombard the cathode dislodging metal atoms or clusters of atoms which then deposit on the substrate.

Sputtering is one of the most convenient methods available for the production of thin films of the high-melting point metals. Thickness of the films may be controlled within narrow tolerances.

Tantalum and titanium, melting at 3000 C and 1670 C respectively have been laid down. These film show sufficiently high resistivity to be useful as resistors.

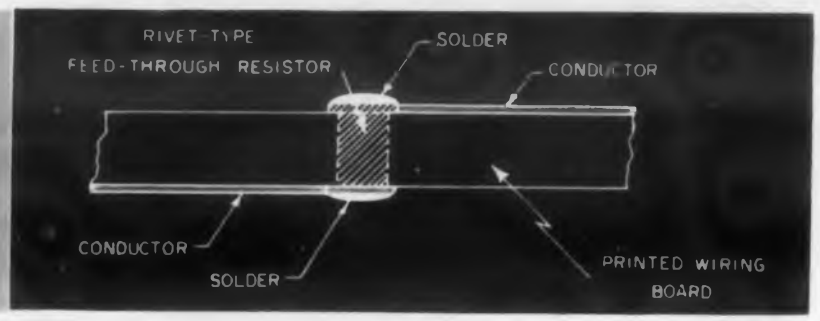



**Fig. 6.** Cross section of Bell Lab's rivet-type resistor mounted in the thickness of a printed-wiring board.

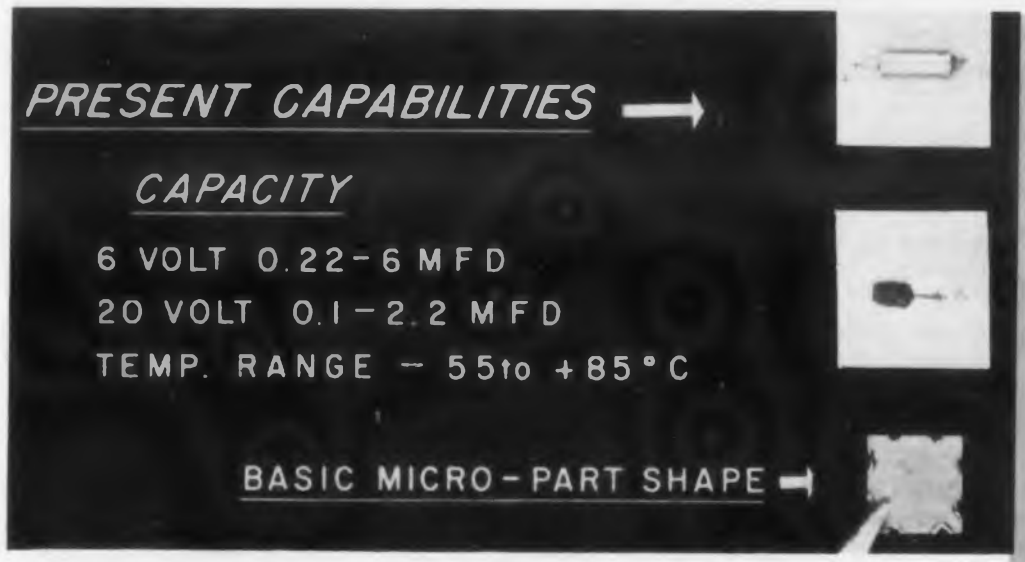



**Fig. 7.** Solid tantalum electrolytic capacitor of the current type (top). The sintered slug, bottom, has been adapted for the micro-module wafer.

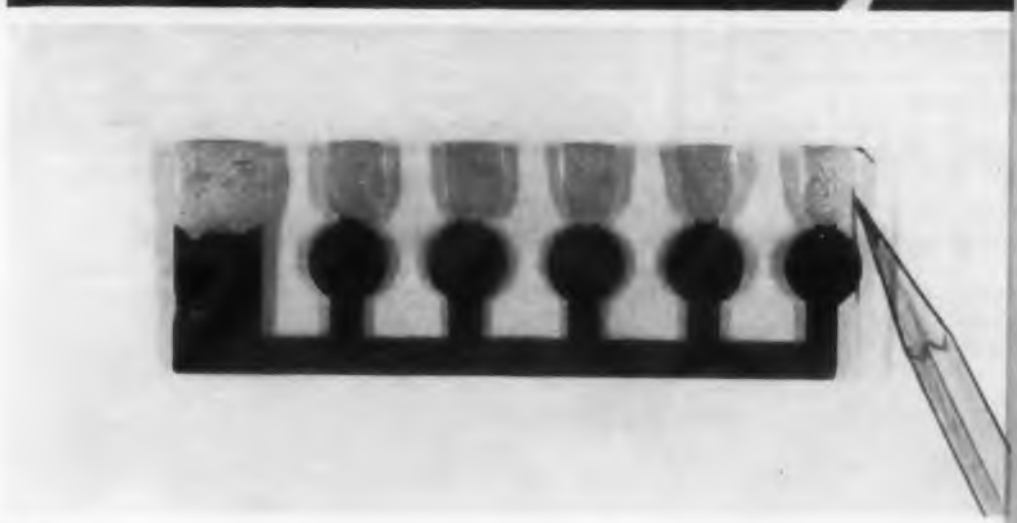


**Fig. 8.** Bell Telephone Labs used a sputtering technique to make these miniature tantalum-oxide capacitors.

### Need Fine Lines

Being able to produce extremely fine lines is important in the production of precision resistors suitable for microminiature circuitry. Bell Labs has been successful through the sputtering technique in making lines only 1 mil wide. At Diamond Ordnance Fuze Labs., lines 2.5 mils wide with 2.5 mil spacing have been successfully reproduced.

At Bell Labs another development possibly more suited to the DOFL 2D approach rather than the Micro-Module approach is the "rivet type" resistor shown in Fig. 6. Length of the resistor is equal to the thickness of the printed wiring board or the substrate on which it will be used. The resistor then, acts as a feedthrough connection between the two sides of the board. Since the ends are flush with the board surface, the connections occupy no space and the resistor is completely hidden within the thickness of the board. International Resistance Co. is also reported to be developing a resistor of the same type.

## Capacitors

Diamond Ordnance Fuze Laboratories has done some work on vacuum deposition of silicon monoxide dielectric capacitors. This material has

received a great deal of attention because of its ease of deposition. Using outer layers of various metals, it was found possible to obtain a wide range of capacitance per unit area, breakdown voltage, insulation resistance, dielectric constant and dissipation factor. The best values found were those using gold as the electrode film. It has high conductivity, resists oxidation and is easy to deposit.

Fused silica was also used as a capacitor dielectric in experimental work at DOFL. It has excellent stability and its dielectric breakdown strength is 15,000 v per mil, the highest known.

So far, the best experimental capacitors using vacuum evaporation techniques were made using dielectrics of silicon oxide and aluminum oxide. Values given for these units show a capacitance of 0.005 microfarads per square cm and an insulation resistance of 100 kilomegohms. Loss factor was less than 1 per cent.

Thin-film ceramic capacitors promising to fulfill the needs of the Signal Corps Micro-Module program were developed at RCA's Advanced Development Laboratories. Initial work produced samples in the range of 150 μμf and 300 μμf. The 150 μμf capacitors contain a 0.001 layer of dielectric material while the 300 μμf units contained twice that amount. Gold was the electrode material; film was a silica-titanate compound on a ceramic base. All the units had a Q greater than 1000 measured at 100 kc. Temperature coefficient was less than plus or minus 100 ppm/C between 25 and 300 C. Breakdown strength was better than 600 v dc below 85 C.

### Making Miniature Dielectrics

Both Mallory and Magnavox are supplying tantalytic capacitor elements to the Micro-Module program. RCA has also been engaged in the development of dry electrolytics for the program. Work has been directed toward the development of tantalytic capacitors made with sintered tantalum slugs to achieve the extremely small size necessary. A capacitance range of 1 to 50 μf is being incorporated into the module structure. An example is illustrated in Fig. 7.

R. W. Berry of Bell Labs has produced printed capacitors, Fig. 8, by a combination of cathode sputtering and chemical methods. A tantalum film of proper shape and size is first sputtered on to the substrate. Then it is anodically oxidized to form a tantaluum oxide dielectric film. The counter electrode, a gold film, is then evaporated onto the dielectric to form the complete capacitor sandwich.

Aerovox Corp. has done some development work in the Micro-Module program. One of their new designs and techniques developed is exemplified in their Cerafil capacitors announced recently.

*(Continued on page 38)*

## MICROELECTRONICS' PROGRESS

One of the most promising developments in the field of microcapacitors is the monolithic structure for ceramic capacitors. Developed by Sprague Electric Co., these units are currently being incorporated into the Signal Corps Micro-Module program.

Sprague's capacitors are high-dielectric constant barium titanate units made by a layering process, Fig. 9. This capacitor consists of five active dielectrics. An early model, for example, consisted of layers each 0.0025-in. thick, occupying a volume of 0.620 by 0.355 by 0.018 in. Capacitance of a unit this size is 0.4 μf.

Sprague manufactures two groups of capacitors by this process. One group utilizes a high dielectric constant material for bypass and coupling applications, and the other utilizes low dielectric constant materials for resonant circuits and other applications requiring high stability. Lead configuration of these units may be modified for particular applications.

Erie Resistor Corp. is marketing the Corning WL-4 miniature fixed capacitor. It is especially designed for printed-circuit applications.

Summing up the problems involved in making these extremely small units, industry must find a way to obtain high stability and low temperature coefficient. Very thin films are not practical if they are unstable. Stability will then be the dominant factor in developing a readily reproducible microcapacitor.

### Inductors

For the Micro-Module program, inductors for rf filters, both fixed and variable, and inductors to be used as transformers must meet the requirements of MIL-C-15305A. Miniature ferrite core inductors are also undergoing development to be compatible with the program (Fig. 10). Variable inductors are being considered for tuning applications, although the Signal Corps has found electric tuning particularly attractive for certain applications.

**Table 1—Characteristics of Ferrite and Metal Magnetic Films**

| | Metal | Ferrite |
|---|---|---|
| Operating Speed | 30 mμsec | 1 μsec |
| Drive Power | 400 ma into 5 ohms (transistor) | 800 ma into 50 ohms (tube) |
| Repetition Rate | 5 mc | 500 kc |

Audio, power, and pulse transformers and inductors are also under development for the Micro-Module program. These units will be required to meet MIL-T-27A.

A zero temperature coefficient is required for most inductor applications. Ferrite material with NPO (zero temperature coefficient) characteristic was investigated to determine the effects of various protective coatings. Some coatings tried seemed to subject the ferrite core to undue stress and strain under varying temperatures. This, of course, nullified the NPO characteristic of the ferrite. A foam coating avoids the problem, and further investigation may reveal other suitable coatings.

RCA and the Signal Corps are looking for cores of higher permeability. They have studied results of adding molybdenum, cobalt, barium and yttrium to nickel-zinc ferrites. Ferrites with low temperature coefficients and high Q (greater than 100) for operation at 50 mc have been prepared. Inductance ranges up to 1.5 mh.

Coil impregnants are also being sought in connection with the Micro-Module program. Some epoxy resins have been tested, but no definite conclusions have yet been reached.

Properties of the impregnant must include corrosion resistance, moisture resistance, resistance to thermal shock, and the necessary electrical properties. It must also be nonreacting with the adhesive used in bonding the coil or with the wire insulation. Work in this area is continuing.

At the Royal Radar Establishment, experiments show that metal is preferable to ferrite as a magnetic film, Table 1. Metal films have superior properties and are easier to evaporate as an alloy. Both metal and ferrite films have rectangular hysteresis loops and are suitable for use in memory planes.

These films consist of nickel-iron in the ratio of 8 to 1. Thickness must be limited to less than a micron or so because of excessive eddy current losses.

Varo Mfg. Co. has made inductors by vacuum evaporation techniques. In a simple rf or i-f transformer, a mask was used to deposit a spiral of pure metal on each side of a substrate. The inductance is controlled by the shape of the mask. The thickness of the substrate, which is the separation of the primary and secondary coils, controls the mutual inductance. Thus bandwidth can be controlled.

Inductors made by vacuum deposition possess the advantage of small size and, more important, reproductibility. By careful control of the substrate thickness and by using the same mask, these vacuum evaporated transformers come out the same.

### Semiconductors

Conventional semiconductor components are relatively large because of their cases. Actually the working material is a very small percentage of the total volume. To overcome the problem of the large transistor package, several techniques have been investigated at Diamond Ordnance Fuze Laboratories for working with caseless transistors. These techniques allow the active element of the transistors to be incorporated as an integral part of a ceramic printed plate, as shown in Fig. 11.

One of the most impressive developments in this area is the extension of photolithographic techniques for the fabrication of transistors. An-

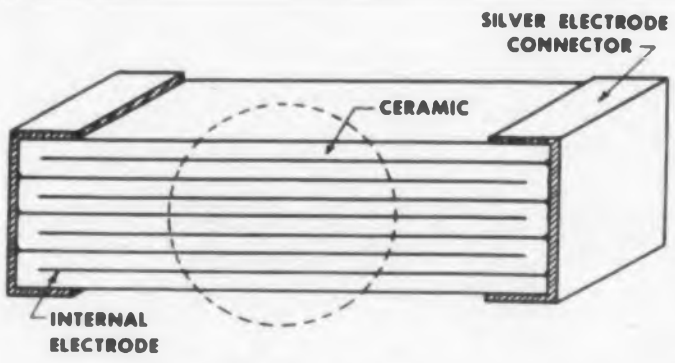



**Fig. 9.** Construction of the Sprague Monolithic capacitor.


**Fig. 10.** Possible method of mounting a toroid on a micro-module wafer.

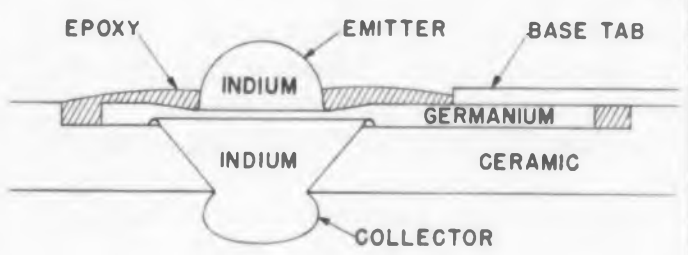



**Fig. 11.** Transistor integrated into a printed-wiring board.

other method is to mask the transistor on the ceramic plate so that the leads may be vacuum deposited to connect the base and emitter contacts to the printed wiring.

In addition, two methods of encapsulating transistors have been developed, one nonhermetic and the other hermetic. The sealed units have been subject to various environments with no change in transistor characteristics.

Two methods have been developed by RCA for microminiature transistors for the Micro-Module program. One method consists of sealing the transistor element between two wafers. Each wafer is recessed to accommodate the transistor.

In the second method, the transistor is placed in a recess in the wafer and covered with a metal lid. This circular lid is sealed to the wafer. Several methods of rf heating are being tried to effect the seals.

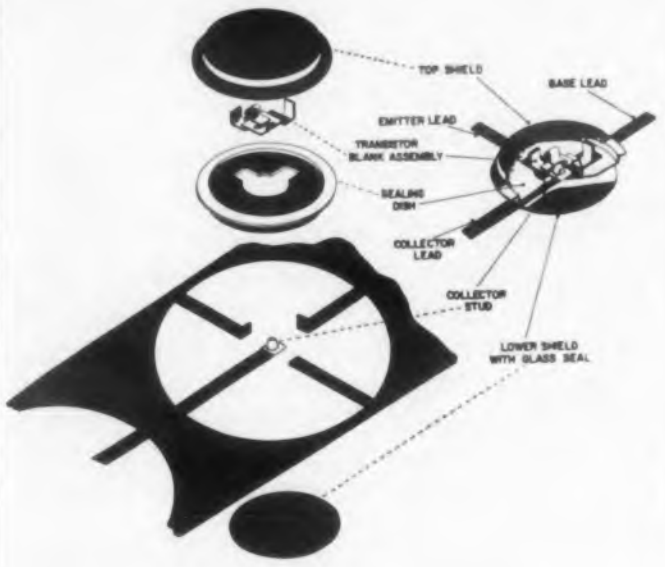



**Fig. 12.** Parts of Philco's micro-module transistor.

Philco's Advanced Research and Development group of the Lansdale Tube Co. is developing semiconductor devices for the Micro-Module program. These devices are expected to afford size and weight reductions of about 10 times that of current components, and may achieve packing densities of 500,000 to 600,000 components per cubic foot. Packing density of current equipment at best is about one-tenth that.

Basic components of a microminiature high-frequency transistor are shown in Fig. 12. The strip for electrode forming is 0.002-in. thick copper.

Hermetic sealing was a problem here, too. A minimum seal length of 0.05-in. is necessary for a reliable seal. This amount of seal length was obtained in the design shown.

An automatic production technique (Fig. 13) was worked out by Philco. Transistor elements

are dropped into the proper holes provided in the continuous strip. A cutter then slices the strip into individual wafers. Because the transistors are hermetically sealed, no special method of insertion is required.

## Other Components

Selenium rectifiers, diodes, crystals, relays, switches, miniature lamps, batteries are among the many other components now being developed in the microminiature size. Midland Mfg. is developing microminiature crystals for the Micro-Module program. These are to operate at frequencies of 7, 10, 20, 45.1, and 70 mc. Other companies also involved in the design of similar units include Bulova, Hycon Eastern and McCoy Electronics. Union Thermoelectric has also submitted a proposal in connection with the Signal Corps program.

Both Varo Mfg. and Servomechanisms, Inc. have reported work on thin film diodes using vacuum evaporation techniques. They feel that field-effect transistors may be possible using this technique also.

Miniature lamps have been developed at Diamond Ordnance Fuze Labs. Smallest of these, Fig. 14, is 0.1-in. long and consumes only 25 ma at about 1 volt. They are designed to operate on the limited currents available in most transistor circuits. They provide a very small source of il-

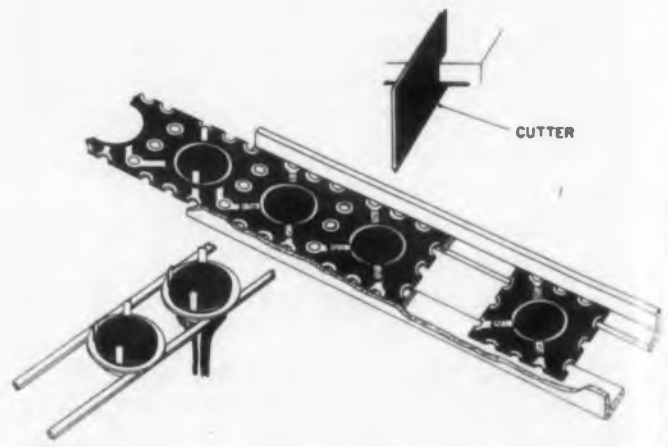



**Fig. 13.** Production of Philco's micro-transistors. Transistors are dropped into holes on the strip (left), then the leads are soldered and the wafers cut from the strip

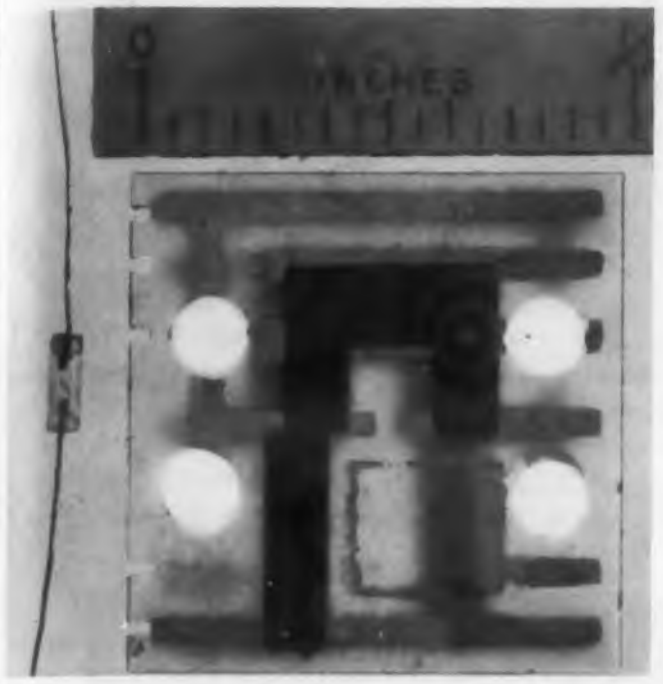


**Fig. 14.** Microminiature lamp is 0.1-in. long, draws about 25 ma at 1 v.

lumination that has been found to be visible from any point in a normally lighted room.

Batteries for microminiature applications are not yet in existence. RCA and the Signal Corps report that no work has been done in this area yet. However, the tentative specifications require batteries to have a nominal voltage of 15 volts with taps at 1.5, 3, 6, 9, and 12 volts also. Their energy yield shall not be less than 6500 milliwatt hours per cubic inch for the first 20 per cent drop. There will be a minimum of eight microminiature cell sizes with capacity ratings ranging from 10 milliwatt hours to 2000 mwh. Further, the batteries will be required to deliver at least 90 per cent of their rated performance at the end of 12 months storage at 70 F.

Switching and relay operations for all types of microminiature circuits will have to be carried out by transistors and other static means wherever possible. Other than that, the mechanical relays will have to be miniaturized as much as possible.

## Assembled Units

Both Diamond Ordnance Fuze Laboratories and the Signal Corps are doing a great deal of development work to find the best means to assemble all of these microminature components to the best advantage. Besides these two groups, many independent laboratories and industry groups have been engaged in the problem. Some of them are working in conjunction with these groups; others are working independently.

Among the private firms working on microminiaturization programs, one, Cleveland Metal Specialties Co. is already offering a microminiature computer circuit for sale. They have been

engaged with work for Diamond Ordnance Fuze Labs, and their approach follows that of building an entire circuit of one printed-wiring wafer (Fig. 15). A binary counter made up of these commercially available units is shown in Fig. 16.

Denver Research Institute of the University of Denver has been active in all phases of microminiaturization in use today. W. A. Alford, R. W. Buchanan, and R. D. Seibel are generally responsible for work at DRI and have been concerned with design of conventional tube circuitry to achieve maximum packaging density and printed circuitry with tube and/or transistor components.

An internally sponsored microcircuitry program was started at DRI with a multivibrator chosen as the test circuit. This circuit has been realized by two techniques: 1. Resistive and conductive inks and 2. Vapor deposition. Fig. 17 illustrates the multivibrator made with resistive and conductive inks. Passive elements made with vacuum deposition techniques are shown in Fig. 18. In both cases, Raytheon CK-28 transistors were used for the active elements. An operating range of from 30 to 100 kc has been obtained by variation of the RC parameters.

One of the potted multivibrators is shown in Fig. 19 with a conventional circuit beside it for comparison. The final size of the potted unit is 3/8-in. in diameter and 5/16-in. tall. Resistor elements used in this circuit are representative of high and low values required in this circuitry. Deposits of manganese can apparently be used for resistances from 20 to about 500 ohms. Tellurium is also a good resistor material for the range between 1000 and 200,000 ohms. These materials have been vacuum deposited and a 5 per cent tolerance was obtained.

In the work to date, a disk of 0.020 thick barium titanate has been used for the dielectric base. Much difficulty was encountered in the mechanical processing of the barium. Other methods are being investigated.

One possible technique for obtaining the required dielectric involves the use of aluminum foil anodized on one side followed by vacuum deposition of an aluminum or silver layer on top of the oxide. Thus, capacitor plates are formed by the original foil and the deposited material with an aluminum oxide dielectric.

Work at Denver Research Institute also covers the problem of removing the case from transistor and diode elements. One method merely involves getting the commercial units from the manufacturer without the cases and putting the active elements into the proper place in the circuit.

The other technique would use microcircuitry approaches. Coupled with this are investigations of vacuum deposition and special heat treating processes. Effects of aging and potting of circuit components is also being studied.

### Black-Box Circuits

Varo Mfg. Co. has been concerned with fabrication of a functionally complete circuit rather than an assembly of components. These circuits are achieved by the alternate deposition of the connecting materials on a suitable substrate in the proper configuration and sequence.

Varo started on this project in 1956, the objective was to perform research and development in this field for use in the Army-Navy Instrumentation program. Their work has resulted in a concept that translates a lumped-constant circuit into one of distributed constants.

For example, a substrate of a high dielectric constant is used with a deposited film of conducting material on one side and a resistive film on the other. The result is a distributed-constant RC network of much smaller size than its lumped-constant equivalent.

Other circuitry made experimentally by Varo

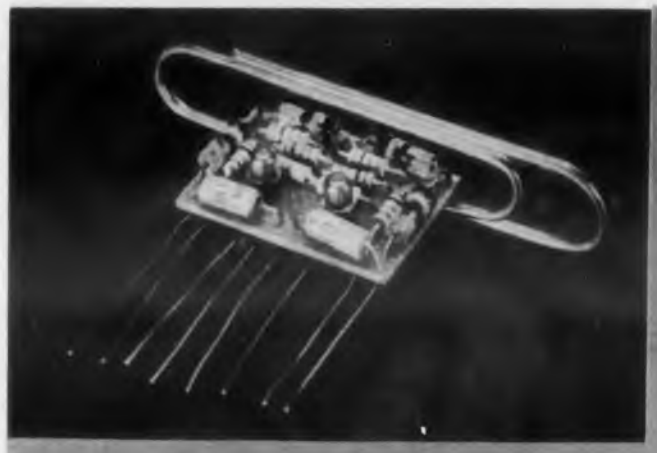


**Fig. 15.** Commercially available wafer-type circuit for a binary counter, being produced by Cleveland Metal Specialties Co.

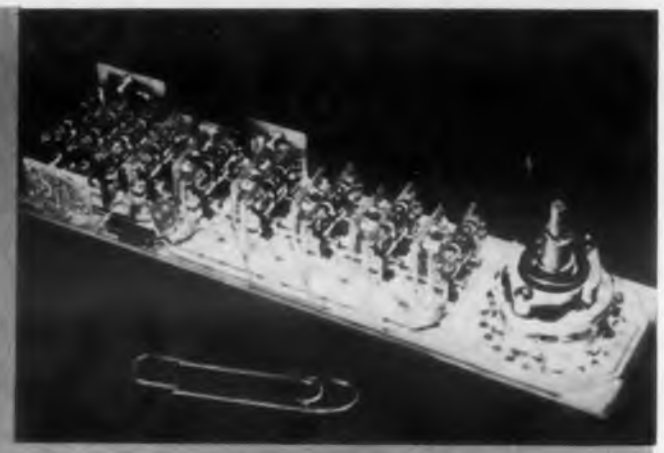


**Fig. 16.** Complete binary counter made of wafer-mounted circuits patterned after the DOFL technique.

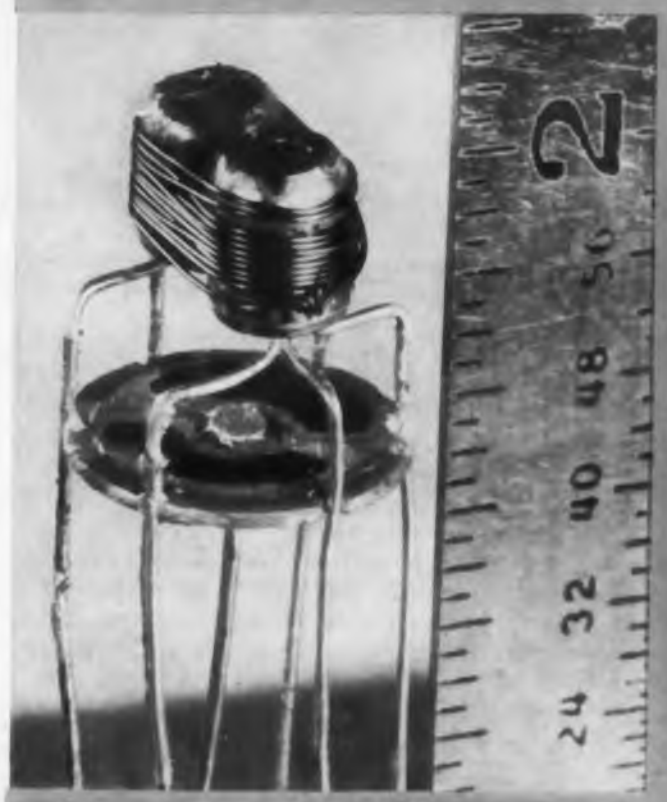



**Fig. 17.** Microminiaturized multivibrator made with resistive and conductive inks. Denver Research Institute made this unit.

**Fig. 18.** Passive elements of a multivibrator circuit made by vacuum deposition techniques.

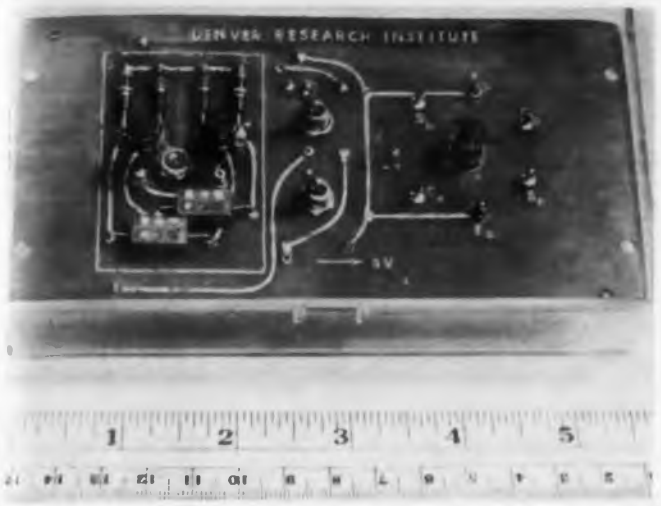


**Fig. 19.** Standard multivibrator unit (left) mounted on same printed-wiring board with Denver Research Institute's potted unit (right).

using their microcircuitry on parallel fabrication technique includes carrier generators, dc amplifiers, multivibrators as well as potentiometers, strain gauges, thermocouples and thin film magnetic memory elements.

Bell Telephone Laboratory has also been developing some concepts in microminature circuits. Their approach, like DOFL's and Varo's is to make one circuit per wafer. They prefer to think of wafers in many sizes. For example, circuits are being built on wafers 1, 2, and 3 in. square. As many components as is necessary should go on one board, they feel. And this depends entirely on the circuit subfunction rather than how many components could be jammed into that space.

International Resistance Co. is examining the microminiature problem from the production versus unit cost approach. In other words, they are more concerned with problems of reproducibility, testing, packaging, production machinery and yield factor. There must be an interaction between the production process and the product to achieve microelectronic packages that are worth making at all.

About 16 circuits made up of the Signal Corps Micro-Modules have been assembled and checked. These include rf and if amplifiers, signal generators, oscillators and others. Up to ten wafers are used in the assembly.

Several experimental units have also been built for demonstration recently. One is the RCA fountain pen radio. Also, RCA engineers have assembled various pieces of military communications equipment for demonstration.

Work in microelectronics at Wright Air Development Center Components Laboratory and the Air Force Cambridge Research Center has been underway for over a year. ARDC programs lean more toward basic research of existing physical phenomena and their possible application to microminiaturization. *(Continued on page 44)*

## MICROELECTRONICS' PROGRESS

**Fig. 20.** Typical wafer-mounted flip-flop made by MF Electronics Inc. Pencil points to transistor leads. Generous allowance after bending puts more strain on the board rather than the leads. (Right)

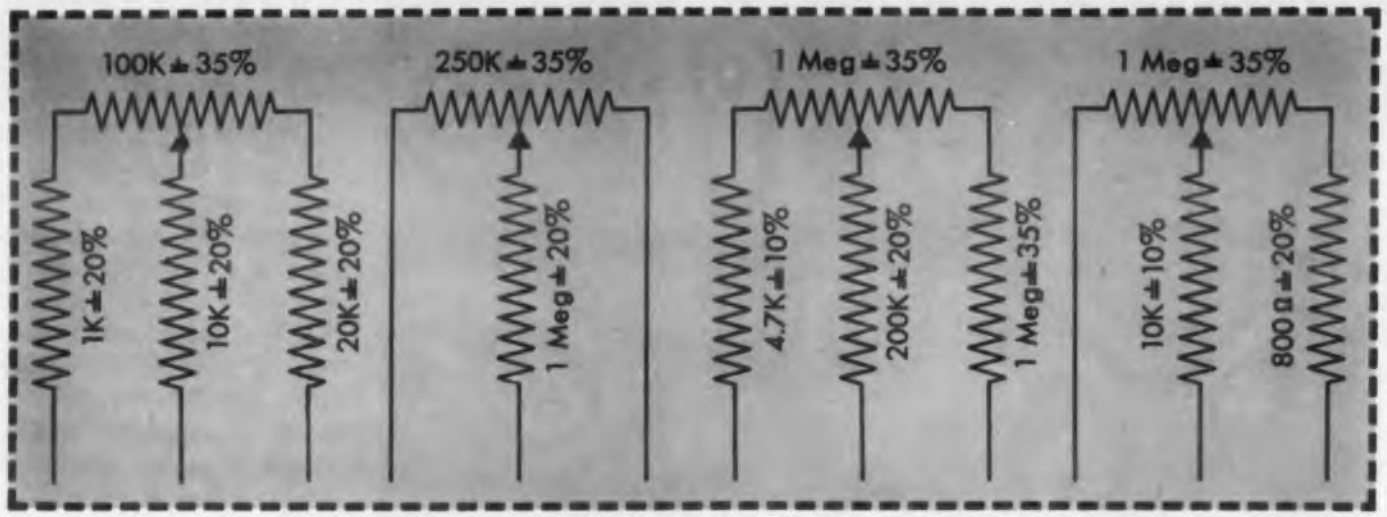



**Fig. 22.** Typical circuit for the variable-resistor assembly shown in Fig. 21.

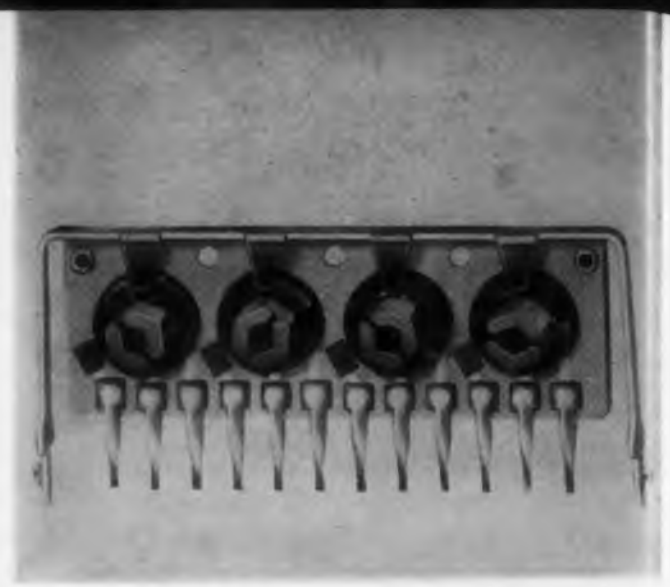


**Fig. 21.** Miniature variable resistors. This Centralab plate is 2-1/4 in. long. Capacitors and fixed resistors may be screened on the other side.

**Fig. 23.** Centralab's four-stage transistor amplifier, below, compared to wafer-type assembly of the same circuit, top. Single stage amplifier made by layering techniques is at the right.

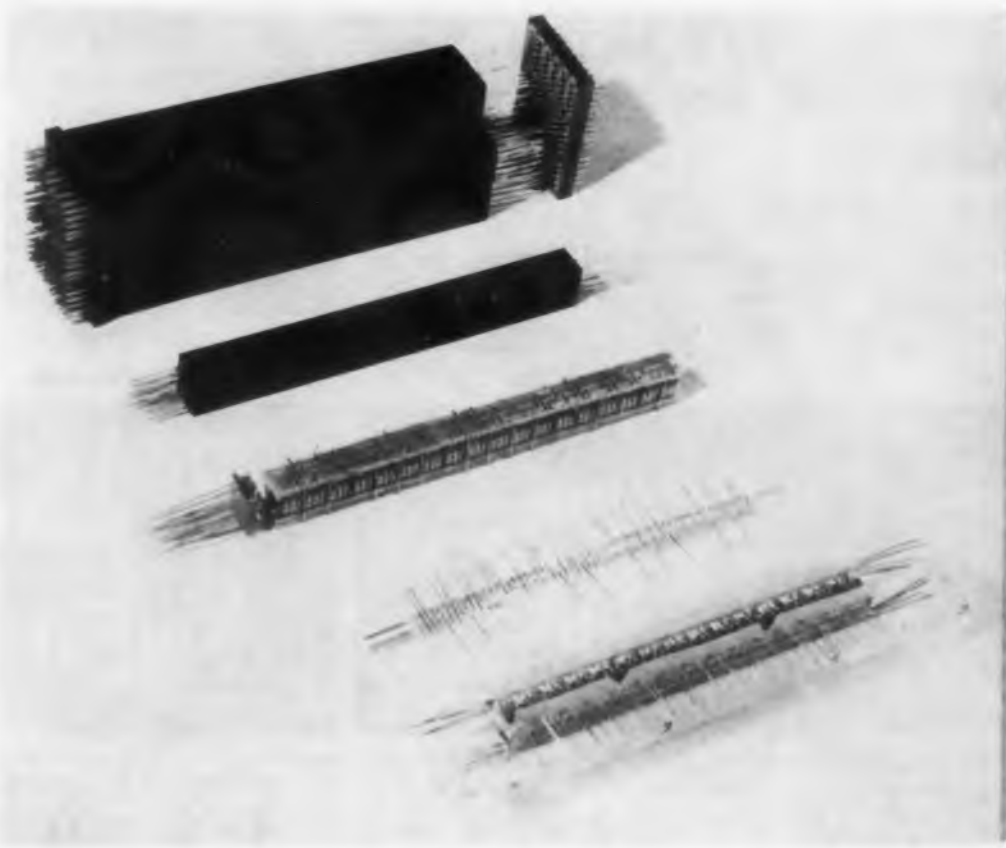


**Fig. 24.** Computer, upper left, is constructed using the high-density electronic packaging process devloped by Sippican Corp. Lower right shows the stick, being constructed, above that the wiring subassembly, next above that the completed stick, and the encapsulated stick is shown below the complete computer. Complete unit contains 2500 components and measures 1.8 x 2.7 x 6 in.

Modules about the size of a postage stamp have been produced by M F Electronics Co. These units are in the form of flip-flops, multivibrators, oscillators and others. They are about 5/16-in. thick and have a components density up to 125,000 parts per cubic foot.

A typical flip-flop made by M F Electronics Co. (Fig. 20) shows on method for mounting transistors in tight places. Here the transistors have been inserted into the board through hole placed so that when the leads are bent, the strain will be taken by the board. This relieves the strain on the glass header and special bending tools are not required.

Centralab introduced the concept of packaged circuits in connection with military devices manufactured during World War II. Their basic philosophy of their approach has been to develop packaging methods of maximum flexibility that can be adapted to the specific requirements of a given product or circuit.

The objective on their standard PEC Couplates has been to design a package that is essentially

two dimensional, eliminating thickness as a dimension of the circuit. A thin ceramic plate with wiring, resistors, capacitors and other components, printed or screened on it, is the basic form. Many times, however, to achieve maximum component density and take advantage of the space available, custom built shapes are used. The plate also serves as a base for the attachment of other components, such as variable resistors, transistors, diodes, etc., that cannot readily be reduced to a two dimensional form.

A typical example of this technique is illustrated in the multiple miniature variable resistor shown in Fig. 21. In addition to the four variable resistors, as many as nine fixed resistors can be screened on the same ceramic plate. Fig. 22 is its schematic. Fixed capacitors, transistors and other components can be attached to the reverse side of the ceramic base plate and, where fewer variable resistors are required, the entire package can be made proportionally smaller.

In some applications, Centralab found that the two dimensional concept results in a package that requires a larger area than might be available in the equipment. Under these circumstances a layering technique (not to be confused with module construction), utilizing several ceramic plates, is used. Under certain circumstances this might result in a package of greater thickness, but of such a shape (Fig. 23) as to be better adapted to the available space. Here, the Centralab TA-11 unit contains a transistorized four stage amplifier constructed on a ceramic plate. This same four stage amplifier constructed by a layering technique is shown directly above the TA-11.

### Packaging with Standard Parts

High Density Electronic Packaging is the name used by Sippican Corp. to describe their method of assembly. Their objective has been to develop an economic process for improving packaging density by more than one order of magnitude over the best density obtainable with printed circuit techniques. This has resulted in a series of developments in layout technique and positioning devices which use photographic processes.

Sippican uses spot welding for making most of the connections and have developed ways of achieving totally "hard" cabling systems which eliminate the "haywire" needed for conventional assemblies. They are using a variety of techniques for heat removal with considerable success.

High Density Electronic Packaging is complementary rather than competitive with both major Micro-Module programs. The standardized modules contemplated in the Signal Corps program will demand interconnections, and the module groups so developed will need cabling systems of one sort or another. High Density Electronic Packaging is a process involving a depth

of techniques, but two of its major features are a system for highly compact intramodular wiring and a number of techniques for "hard" intermodule cabling. These techniques, which are themselves in a state of rapid evolution, support the Micro-Module program.

High Density Electronic Packaging (Fig. 24) results in a density of well beyond one order magnitude improvement over printed circuit techniques, the typical 30x reduction in space being approximately 1.5 orders of magnitude. The density figure obtainable over a complete system with High Density Packaging, using currently available and well-proven components, runs in the region of 1 or 2 x $10^5$ components per cubic foot. Announced objectives of the micro-module program are considerably below this density level; 600,000 components per cubic foot being a figure which is often mentioned in relation to parts of systems, with 250,000 per cubic foot mentioned for complete systems.

## Variable Components

It is generally agreed that variable components should not be used. Variable capacitors are too bulky and may be replaced with a few smaller components. Electric tuning by means of Pacific Semiconductor's Varicap is one possible way to eliminate variable capacitors.

RCA and the Signal Corps eliminate the usual variable tuning of if transformers by using a deposited metal capacitor which is tuned by eating part of one electrode away with an abrasive spray. Thus, an if amplifier is tuned by "sanblasting" the capacitors until the right value is reached.

While rotating, or adjustable components can be made very small, the limiting factor is the size of the operator's hand or fingers that has to turn the knob. There is little problem when the adjustment is made by means of a screwdriver. But a continuously tunable radio receiver or a device requiring manual switching or operation of any kind cannot be made so small that the controls cannot be operated.

## Interconnection of Modules

Interconnection of microminiature devices is of great concern to everyone working in the field. Here reliability becomes a problem. More important is the fact that the connections between n od-

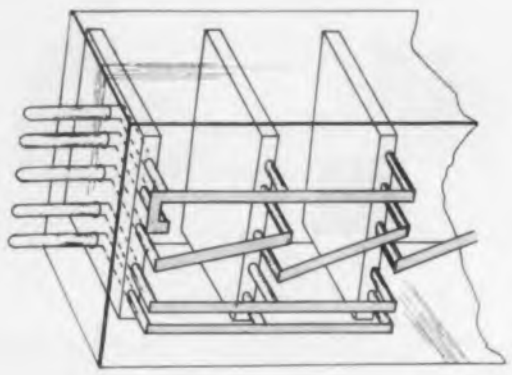


Fig. 25. How a stack of DOFL's 2D wafers can be interconnected. Interconnection wires are deposited by copper reduction.

ules or components may become larger than the assembly itself.

Methods for connecting extremely small wafers having volumes of about 0.005 cu in. have been under investigation at Diamond Ordnance Fuze Labs. Their basic technique involves stacking the wafers so that all leads protrude from one side of the assembly (Fig. 25).

The assembly is then encapsulated and the side containing the leads is faces off to expose the cross-sections of the wires. These are the interconnecting points. Interconnecting these points was accomplished using chemically deposited copper or by printed silver wiring.

Finer connections were produced using the deposited metal method than with the screened silver method. In the latter method, ink flows through the stencil, resulting in wider lines than desired. It should be noted also that interconnecting lines have a finite resistance and must be taken into account in the circuit.

Interconnections of the Signal Corps Micro-Modules are made between the wafers by conductors placed in the groove cut into the edges. By properly positioning the wafers and locating component leads, an entire circuit can be wired using the 12 connecting wires.

To interconnect the modules, RCA and the Signal Corps are investigating the use of Flexprint, a flexible printed-wire cable made by Sanders Associates.

According to Sanders, a Flexprint wiring system provides a degree of space conservation proportional to that offered by the module itself, while affording the production uniformity characteristic of its photo-mechanical manufacturing process. Sanders' chief efforts have been directed toward increasing the density of interconnecting wiring within and between assemblies of both conventional and micro-size. The ultimate size of a functional cluster or train of modules depends to a great extent, they feel, on the physical characteristics of the wiring system used to interconnect its individual units. *(Continued on page 48)*

Bending radius is the most significant figure in terms of volume saving if the full potential of the micromodule concept is to be realized, and the amount of space occupied by each bend in the wiring system must be held to a minimum if the overall group is to be packaged in the most effective manner. Sanders' experiments indicate flexible printed wiring interconnection of two mircromodules at a volume penalty of only 0.014-in. This is the thickness of copper conductor that can be bent back on itself while still providing adequate (0.0012-in.) insulation at the outside radius of the 180 deg bend. One form of flexible interconnection is shown in Fig. 26.

Sanders estimates a volume saving of 50 per cent achieved by making interconnections on a flat layer of flexible circuitry and post-forming the layer around a module grouping, Fig. 27, instead of making wire interconnections. The saving is 90 per cent compared with conventional printed circuit techniques at a standard center-to-center distance of 0.4-in.

Complex wiring harnesses have also been constructed using a new matrix-forming technique which permits feeder connections to be attached at any point along a main conductor by either spot welding or soldering, with complete insulation of the joint from both atmosphere and adjoining circuits. Investigations in the area of sonic welding indicate that this method of joining conductors is also capable of development, with the possibility of permitting further reductions in the size of both micromodules and interconnections.

### Production

Saving space and weight is not the only advantage of microminiature devices. Since the parts are generally uniform, they lend themselves easily to automatic production methods.

Micro-Module wafers were designed with production in mind, and equipment has been de-

**Fig. 26.** Flexible printed wiring harness developed by Sanders Assoc. for interconnection of micro-modules

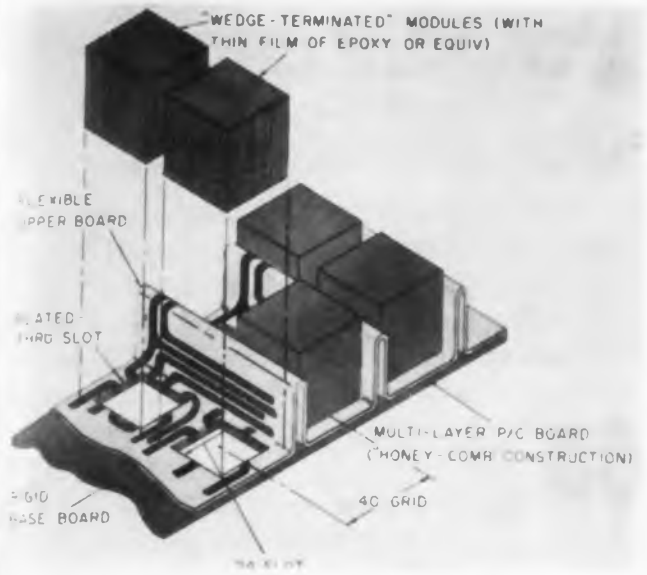



**Fig. 27.** How Sander's Flexprint wiring can be formed to make the interconnections between modules.

signed for automatic assembly of the wafers. While this is preliminary equipment, the final phase of the program will involve the design and construction of prototype production machinery. All phases from production of the components, their assembly and their integration into equipment subassemblies is part of the program.

Diamond Ordnance Fuze Laboratories has conducted a survey of equipment now available or adaptable to production of these units. Their survey covers all types of circuit elements, discusses their properties as related to physical handling, and some equipment that might do the job.

## For the Future

Engineering samples of Micro-Modules will be available to the military for prototype development late this year. Copies of 17 types of components currently under development will be supplied to equipment manufacturers. They will familiarize themselves with a few working models. Status of the Signal Corps Micro-Module program will be detailed in the May 13th issue of ELECTRONIC DESIGN in an article by Vincent Kublin.

Circuit designers will have a major role in the future of microelectronics. Their job will be to design circuits to eliminate large volume components. Almost every branch of science will be involved in microminiaturization.

And the importance of the concept is well illustrated by a statement made recently by W. Walter Watts, Group Executive Vice President of RCA. He said, "At the risk of appearing brash, I want to make clear at the outset my belief that the revolution now taking place in materials, devices and techniques in what we call electronic components will reshape the entire electronics industry in the next few years." ■ ■



* *Quotation from "Designing Electronic Equipment for Maintainability"; Machine Design, July 12, 1956.*

# Random Reliability Notes

DESPITE the plethora of papers written on Reliability In Electronics, the topic continues to provoke discussions and disputes. The final chapter on the subject has not been written, and there is still much talk on such related matters as cost and methods of achievement. That reliability is desirable is one of the few areas where agreement exists.

Explaining why unreliability exists, H. T. Hallowell, president of the Standard Pressed Steel Co., told the Franklin Institute recently that in satellites, in missiles and even in consumer appliances, performance criteria are being set on the basis of price in an attempt to save "pennies." He said that the consumer repair bill was 20 billion dollars annually.

More reasons behind unreliability: Equipment and part manufacturers compete with each other on the basis of design, price, delivery, and more recently, reliability or trouble-free operation. So explained R. F. Edwards in a paper called "The Reliability Game" at this year's IRE Convention.

"The control system in use by these groups is a democratic one that sets the punishment level for poor reliability at that of the manufacturer of the parts with the most marginal reliability.

"The solution is simply to alter the wording of the purchase contracts all down the line to reflect the true value of reliability. This will automatically change the structure of the organizations to those more suited to produce reliable products."

### The Cost Of Reliability

On the subject of cost we reported in the January 7, 1959, issue of ELECTRONIC DESIGN that, "Extensive tests are fine for reliability—but the price is high in dollars and time."

Even before the issue had been mailed we received a letter from one of our readers who reported: ". . . If a supplier has a single High Reliability Specification against which to process his parts, he can certainly do the processing much more economically than by manufacturing pieces against a number of individual customer's specifications. An a matter of fact, our Specification S-1002 only cost a 30% premium over base prices which is not only much less expensive than we could process against customer specifications, but really is a very nominal sum for the customer to pay in order to have a good reliability assurance.

". . . Many of our customers are dropping their own processing specifications in favor of purchas-

## Failure Rate in a Typical Electronic System

| Element | Population Density Ratio | Quantity Per System | Failure Rate Per 1,000,000 Hrs. | System Failure Rate 1,000,000 Hrs. | Failure Rate % |
|---|---|---|---|---|---|
| Tubes, Transistors | 1 | 100 | 1 | 100 | 2.71 |
| Connectors | 1.01 | 101 | .8 | 80.8 | 2.2 |
| Diodes | 1.1 | 110 | 4.5 | 495 | 13.4 |
| Gyros | .01 | 1 | 50 | 50 | 1.35 |
| Inductors | .02 | 2 | 2 | 4 | .1 |
| Motors | .03 | 3 | 50 | 150 | 4.06 |
| Potentiometers | .26 | 26 | 40 | 1040 | 28.25 |
| Relays | .15 | 15 | 25 | 375 | 10.23 |
| Resistors (fixed) | 4.4 | 440 | 1.4 | 616 | 16.76 |
| Switches | .11 | 11 | 10 | 110 | 2.9 |
| Transformers | .09 | 9 | 10 | 90 | 2.44 |
| Choppers | .01 | 1 | 5 | 5 | .13 |
| Printed Ckt. Board | .2 | 20 | 1 | 20 | .54 |
| Soldered Connection | 10 | 1000 | .4 | 400 | 10.84 |
| Capacitors | 1.8 | 180 | .84 | 151.2 | 4.09 |
| | | | | Total 3687.0 | |

**This data was extracted from inherent reliability studies made at Autotechnics, Division of North American Aviation, Inc. In the typical system 3687 failures occurred during an operating period of one million hours. The Mean-Time-To-Failure, the reciprocal of the failure rate, is 271.2 hours. The data was in a paper presented by I. G. Rabbin at the recent EIA Conference on Reliable Electrical Connections.**

ing pieces against our standard document." This letter cheering the merits of standardization came from C. H. Tuttle, Jr., of Vitramon, Inc.

### Milspecs Reduce Costs Says One Reader

High reliability military specifications are not raising costs writes another one of our readers. ". . . Every large manufacturer of capacitors has made application for Q.P.L. testing under Mil-C-26244 (USAF). Within several months one of the largest capacitor companies was able to reduce prices approximately 25%." So says F. J. Ruther of Dayton, Ohio.

Mil-C-26244 specifies both a failure rate and limits on confidence numbers.

### Milspecs Confuse Says Another

Speaking of Milspecs in general and mentioning Mil-C-26244 in particular, a representative of a capacitor company we recently interviewed said: "Milspecs sometimes hinder. In Mil-C-25, the bible, tab construction is called for. This is unreliable, compared to extended-foil construction, though somewhat smaller and cheaper. Mil-C-25 doesn't recognize today's high vibration requirements, calling for only 55 vps.

"Other specs attempt to supplement this spec. Mil-C-14157 and Mil-C-26244 are two of them. They create confusion and havoc in the field. To get a high reliability product, which 14157 and 26244 call for, we have to charge for the production process because more quality control is involved. But many companies demand high reliability and are unwilling to pay for it." He said that Mil-C-14157 and Mil-C-26244 should be combined and used as a universal spec because they are very similar.

And so the debate continues.

### Computers Will Play Bigger Part

"Future military performance requirements may preclude important selections of alternate solutions to tradeoff problems by informal means," said D. Ehrenpreis at an IRE Long Island Chapter Meeting, speaking on Reliability. He is a consulting engineer serving the Countermeasures Division of the Sperry Gyroscope Co.

"Formal calculations with mathematical relationships will provide a more logical engineering-like approach to decision-making.

"It is predicted that one major aid in meeting the challenge of today for developing future military electronic equipment will be the greater use of high-speed digital computers.

"Organizations must become aware of the types of problems which lend themselves ideally to solution by analog or digital computers. The next step is to set up and arrange the analytical format for minimum computer programming and rental time." ■ ■

# Design Data on Rechargeable Dry Cells

NICKEL-CADMIUM sealed cells have achieved extremely high interest among design engineers in the past few months, with the advent of lines of standard dry-cell replacements. We review here some of the later developments in rechargeable dry cells.

Sealed nickel-cadmium batteries of French design, distributed and partly manufactured by Gulton Industries, Metuchen, N. J., cover a wide range of sizes, the most popular being a button cell and a D cell. Capacities range from 100 mah to 1750 mah.

D-Ac, a pressed powder type of nickel-cadmium battery from Germany has been marketed to some extent in the United States by Burdgess Battery Co., Freeport, Ill., and Gould National Batteries, Nicad Div., Easthampton, Mass.

Of entirely American manufacture, a very complete line of dry-cell replacements is being marketed by Sonotone Corp., Elmsford, N. Y. It includes the 1/3-C, 1/2-C, 1 x 0.225, 1 x 1/4, 1/4-D, D and F sizes, as well as the very popular "pencil light" AA size used in meters and portable test equipment. Employed in equipment drawing 360 ma, the Model S101 AA battery should last an hour before recharging; at 90 ma, about 4-1/2 hours; at 20 ma, some 21 hours. Discharge curves for the Sonotone Model S103 D Cell are shown in Fig. 1. This battery is designed to replace the D-size dry cell. Note the relative flatness of the curves. During continuous use until discharge, little deterioration of performance is observed in equipment using the battery.

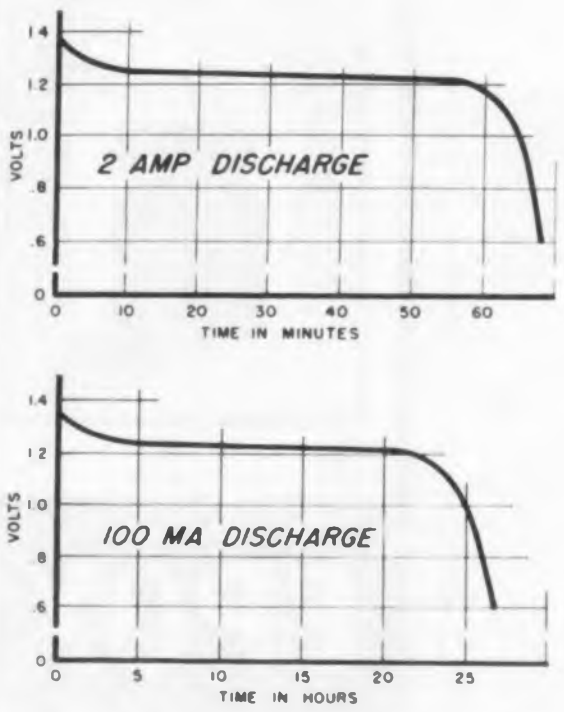



**Fig. 1.** Typical discharge curves showing constant current output.

An outgrowth of work in reliable space platform batteries, the rechargeable sealed sintered-plate Ni-Cd cells are claimed to last "for the life of the product" in which they are used. Life tests to 10,000 cycles have been made, and 20,000 cycles without deterioration is hoped for.

Any of the batteries can be stored without deterioration at temperatures of −65 to 160 F. A standard recharging will bring the cell back to full operating charge. A cell will maintain a usable charge for six months without recharging.

Sealed sintered-plate construction, claims Sonotone, is the key to the batteries' long life.

Each cell is made up of plates which have a foundation of nickel wire mesh. Sintered to the mesh is a carbonyl nickel powder which forms a porous surface, giving a larger area than would be possible using a flat plate.

Nickel oxide is the active material in the positive plate, cadmium in the negative. The electrolyte is a 30 per cent by weight solution of potassium hydroxide in distilled water. The entire construction is sealed.

The low internal resistance of the sintered plates allows a high discharge rate—limited only by the short circuit peak. Pulse discharges as high as 40 times capacity are possible.


Fig. 2. Sonotone rechargeable battery has built in charger.

Sealed Ni-Cd cells can be discharged over a temperature range of —40 to 160 F. At —40 F the cell delivers 50 to 70 per cent of the room temperature capacity, while at 125 F it delivers from 80 to 95 per cent.

So far the only battery package containing a built-in charger is the flashlight cell of Fig. 2. It is the size of two end-to-end D cells. Per-cycle use in a flashlight is about two continuous hours. To recharge, the top is unscrewed and the cell is plugged into a standard 110 vac wall receptacle. A built-in transformer steps down the voltage: and a silicon diode rectifies it. Optimum charging rate is 16 hours—at this rate the cell can be left plugged in for months without any damage. It will last at least 10,000 charging cycles.

Cost of the flashlight battery is on the order of $5.00 for small orders, less than half that for large orders. For batteries without the internal charging mechanism, an inexpensive charger can be purchased from Sonotone.

For further information on these rechargeable sealed sintered-plate Ni-Cd cells, turn to the Reader's-Service card and circle **103**.

# NEW PRODUCTS

*Covering all new products that might generally be specified by an electronics engineer engaged in the design of original equipment.*

## MULTI-WIRE FABRIC

**Depending on the diameter** of the wires used, this flat belt of interwoven copper wires can pass through a clearing of less than 1/32 in. high. The teflon-coated wires are run side by side in perfect alignment. These are woven together by cross threads of nylon, fiber glass or teflon yarn. Wires are of different colors to provide immediate identification for each individual wire from either end. Designed for aircraft or missile applications, the wire fabric can be made any width, the number of wires per inch being determined by the diameter of the coated wire used.

The Fletcher Works, Inc., Dept. ED, Philadelphia, Pa.

CIRCLE 44 ON READER-SERVICE CARD

## ROTARY SWITCH

**Any wafer** of this rotary switch lifts out instantly without unsoldering or disassembling for fast, easy cleaning or instant replacement. Switches are available in sizes approximately 2 x 2 in., 3 x 3 in., and 4 x 4 in. with lengths to accommodate up to 36 wafers. There is an almost unlimited choice of switch circuit configurations. All connections are to a single bank of receptacles and are accessible from one side of the aluminum housing. Contacts are silver, gold or rhodium plated on a copper base.

Chicago Dynamic Industries, Inc., Precision Products Div., Dept. ED, 1725 Diversey Blvd., Chicago 14, Ill.

CIRCLE 45 ON READER-SERVICE CARD


## CIRCUIT PACKAGES

**These circuit packages** can be used to simplify equipment assembly, reduce production errors, and increase reliability, They contain semiconductor devices and other components connected to provide the desired circuit. Many different types of circuit packages are available, including: bridge rectifiers; phase comparators; diode switches; amplifiers; and flip-flops. The final assembly is light weight and free from atmospheric effects.

Raytheon Mfg. Co., Semiconductor Div., Dept. ED, 215 First Ave., Needham Heights 94, Mass.

CIRCLE 46 ON READER-SERVICE CARD

## INDUCTORS

**These metallized glass inductors** are designed for tuned circuit applications at frequencies above 30 mc. Operating temperature range: from −55 to +125 C. The temperature coefficient ranges from 8 to 16 ppm per deg C for an inductor without cores or tuning devices. Inductance values for the standard units range from 0.05 to 0.1 μh in increments of 0.01 μh, and from 0.1 to 1.3 μh in increments of approximately 0.1 μh.

Corning Glass Works, Electronic Components Dept., Dept. ED, Bradford, Pa.

CIRCLE 47 ON READER-SERVICE CARD


## MAGNETIC AMPLIFIER

**Engineered to perform** as an AND, OR or NOT gate, or as a bi-stable memory device, this magnetic amplifier has all-static construction. Called the PMC-785 logic type magnetic amplifier, the unit is made primarily for missile control and checkout applications. It operates from a 70 v center-tapped transformer on a 115 v line at 400 cps, has a 2.5 msec response, and accepts a minimum input signal of only 3 mw.

Pacific Magnetic Corp., Electronic Center, Dept. ED, Romoland, Calif.

CIRCLE 48 ON READER-SERVICE CARD

CIRCLE 49 ON READER-SERVICE CARD ➤

# Creative Microwave Technology

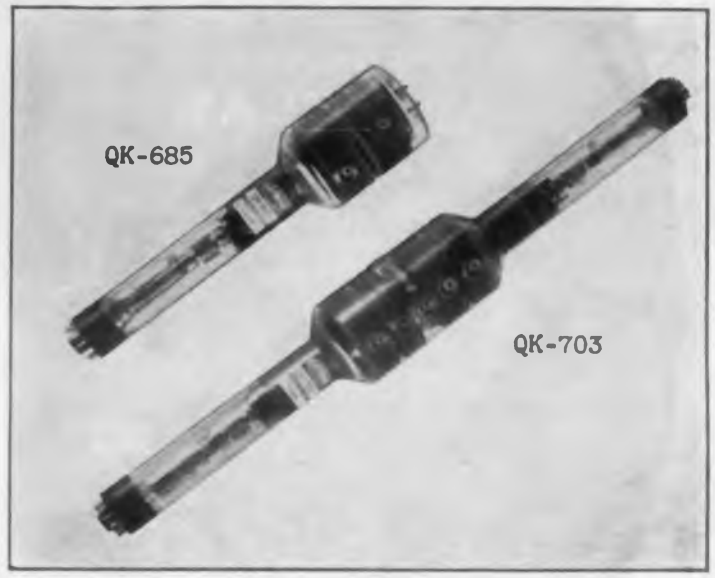
Published by Microwave and Power Tube Division, Raytheon Manufacturing Company, Waltham 54, Mass., Vol. 1, No. 4

## NEW KILO-LINE RECORDING STORAGE TUBES SPECIALLY DESIGNED FOR SCAN CONVERSION

**To meet the need for low-noise, high-resolution devices for frequency and scan conversion, Raytheon scientists and engineers have developed two new storage tubes: the single-gun QK-685 and the dual-gun QK-703. These tubes are now available in production quantities.**

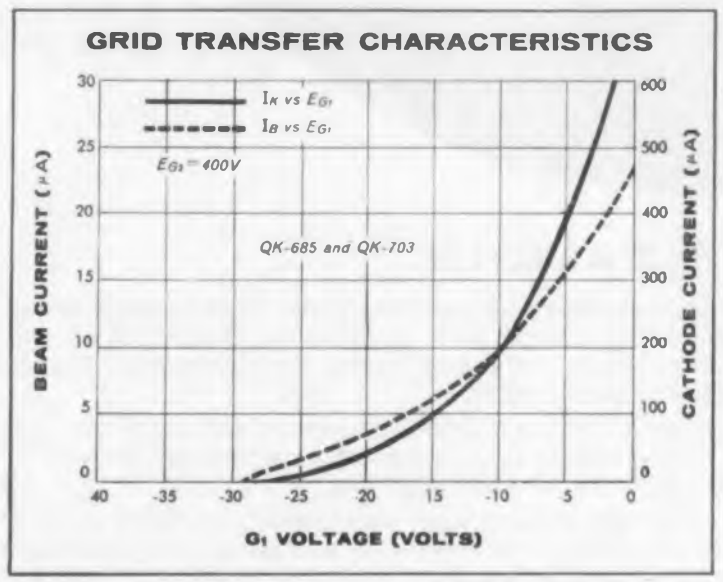
Both types incorporate a specially designed tetrode electron gun for higher resolutions — 1,000 TV lines at 50% modulation — and better control over beam cut-off than conventional triode guns. A new multiple collimating lens improves background uniformity and results in shading-to-signal ratios of less than 10%.

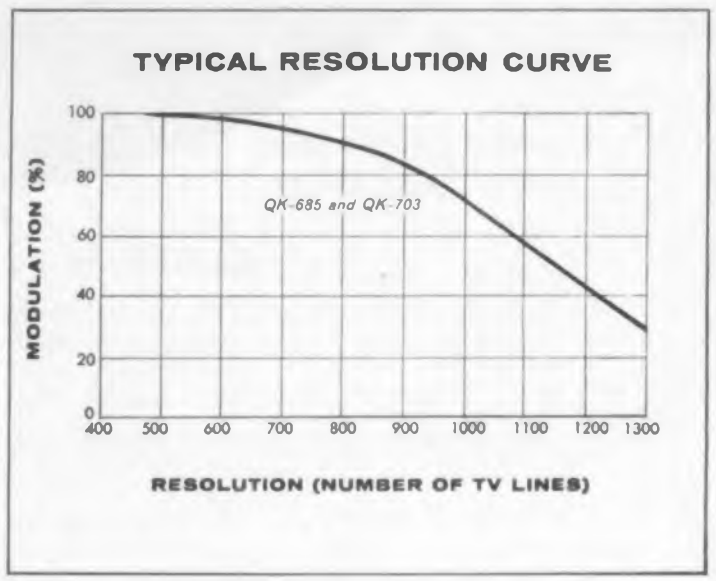
The ability of the dual-gun type to read and write simultaneously makes this tube particularly applicable to slow-down video and conversion from PPI to TV scan patterns for "Bright Display."




Typical Operating Characteristics

| | QK-685 and QK-703 |
|---|---|
| Anode Voltage | 4,000 Vdc (Max.) |
| Resolving Power | |
| Magnetic Focus | 1,000 Lines (Nom.) |
| Electrostatic Focus | 700 Lines (Nom.) |
| Output Capacitance | QK-685—10 μμf (Nom.) |
| | QK-703—20 μμf (Nom.) |
| Maximum Deflection Angle | 30° |

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You can obtain detailed application information and special development services by contacting: Microwave and Power Tube Division, Raytheon Manufacturing Company, Waltham 54, Massachusetts

**A LEADER IN CREATIVE MICROWAVE TECHNOLOGY**

# NEW PRODUCTS

## Voltage Regulator Tubes

**Provide 1% regulation**

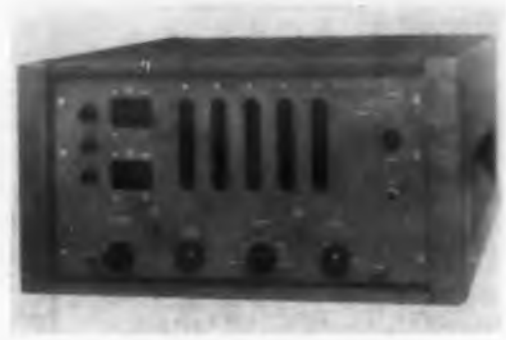
These metal ceramic, corona discharge voltage regulator tubes cover a range from 400 to 4000 v. Regulation is better than 1% from $10^{-11}$ to $10^{-7}$ amp, and the prebreakdown current is less than $10^{-12}$ amp at room temperature. The units are resistant to shock and vibration and operate from −55 to +200 C. Overall length is under 1 in. and OD is 0.3 in.

Radiation Research Corp., Dept. ED, 1114 First Ave., New York 21, N.Y.

CIRCLE 51 ON READER-SERVICE CARD

## Frequency Counter

**Limit indicating**



Frequency meter model 7153 indicates whether metered frequency is below, within, or above two selected limits by lighting one of three panel lamps. Relay contact closures, occurring at the same time the panel lamps are lit, may be used to actuate audible alarms or to control the source of the input frequency. The unit has a range of dc to 100 kc and a sensitivity of 0.1 v rms into 10 meg.

Beckman Instruments, Inc., Berkeley Div., Dept. ED, 2200 Wright Ave., Richmond 3, Calif.

CIRCLE 52 ON READER-SERVICE CARD

This is the time of our annual subscription renewal.

## Rotary Positioning Controls

**For loads to 200 in.-lb**

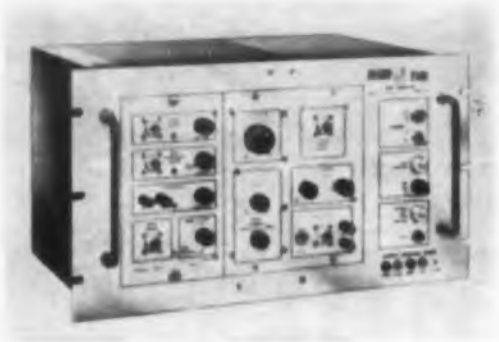
Loads from inch ounces to 200 in.-lb can be positively and accurately held in an infinite number of positions for clockwise or counterclockwise rotation by these rotary positioning controls. Diameters are 3/4 and 1-1/4 in. with a depth of 5/16 in., and 1-3/4 in. with a depth of 5/8 in. The 3/4 in. model is rated for loads to 50 in.-oz, the 1-1/4 in. for loads to 50 in.-lb, and the 1-3/4 in. for loads to 200 in.-lb. Designed for applications as no-back devices, valve and potentiometer positioners, dial controls, clutches, and couplings, the units have zero backlash, low breakaway torques, and rotating speeds to 3800 rpm.

Reid Controls, Reid Metal Products, Inc., Dept. ED, 2021 N. Lincoln St., Burbank, Calif.

CIRCLE 53 ON READER-SERVICE CARD

## Pulse Generator

**Uses plug-in adaptors**



Model MPG-4A pulse generator is designed to solve a variety of pulse problems with a series of plug-in trigger generators. The pulses it generates are readily adaptable to the measurement of magnetic material saturation properties, circuit step function response, precise time delays, and other factors. The plug-in trigger generators permit the separation of trigger and pulse forming circuitry, making available a variety of triggering modes for specialized needs. Any pulse width from 0.3 to 200 μsec may be obtained, and any pulse amplitude from 10 to 175 v may be achieved in a 93 ohm resistive load. Rise time is 0.02 μsec, decay time is 0.08 μsec, and pulse top is flat within 5% of total amplitude.

PCA Electronics, Inc., Dept. ED, 16799 Schoenborn St., Sepulveda, Calif.

CIRCLE 54 ON READER-SERVICE CARD

# NEW PRODUCTS

## Axial Blower

### Delivers up to 169 cfm

This axial blower will deliver up to 169 cfm and can deliver 100 cfm against a static pressure of 3.5 in. of $H_2O$. It is powered by the company's type FC motor and operates at 115 v or 200 v ac, 400 cps, three phase. Power input at peak air volume is 120 w. The unit is 2-3/8 in. long and 2.812 in. in diameter with the 3-in. servo ring attached.

Globe Industries, Inc., Dept. ED, 1784 Stanley Ave., Dayton 4, Ohio.

CIRCLE 109 ON READER-SERVICE CARD

## FM-FM Telemetry Transmitter

### Meets IRIG requirements

Available in two models which cover 215 to 235 and 235 to 260 mc, the type 86600 fm-fm telemetry transmitter meets all IRIG requirements. Spurious and harmonic output are 60 db down from the carrier level and power output is 2 w minimum at a plate supply of 125 v dc, ±5% at 130 ma. The carrier frequency adjusts to within ±0.001% of the assigned frequency, and frequency stability is ±0.01% from —25 to +85 C.

Gilfillan Bros., Inc., Dept. ED, 1815 Venice Blvd., Los Angeles 6, Calif.

CIRCLE 110 ON READER-SERVICE CARD

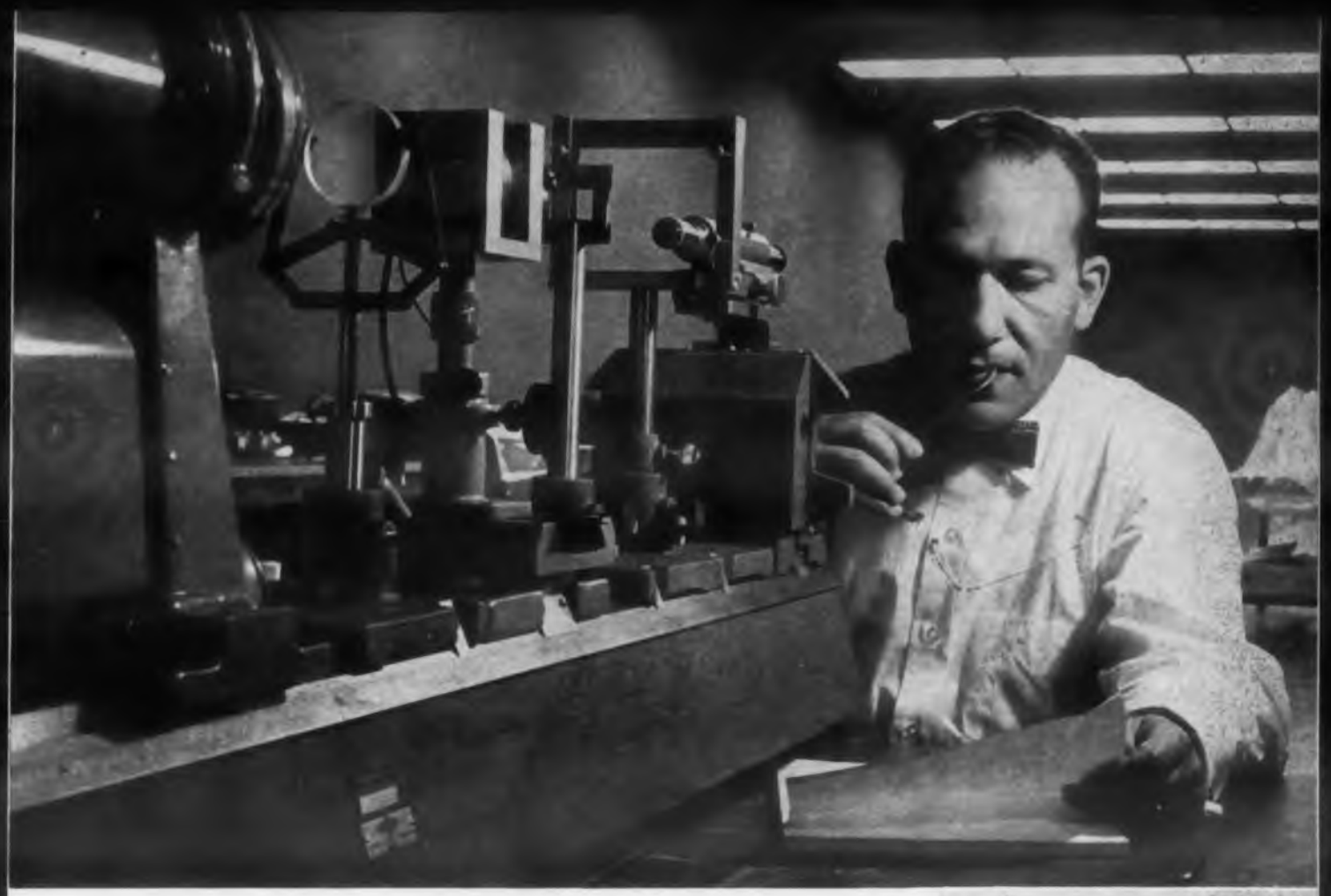
## Flexible Printed Circuits

### Single or multiple layers

These flexible printed circuits consist of etched copper patterns bonded between thin flexible sheets of plastic insulating materials such as Kel-F, Teflon, and epoxy. Available in single or multiple layers, the circuits are low cost, space and weight saving, and reliable.

International Resistance Co., Dept. ED, 401 N. Broad St., Philadelphia 8, Pa.

CIRCLE 111 ON READER-SERVICE CARD



*(above)* Setting up a diffraction image for a research study in near-infrared optics

*(left)* Nation's first successful re-entry tests were conducted with the Lockheed X-17

*(bottom right)* Research and Development facility in the Stanford Industrial Park at Palo Alto, California, provides the latest in technical equipment

## RECONNAISSANCE

# EXPANDING THE FRONTIERS OF SPACE TECHNOLOGY

Lockheed Missiles and Space activities in reconnaissance are among the most advanced in industry. They include such areas as radar, optics, infrared and TV. Work in the fields of radar and data link is concerned with research, design and development of systems and equipment for missile tracking, command guidance, detection and relay of information. Noise modulation techniques are under study as part of statistical communication theory and implementation of automatic space communication systems. Of special significance is the development of a radar firing error indicator that measures the intercept trajectory between target and attacking missile.

Solid state work in infrared embraces the development of new systems and sub-systems for long range infrared communications, surveillance, range findings and target tracking. Considerable work is being conducted in optical devices and systems employing optics. Capability in this area also extends to scanners, encoders, detectors, read-out devices, and analytics of information processing.

Opportunities exist for engineers and scientists of inquiring mind to contribute to the solution of new problems in these fields. If you are experienced in physics, mathematics, chemistry, or one of the engineering sciences, we invite your inquiry. Write: Research and Development Staff, Dept. D3-21, 962 W. El Camino Real, Sunnyvale, California. U.S. Citizenship required.

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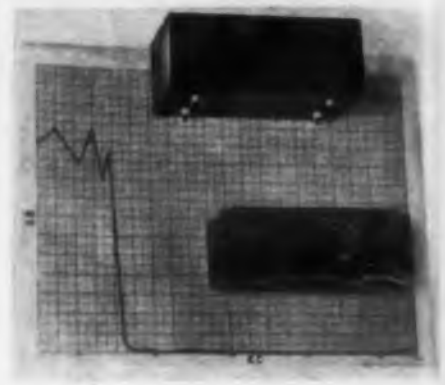
*Weapons Systems Manager for the Navy POLARIS FBM; DISCOVERER SATELLITE; Army KINGFISHER; Air Force Q-5 and X-7*

# NEW PRODUCTS

## SSB Crystal Filters

**10 to 500 kc range**



Ranging from 10 to 500 kc, these SSB filters have high bandwidth ratios and good shape factors. With a carrier frequency of 85 kc, an upper side band unit has a 3 db bandwidth of 3.4 kc and an attenuation band over 40 db. A shape factor of 1.08 is obtained in the slope region. Using a more complex design, a 60 db attenuation can be achieved with a similar shape factor. Insertion loss is about 9 db. Dimensions of this unit are 5 x 2 x 2 in. Bandwidth ratios of better than 10% may be reached with side band crystal filters from 60 to 200 kc, and ratios of 2 to 3% are obtainable from 10 to 60 and 200 to 500 kc.

Bulova Watch Co., Electronic Div., Dept. ED, Woodside 77, N.Y.

CIRCLE 60 ON READER-SERVICE CARD

## Precision Potentiometer

**Watertight**

A 1/2 in. watertight potentiometer, the model APW 1/2 has a glass-to-metal solder sealed header and terminal lugs that are installed with a glass-to-metal seal and positioned for easy wiring. It has an O ring shaft seal per Mil-E-5272A specifications, and the terminal board is solder sealed to the case. Suited for high temperature use, the unit is available with mechanical rotation stops, special winding angles, and resistance values to 100 K.

Waters Mfg., Inc., Dept. ED, Boston Post Rd., Wayland, Mass.

CIRCLE 61 ON READER-SERVICE CARD

CIRCLE 62 ON READER-SERVICE CARD

CIRCLE 63 ON READER-SERVICE CARD

# Very High Frequency Silicon Power Transistors

*N-P-N Triple-diffused silicon mesa*

## VHF POWER AMPLIFIER TYPES

**XT-518** TYPICAL 70 MC POWER GAIN 10 db WITH 75 mw POWER OUTPUT; 4 db WITH 250 mw POWER OUTPUT. $V_{CB}$ = 75V, $I_C$ = 30 mA.

**XT-519** TYPICAL 70 MC POWER GAIN 10 db WITH 250 mw POWER OUTPUT; 4 db WITH 500 mw POWER OUTPUT. $V_{CB}$ = 75V, $I_C$ = 30 mA.

**XT-520** TYPICAL 70 MC POWER GAIN 10 db WITH 500 mw POWER OUTPUT; 4 db WITH 750 mw POWER OUTPUT. $V_{CB}$ = 75V, $I_C$ = 30 mA.

See Footnotes 1 and 2.

**ABSOLUTE MAXIMUM RATINGS** (25° ± 3°C except as noted)

| | | |
|---|---|---|
| Collector-Base Voltage | $V_{cb}$ | 160 Vac Peak |
| | $V_{CB}$ | 120 Vdc |
| Collector Current | $I_C$ | 75 mAdc |
| Emitter-Base Voltage | $V_{EB}$ | 4 Vdc |
| Junction Temperature | $T_J$ | 150°C |
| Collector Dissipation | $P_C$ | 2.8 W @ 25°C case temp. |
| | | 2.25 W @ 50°C case temp. |
| | | 1.1 W @ 100°C case temp. |

**OTHER ELECTRICAL CHARACTERISTICS** (25° ± 3°C except as noted)

| Symbol | Characteristics | Test Conditions | Min. | Typical | Max. | Unit |
|---|---|---|---|---|---|---|
| $I_{EBO}$ | Emitter Cutoff Current | $V_{EB}$ = 2V, $I_C$ = 0 | | | 100 | μA |
| $I_{CBO}$ | Collector Cutoff Current | $V_{CB}$ = 10V, $I_E$ = 0 | | | 1.5 | μA |
| $I_{CBO}$ | Collector Cutoff Current | $V_{CB}$ = 100V, $I_E$ = 0 | | | 1.0 | mA |
| $h_{fe}$ | HF Current Gain | $V_{CB}$ = 50V, $I_C$ = 30mA, f = 70mc. | 1.0 | 1.5 | | |
| $h_{fe}$ | LF Current Gain | $V_{CB}$ = 50V, $I_C$ = 30mA, f = 1kc | | 13 | | |
| $r_b'$ | HF Base Resistance | $V_{CB}$ = 12V, $I_E$ = −10mA, f = 150mc | | | 100 | ohm |
| $C_{ob}$ | Output Capacitance[3] | $V_{CB}$ = 50V, $I_E$ = 0 f = 140kc | | | 7.5 | μμf |
| $r_e+r_e'$ | Emitter Resistance | $I_E$ = −10mA, $I_C$ = 0 f = 1kc | | 7 | | ohm |
| $r_c'$ | Collector Series Resistance | $I_E$ = −20mA, $I_C$ = 10mA, f = 1kc | | 15 | | ohm |

Footnotes:
1. Case temperature 50°C maximum.
2. Neutralized common emitter power gain with input and output conjugate matching.
3. Includes approximately 1.5μμf header capacitance.

## VHF POWER OSCILLATOR TYPES

**XT-515** OSCILLATOR POWER OUTPUT 250 mw MIN. @ 70 mc. $V_{CB}$ = 80V, $I_C$ = 30 mA.

**XT-516** OSCILLATOR POWER OUTPUT 500 mw MIN. @ 70 mc. $V_{CB}$ = 90V, $I_C$ = 30 mA.

**XT-517** OSCILLATOR POWER OUTPUT 750 mw MIN. @ 70 mc. $V_{CB}$ = 100V, $I_C$ = 30 mA

See Footnotes 1 and 2.

**ABSOLUTE MAXIMUM RATINGS** (25° ± 3°C except as noted)

| | | |
|---|---|---|
| Collector-Base Voltage | $V_{cb}$ | 160 Vac Peak |
| | $V_{CB}$ | 120 Vdc |
| Collector Current | $I_C$ | 75 mAdc |
| Emitter-Base Voltage | $V_{EB}$ | 3 Vdc |
| Junction Temperature | $T_J$ | 150°C |
| Collector Dissipation | $P_C$ | 2.8 W @ 25°C case temp. |
| | | 2.25 W @ 50°C case temp. |
| | | 1.1 W @ 100°C case temp. |

**OTHER ELECTRICAL CHARACTERISTICS** (25° ± 3°C except as noted)

| Symbol | Characteristics | Test Conditions | Typical | Max. | Unit |
|---|---|---|---|---|---|
| $I_{EBO}$ | Emitter Cutoff Current | $V_{EB}$ = 1V, $I_C$ = 0 | | 100 | μA |
| $I_{CBO}$ | Collector Cutoff Current | $V_{CB}$ = 10V, $I_E$ = 0 | | 1.5 | μA |
| $I_{CBO}$ | Collector Cutoff Current | $V_{CB}$ = 100V, $I_E$ = 0 | | 1.0 | mA |
| $h_{fe}$ | LF Current Gain | $V_{CB}$ = 50V, $I_C$ = 30mA f = 1kc | 6 | | |
| $r_b'$ | HF Base Resistance | $V_{CB}$ = 12V, $I_E$ = −10mA f = 150mc | 60 | | ohm |
| $C_{ob}$ | Output Capacitance[3] | $V_{CB}$ = 50V, $I_E$ = 0 f = 140kc. | 4.0 | | μμf |
| $r_e+r_e'$ | Emitter Resistance | $I_E$ = −10mA, $I_C$ = 0 f = 1kc | 7 | | ohm |
| $r_c'$ | Collector Series Resistance | $I_E$ = −20mA, $I_C$ = 10mA f = 1kc | 15 | | ohm |

Footnotes:
1. Case temperature 50°C maximum.
2. Power output in parallel line oscillator.
3. Includes approximately 1.5 μμf header capacitance.

# Eight new EIA types Fast Recovery Silicon Diffusion Computer Diodes


| Type Number | Min. Sat. Voltage @ 100 μa (v) | Min. Fwd. Current @ 1.0v | Maximum Reverse Current (μA) 25°C | Maximum Reverse Current (μA) 100°C | Reverse Recovery Characteristics: Reverse Res. (ohms) | Reverse Recovery Characteristics: Max. Recov. Time (μs) |
|---|---|---|---|---|---|---|
| 1N789 | 30 | 10 | 1 (20v) | 30 (20v) | 200K | 0.5 |
| 1N791 | 30 | 50 | 5 (20v) | 30 (20v) | 200K | 0.5 |
| 1N792 | 30 | 100 | 5 (20v) | 30 (20v) | 100K | 0.5 |
| 1N793 | 60 | 10 | 1 (50v) | 30 (50v) | 200K | 0.5 |
| 1N795 | 60 | 50 | 5 (50v) | 30 (50v) | 200K | 0.5 |
| 1N801 | 150 | 10 | 1 (125v) | 30 (125v) | 200K | 0.5 |
| 1N802 | 150 | 50 | 5 (125v) | 50 (125v) | 200K | 0.5 |
| 1N804 | 200 | 50 | 10 (175v) | 50 (175v) | 200K | 0.5 |

# ...added to the broadest line of Fast Recovery Silicon Computer Diodes in the industry!

**MILITARY TYPES**

| Type Number | Min. Sat. Voltage @ 100 μa (v) | Min. Fwd. Current @ 1.0 v | Maximum Reverse Current (μa) 25°C | Maximum Reverse Current (μa) 100°C | Reverse Recovery Characteristics: Reverse Res. (ohms) | Reverse Recovery Characteristics: Max. Recov. Time (μs) |
|---|---|---|---|---|---|---|
| *1N643 | 200 | 10 | .025 (10v) | 5 (10v) | 200K | 0.3 |
| #1N662 | 100 | 10 | 1 (100v) 1 (10v) | 15 (100v) 20 (10v) | 100K | 0.5 |
| §1N663 | 100 | 100 | 20 (50v) 5 (75v) | 100 (50v) 50 (75v) | 200K | 0.5 |

*Mil-E-1/1171 (SigC). #Mil-E-1/1139 (SigC) §Mil-E-1/1140 (SigC)

**HIGH CONDUCTANCE TYPES**

| | | | | | | |
|---|---|---|---|---|---|---|
| PS700 | 30 | 100 | 5 (20) | 25 (20) | 100K | 1.0 |
| PS701 | 60 | 50 | 5 (45v) | 50 (45v) | 100K | 0.5 |
| PS702 | 100 | 75 | 20 (75v) | 50 (75v) | 200K | 1.0 |
| PS703 | 100 | 50 | 5 (75v) | 50 (75v) | 100K | 0.5 |
| PS704 | 150 | 50 | 5 (75v) | 50 (75v) | 100K | 0.5 |
| PS705 | 200 | 50 | 5 (75v) | 50 (75v) | 100K | 0.5 |

**MEDIUM CONDUCTANCE TYPES**

| | | | | | | |
|---|---|---|---|---|---|---|
| PS720 | 30 | 3 | 5 (20v) | 25 (20v) | 100K | 0.5 |
| PS721 | 60 | 5 | 5 (45v) | 50 (45v) | 100K | 0.3 |
| PS722 | 100 | 5 | 5 (75v) | 50 (75v) | 100K | 0.3 |
| PS723 | 200 | 3 | 20 (175v) | 100 (175v) | 100K | 0.3 |
| PS724 | 150 | 4 | 20 (125v) | 100 (125v) | 100K | 0.3 |

**LOW CONDUCTANCE TYPES**

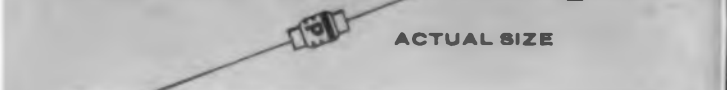
| | | | | | | |
|---|---|---|---|---|---|---|
| 1N625 | 30 | 4 @ 1.5v | 1 (20v) | 30 (20v) | 400K | 1μsec |
| 1N626 | 50 | 4 @ 1.5v | 1 (35v) | 30 (35v) | 400K | 1μsec |
| 1N627 | 100 | 4 @ 1.5v | 1 (75v) | 30 (75v) | 400K | 1μsec |
| 1N628 | 150 | 4 @ 1.5v | 1 (125v) | 30 (125v) | 400K | 1μsec |
| 1N629 | 200 | 4 @ 1.5v | 1 (175v) | 30 (175v) | 400K | 1μsec |

*Please Note:*

All specifications and information contained herein are current as of:

*April 28, 1959*

# Zener Diodes 500 mW Power Dissipation




**LOW VOLTAGE GROUP**

| PSI Type Number | Elect. Equiv. | Zener Voltage @ 5 mA @ 25°C: E_z Min. (v) | Zener Voltage @ 5 mA @ 25°C: E_z Max. (v) | Maximum Dynamic Resistance (ohms) | Maximum Inverse Current: I_R @ 25°C (μA) | Maximum Inverse Current: I_R @ 100°C (μA) | At Inverse Voltage (v) |
|---|---|---|---|---|---|---|---|
| PS6465 | 1N465 | 2.0 | 3.2 | 60 | 75 | 100 | 1 |
| PS6466 | 1N466 | 3.0 | 3.9 | 55 | 50 | 100 | 1 |
| PS6467 | 1N467 | 3.7 | 4.5 | 45 | 5 | 100 | 1 |
| PS6468 | 1N468 | 4.3 | 5.4 | 35 | 5 | 100 | 1.5 |
| PS6469 | 1N469 | 5.2 | 6.4 | 20 | 5 | 100 | 1.5 |
| PS6470 | 1N470 | 6.2 | 8.0 | 10 | 5 | 50 | 3.5 |

1. Measured at 10mA DC Zener current with 1mA RMS signal superposed.

**MEDIUM VOLTAGE GROUP**

| PSI Type Number | Elect. Equiv. | Zener Voltage @ 200 μA @ 25°C: E_z Min. (v) | Zener Voltage @ 200 μA @ 25°C: E_z Max. (v) | Maximum Inverse Current: I_R @ 25°C (μA) | Maximum Inverse Current: I_R @ 100°C (μA) | At Inverse Voltage (v) |
|---|---|---|---|---|---|---|
| PS6313 | 1N1313 | 7.5 | 10 | 5 | 5 | 6.8 |
| PS6314 | 1N1314 | 9 | 12 | 5 | 5 | 8.2 |
| PS6315 | 1N1315 | 11 | 14.5 | 5 | 5 | 10.0 |
| PS6316 | 1N1316 | 13.5 | 18 | 5 | 5 | 12.0 |
| PS6317 | 1N1317 | 17 | 21 | 5 | 5 | 15.0 |
| PS6318 | 1N1318 | 20 | 27 | 1 | 10 | 18.0 |

**HIGH VOLTAGE GROUP**

| PSI Type Number | Elect. Equiv. | Zener Voltage @ 200 μA @ 25°C: E_z Min. (v) | Zener Voltage @ 200 μA @ 25°C: E_z Max. (v) | Maximum Inverse Current: I_R @ 25°C (μA) | Maximum Inverse Current: I_R @ 100°C (μA) | At Inverse Voltage (v) |
|---|---|---|---|---|---|---|
| PS6319 | 1N1319 | 25 | 32 | 1 | 10 | 22 |
| PS6320 | 1N1320 | 30 | 39 | 1 | 10 | 27 |
| PS6321 | 1N1321 | 37 | 45 | 1 | 10 | 33 |
| PS6322 | 1N1322 | 43 | 54 | 1 | 10 | 39 |
| PS6323 | 1N1323 | 52 | 64 | 1 | 10 | 47 |
| PS6324 | 1N1324 | 62 | 80 | 1.0 | 50 | 56 |
| PS6325 | 1N1325 | 75 | 100 | 1.0 | 50 | 68 |
| PS6326 | 1N1326 | 90 | 120 | 1.0 | 50 | 82 |
| PS6327 | 1N1327 | 110 | 145 | 1.0 | 50 | 100 |

MAXIMUM Power Dissipation 500 mW @ 25°C
Operating Range −65°C to 200°C

- **For Employment Opportunities**

Write PSI Technical Staff Placement, 10451 West Jefferson Blvd., Culver City, Calif.

PSI

*Pacific Semiconductors, Inc.*

A SUBSIDIARY OF THOMPSON RAMO WOOLDRIDGE INC.

## Standard Encapsulations


A variety of assemblies can be furnished for matched pairs and quads, ring modulators, full wave and bridge rectifiers and many other applications.

Numerous lead arrangements are possible in these three basic configurations. Up to four diodes or rectifiers can be encapsulated in the "S" or "T" packages. Up to 12 units can be contained in the "R" package. The number of units contained determines its maximum length.

Leads .020" diameter,
1" minimum length.
Spaced on .1" grid centers.

⅔ ACTUAL SIZE

**DIMENSIONS**

| | "R" Package | "S" Package | "T" Package |
|---|---|---|---|
| Length | .375" to 1.75" | .45" | .50" |
| Width | .25" | .39" | — |
| Height | .50" | .40" | — |
| Diameter | — | — | .375" |

## Non-Linear Resistors

ACTUAL SIZE

| PSI Type | E @ 1mA (volts) | I @ 1VDC min (mA) | Max Dyn Res @ 1mA (ohm) | In @ 25°C (μA) Max. |
|---|---|---|---|---|
| PS594 | 0.62 ± 10% | 100 | 60 | 1.0 @ −5v |
| PS594G | 0.62 ± 5% | 100 | 60 | 1.0 @ −5v |
| PS595 | 0.62 ± 10% | 250 | 60 | 5.0 @ −5v |
| PS595G | 0.62 ± 5% | 250 | 60 | 5.0 @ −5v |

## Silicon
## General Purpose Diodes

ACTUAL SIZE

| EIA TYPE NUMBER | Minimum Saturation Voltage @ 100 μa @ 25°C (volts) | Minimum Forward Current @ +1.0 VDC @ 25°C (mA) | Maximum Inverse Current at Maximum DC Operating Voltage (μa @ volts) @ 25°C | @ 150°C | Maximum Average Rectified Current (mA) @ 25°C | @ 150°C |
|---|---|---|---|---|---|---|
| 1N456 | 1.5 | 40 | .025 @ 25 | 5 @ 25 | 90 | |
| 1N456A | 1.0 | 100 | .025 @ 25 | 5 @ 25 | 200 | 70 |
| *1N457 | 70 | 70 | .025 @ 60 | 5 @ 60 | 75 | |
| 1N457A | 70 | 100 | .025 @ 60 | 5 @ 60 | 200 | 70 |
| *1N458 | 150 | 7 | .025 @ 125 | 5 @ 125 | 55 | |
| 1N458A | 150 | 100 | .025 @ 125 | 5 @ 125 | 200 | 70 |
| *1N459 | 200 | 3 | .025 @ 175 | 5 @ 175 | 40 | |
| 1N459A | 200 | 100 | .025 @ 175 | 5 @ 175 | 200 | 70 |
| 1N461 | 30 | 15 | .5 @ 25 | 30 @ 25 | 60 | |
| 1N461A | 30 | 100 | .5 @ 25 | 30 @ 25 | 200 | 70 |
| 1N462 | 70 | 5 | .5 @ 60 | 30 @ 60 | 50 | |
| 1N462A | 70 | 100 | .5 @ 60 | 30 @ 60 | 200 | 70 |
| 1N463 | 200 | 1 | .5 @ 175 | 30 @ 175 | 30 | |
| 1N463A | 200 | 100 | .5 @ 175 | 30 @ 175 | 200 | 70 |
| 1N464 | 150 | 3 | .5 @ 125 | 30 @ 125 | 40 | |
| 1N464A | 150 | 100 | .5 @ 125 | 30 @ 125 | 200 | 70 |

*JAN Types

OTHER ABSOLUTE MAXIMUM RATINGS:
Power Dissipation 0.5 Watts @ 25°C Power Dissipation 0.25 Watts @ 150°C 1 Second Surge Current 1.5 Amperes @ 25°C Storage and Operating Temperature Range −80° to 200°C

## Silicon
## High Conductance Diodes

ACTUAL SIZE

| PSI or EIA TYPE NUMBER | Minimum Saturation Voltage @ 100 μa @ 25°C (volts) | Maximum Forward Voltage DC @ 25°C (volts) @ 100 mA | @ 200 mA | Maximum Inverse Current @ Maximum DC Operating Voltage (μa @ volts) @ 25°C | @ 150°C | Maximum Average Rectified Current (mA) @ 25°C | @ 150°C |
|---|---|---|---|---|---|---|---|
| 1N482 | 40 | 1.1 | | 250 @ −30v | 30 | 125 | 50 |
| 1N482A | 40 | 1.0 | | .025 @ −30v | 15 | 200 | 70 |
| 1N482B | 40 | 1.0 | | .025 @ −30v | 5 | 200 | 70 |
| PS603 | 40 | | 1.0 | 250 @ −30v | 30 | 200 | 100 |
| PS604 | 40 | | 1.0 | .025 @ −30v | 15 | 200 | 100 |
| PS605 | 40 | | 1.0 | .025 @ −30v | 5 | 200 | 100 |
| 1N483 | 80 | 1.1 | | 250 @ −60v | 30 | 125 | 50 |
| 1N483A | 80 | 1.0 | | .025 @ −60v | 15 | 200 | 70 |
| 1N483B | 80 | 1.0 | | .025 @ −60v | 5 | 200 | 70 |
| PS609 | 80 | | 1.0 | 250 @ −60v | 30 | 200 | 100 |
| PS610 | 80 | | 1.0 | .025 @ −60v | 15 | 200 | 100 |
| PS611 | 80 | | 1.0 | .025 @ −60v | 5 | 200 | 100 |
| 1N484 | 150 | 1.1 | | 250 @ −125v | 30 | 125 | 50 |
| 1N484A | 150 | 1.0 | | .025 @ −125v | 15 | 200 | 70 |
| 1N484B | 150 | 1.0 | | .025 @ −125v | 5 | 200 | 70 |
| PS615 | 150 | | 1.0 | 250 @ −125v | 30 | 200 | 100 |
| PS616 | 150 | | 1.0 | .025 @ −125v | 15 | 200 | 100 |
| PS617 | 150 | | 1.0 | .025 @ −125v | 5 | 200 | 100 |
| 1N485 | 200 | 1.1 | | 250 @ −175v | 30 | 125 | 50 |
| 1N485A | 200 | 1.0 | | .025 @ −175v | 15 | 200 | 70 |
| 1N485B | 200 | 1.0 | | .025 @ −175v | 5 | 200 | 70 |
| PS621 | 200 | | 1.0 | 250 @ −175v | 30 | 200 | 100 |
| PS622 | 200 | | 1.0 | .025 @ −175v | 15 | 200 | 100 |
| PS623 | 200 | | 1.0 | .025 @ −175v | 5 | 200 | 100 |
| 1N486 | 250 | 1.1 | | 250 @ −225v | 50 | 125 | 50 |
| 1N486A | 250 | 1.0 | | .050 @ −225v | 25 | 200 | 70 |
| 1N486B | 250 | 1.0 | | .050 @ −225v | 10 | 200 | 70 |
| PS627 | 250 | | 1.0 | 250 @ −225v | 50 | 200 | 100 |
| PS628 | 250 | | 1.0 | .050 @ −225v | 25 | 200 | 100 |
| PS629 | 250 | | 1.0 | .050 @ −225v | 10 | 200 | 100 |
| 1N487 | 330 | 1.1 | | 250 @ −300v | 50 | 125 | 50 |
| 1N487A | 330 | 1.0 | | 100 @ −300v | 25 | 200 | 70 |
| PS632 | 330 | | 1.0 | 250 @ −300v | 50 | 200 | 100 |
| PS633 | 330 | | 1.0 | 100 @ −300v | 25 | 200 | 100 |
| 1N488 | 420 | 1.1 | | 250 @ −380v | 50 | 125 | 50 |
| 1N488A | 420 | 1.0 | | 100 @ −380v | 25 | 200 | 70 |
| PS636 | 420 | | 1.0 | 250 @ −380v | 50 | 200 | 100 |
| PS637 | 420 | | 1.0 | 100 @ −380v | 25 | 200 | 100 |

OTHER ABSOLUTE MAXIMUM RATINGS:
Maximum Power Dissipation 0.5 Watts @ 25°C Maximum Power Dissipation 0.25 Watts @ 150°C Maximum 1 Second Surge Current 1.5 Amperes @ 25°C Storage and Operating Temperature Range −80° to 200°C

## Varicap®
## Voltage-Variable Capacitor

ACTUAL SIZE

| Varicap Type | Capacitance @ 4VDC mmf | Capacitance Approx. Range mmf* | Quality Factor Q @ 50 mc. Minimum @ 4VDC | Typical @ 4VDC | Typical @ MWV | Maximum Working Voltage (MWV) Volts D.C |
|---|---|---|---|---|---|---|
| MODULATION, AFC AND OTHER APPLICATIONS | | | | | | |
| V-7 | 7 | 3.0-18 | 13 | 18 | 43 | 25 |
| V-10 | 10 | 4.3-26 | 13 | 18 | 43 | 25 |
| V-12 | 12 | 5.2-31 | 13 | 18 | 43 | 25 |
| V-15 | 15 | 6.5-39 | 13 | 18 | 43 | 25 |
| V-20 | 20 | 10-50 | 7.0 | 18.7 | 40.2 | 20 |
| V-27 | 27 | 14-70 | 7.0 | 15.7 | 33.8 | 20 |
| V-33 | 33 | 17-85 | 7.0 | 14.6 | 31.4 | 20 |
| V-39 | 35 | 20-100 | 7.0 | 15.1 | 32.4 | 20 |
| V-47 | 47 | 24-120 | 7.0 | 15.4 | 32.4 | 20 |
| V-56 | 56 | 32-145 | 7.0 | 13.5 | 24.8 | 15 |
| V-68 | 68 | 39-175 | 9.0 | 14.0 | 25.8 | 15 |
| V-82 | 82 | 47-210 | 9.0 | 13.0 | 23.9 | 15 |
| V-100 | 100 | 57-260 | 8.0 | 11.0 | 20.2 | 15 |
| HIGH VOLTAGE TYPES TUNING AND OTHER APPLICATIONS | | | | | | |
| V-7E | 7 | 1.5-18.0 | 3.0 | 4.5 | 22.5 | 100 |
| V-10E | 10 | 2.2-26.0 | 3.5 | 5.5 | 27.5 | 100 |
| V-12E | 12 | 2.7-31.0 | 4.0 | 6.5 | 32.5 | 100 |
| V-15E | 15 | 3.3-39.0 | 4.5 | 7.5 | 37.5 | 100 |
| V-20E | 20 | 5.0-50.0 | 7.0 | 18.7 | 78.5 | 70 |
| V-27E | 27 | 7.0-70.0 | 7.0 | 15.7 | 63.5 | 65 |
| V-33E | 33 | 9.0-85.0 | 7.0 | 14.6 | 56.5 | 60 |
| V-39E | 39 | 11.0-100.0 | 7.0 | 15.1 | 55.8 | 55 |
| V-47E | 47 | 14.0-120.0 | 7.0 | 15.4 | 53.8 | 50 |
| V-56E | 56 | 20.0-145.0 | 7.0 | 13.5 | 41.8 | 30 |

*C range specified from 0.1 volts to maximum working voltage

"VARICAP" is the registered trade mark of silicon voltage-variable capacitors manufactured by Pacific Semiconductors, Inc.

# NEW!

**Now available! Two new semiconductor devices which may revolutionize present concepts of Micro-Miniaturization and Electrical circuitry!**

## 1. PSI microdiode

A major advance in micro-miniaturization. Volume and weight of these new PSI types are approximately 1/20th of present subminiature diodes. Six Fast Recovery Silicon Computer Microdiodes are now available.

actual size!

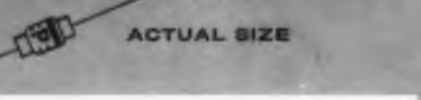
Pacific Semiconductors, Inc.

## 2. PSI High Q Varicap

A complete new approach to advanced circuit design is possible with these new High Q Varicap voltage-variable capacitors. Six types with Q Factors of 50 and 100 and 10, 22, 47 mmf. capacitance are available in standard subminiature package.

**Phone, wire or write for complete specifications, delivery schedules and prices.**

# Silicon Subminiature Rectifiers




## MEDIUM POWER TYPES

| EIA TYPE NUMBER | MAXIMUM RATINGS | | | ELECTRICAL CHARACTERISTICS | | | |
|---|---|---|---|---|---|---|---|
| | Peak Inv. Voltage (v) | Maximum Avg. Rectified Current (mA)[1] | | Minimum Saturation Voltage @ 100°C | Maximum Reverse Current @ PIV (μA) | | Max. Avg. Voltage Drop @ Io = 400 mA @ 25°C (v)[1] |
| | | @ 25°C | @ 150°C | | @ 25°C | @ 100°C | |
| 1N645 | 225 | 400 | 150 | 275 | 0.2 | 15 | 1.0 |
| 1N646 | 300 | 400 | 150 | 360 | 0.2 | 15 | 1.0 |
| 1N647 | 400 | 400 | 150 | 480 | 0.2 | 20 | 1.0 |
| 1N648 | 500 | 400 | 150 | 600 | 0.2 | 20 | 1.0 |
| 1N649 | 600 | 400 | 150 | 720 | 0.2 | 25 | 1.0 |

## 400 MILLIAMPERE PSI TYPES

400 mA @ 25°C—150 mA @ 150°C

| PSI TYPE NUMBER | MAXIMUM RATINGS @ 100°C | | | ELECTRICAL CHARACTERISTICS | |
|---|---|---|---|---|---|
| | Peak Recurr. Inverse Voltage (volts) | Maximum RMS Input Voltage[1] (volts) @ 150°C | Maximum Average Rectified Current[1] (mA) | DC Forward Voltage @ Specified Current @ 25°C (volts @ mA) | Maximum Average Inverse Current[2] @ 100°C (mA) |
| TYPE | | | | @ 25°C | @ 150°C |
| PS 405 | 50 | 35 | 150 | 1.5 @ 500 | 500 |
| PS 410 | 100 | 70 | 150 | 1.5 @ 500 | 500 |
| PS 415 | 150 | 105 | 150 | 1.5 @ 500 | 500 |
| PS 420 | 200 | 140 | 150 | 1.5 @ 500 | 500 |
| PS 425 | 250 | 175 | 150 | 1.5 @ 500 | 500 |
| PS 430 | 300 | 210 | 150 | 1.5 @ 500 | 500 |
| PS 435 | 350 | 245 | 150 | 1.5 @ 500 | 500 |
| PS 440 | 400 | 280 | 150 | 1.5 @ 500 | 500 |
| PS 450 | 500 | 350 | 125 | 1.5 @ 500 | 500 |
| PS 460 | 600 | 420 | 125 | 1.5 @ 500 | 500 |

## 250 MILLIAMPERE PSI TYPES

250 mA @ 25°C—140 mA @ 100°C

| | | | | | |
|---|---|---|---|---|---|
| PS 005 | 50 | 35 | 140 | 1 @ 100 | 100 |
| PS 010 | 100 | 70 | 140 | 1 @ 100 | 100 |
| PS 015 | 150 | 105 | 140 | 1 @ 100 | 100 |
| PS 020 | 200 | 140 | 140 | 1 @ 100 | 100 |
| PS 025 | 250 | 175 | 140 | 1 @ 100 | 100 |
| PS 030 | 300 | 210 | 140 | 1 @ 100 | 100 |
| PS 035 | 350 | 245 | 140 | 1 @ 100 | 100 |
| PS 040 | 400 | 280 | 140 | 1 @ 100 | 100 |
| PS 050 | 500 | 350 | 140 | 1 @ 100 | 100 |
| PS 060 | 600 | 420 | 140 | 1 @ 100 | 100 |

1. Resistive or inductive load.
2. Averaged over one cycle for half wave resistive or choke input circuit with rectifier operating at full rated current and maximum RMS input.

Storage and Operating Temperature Range—65°C to 200°C

**500 MA TYPES IN MINIATURE PACKAGE ALSO AVAILABLE.**

# Silicon High Voltage Rectifiers

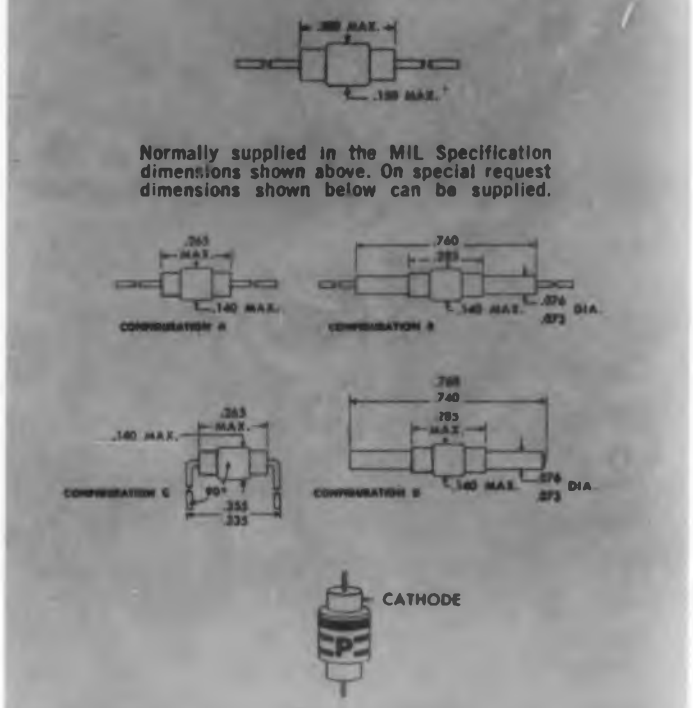

| EIA TYPE NUMBER | Peak Inverse Voltage @ 25 & 100°C (volts) | Continuous DC Voltage @ 25 & 100°C (volts) | Average Rectified Current (mA) @ 25°C | Average Rectified Current (mA) @ 100°C | RMS Input Voltage @ 25 & 100°C (volts) | Max. DC Fwd. Voltage Drop @ 100mA DC 25°C |
|---|---|---|---|---|---|---|
| 1N1730 | 1000 | 1000 | 200 | 100 | 700 | 5 |
| 1N1731 | 1500 | 1500 | 200 | 100 | 1050 | 5 |
| 1N1732 | 2000 | 2000 | 200 | 100 | 1400 | 9 |
| 1N1733 | 3000 | 3000 | 150 | 75 | 2100 | 12 |
| 1N1734 | 5000 | 5000 | 100 | 50 | 3500 | 18 |

Maximum DC Reverse Current @ Rated PIV—25°C 10μA 100°C 100μA
Maximum Surge Current (8msec.) @ 25 & 100°C—2.5 Amps.
Dimensions: Length—1N1730 and 1N1731 .50", 1N1732, 1N1733 and 1N1734 1.0"
Diameter—.375" (1N1734 .50")
Leads .030" diam., 1¼" long on all units.

# Silicon Very High Voltage Cartridge Rectifiers


| EIA Type | Length Inches | Absolute Max. Rtgs. H. W. Res. Load at 75°C Ambient: Peak Inverse Voltage Volts | Absolute Max. Rtgs. H. W. Res. Load at 75°C Ambient: Max. Rectified DC Output Current MA | Electrical Characteristics at 25°C Ambient: Forward DC Volt Drop at Rated DC Current Volts | Electrical Characteristics at 25°C Ambient: Reverse DC Current at Rated PIV MA |
|---|---|---|---|---|---|
| IN1139 | 4⅜₁₆ | 3600 | 65 | 27.0 | 025 |
| IN1140 | 2½ | 3600 | 65 | 18.0 | 025 |
| IN1141 | 4⅜₁₆ | 4800 | 60 | 36.0 | 025 |
| IN1142 | 2½ | 4800 | 50 | 24.0 | 025 |
| IN1143 | 4⅜₁₆ | 6000 | 50 | 45.0 | 025 |
| IN1143A | 4⅜₁₆ | 6000 | 65 | 30.0 | 025 |
| IN1144 | 6⅛₁₆ | 7200 | 50 | 54.0 | 025 |
| IN1145 | 4⅜₁₆ | 7200 | 60 | 36.0 | 025 |
| IN1146 | 6⅛₁₆ | 8000 | 45 | 60.0 | 025 |
| IN1147 | 6⅛₁₆ | 12000 | 45 | 60.0 | 025 |
| IN1148 | 6⅛₁₆ | 14000 | 50 | 52.0 | 025 |
| IN1149 | 6⅛₁₆ | 16000 | 45 | 60.0 | 025 |

Storage and Operating Temperature Range—55°C to 150°C




## Physical Characteristics

**HERMETICALLY SEALED** — Glass-to-metal fused and metal-to-metal welded seals.

**TERMINALS** — Tinned copper leads .020 inches diameter. Lead length 1¼ inch minimum.

**MARKING** — Wide color band indicates cathode end. (Wide band indicates positive bias on Varicaps.) Type number designated by color bands reading from cathode.

**ALL DIMENSIONS SHOWN IN INCHES** — Patented under one or more of the following United States Patents: No. 2815474, No. 2827403.
Other patents pending.

PSI®

# PSI Pacific Semiconductors, Inc.

10451 West Jefferson Boulevard, Culver City, California
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## Four Layer Diodes

### Switch 30 to 200 v

A high power four layer diode, type AD is a self-actuated silicon switch similar in function to a relay or gas tube. It is turned on by a voltage pulse and turned off by dropping the current or reversing the voltage. To match circuit requirements, it is available with switching voltages of 30, 40, 50, and 200 v and holding currents of 5 to 45 ma. Compact and rugged, it can handle 300 ma steady dc or a 20 amp pulse current. A string of four in series will switch 800 v, resulting in a peak power of 16 kw for magnetron pulsing, radar beacons, and other modulator applications. The unit can also be used for pulse generator circuits, detonator firing circuits, and dc to dc power conversion.

Shockley Transistor Corp., Dept. ED, Stanford Industrial Park, Palo Alto, Calif.

CIRCLE 64 ON READER-SERVICE CARD

## Noise Figure Test Set

### For 200 mc operation

The NF-200 noise figure test set checks tube performance in rf tuners or preamplifiers at 200 mc. It uses a GE ceramic 7077 tube and a 200 mc amplifier of 100 db gain. An integral 3 db attenuator, an output meter, and a separate filtered detector output are included. The unit is designed to JETEC 5.4 subcommittee specifications and may also be supplied for other frequencies in the lf, vhf, and uhf ranges.

LEL, Inc., Dept. ED, 380 Oak St., Copiague, N.Y.

CIRCLE 65 ON READER-SERVICE CARD

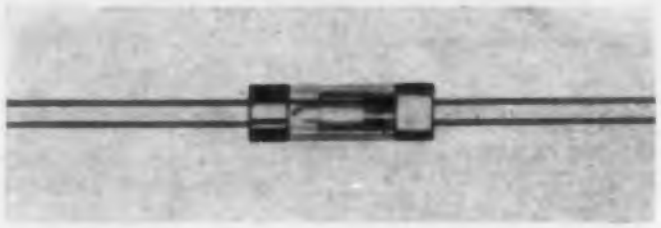
CIRCLE 66 ON READER-SERVICE CARD ➤

➤ CIRCLE 63 ON READER-SERVICE CARD

# NEW PRODUCTS

## Current Sensitive Switch

### Operates continuously at 750 F



The Pyristor switch is a single shot, current sensitive unit for testing circuitry, bypassing squibs, and protecting devices against surge currents. It is also applicable in current operated triggering devices. Hermetically sealed, the unit is spst, normally open or closed. It operates continuously from —100 to +750 F and for 30 min at 1000 F. It meets MIL-E-5272B humidity requirements and withstands 250 g, 2 to 4 msec shocks and 20 to 20,000 cps, 40 g vibration. It can be used at any altitude.

Thermocal, Inc., Dept. ED, 1627 Colorado St., Santa Monica, Calif.

CIRCLE 67 ON READER-SERVICE CARD

## Precision Strain Indicator

### Tests strain gage transducers

For strain gage transducer testing and production line quality control, the model LC-261 automatic strain indicator has 0.005% resolution, 0.02% linearity, 0.01% repeatability, and 0.05% absolute accuracy. The unit is a true mv per v indicator. Instrument calibration is continuously adjustable from 1 to 15 mv per v and is independent of input and output impedance from 60 to 1000 ohms. Input power to the transducer is regulated dc voltage, continuously adjustable from 5 to 15 v, and instrument calibration is independent of transducer supply voltage and zero balance adjustment.

Bytrex Corp., Dept. ED, 294 Centre St., Newton 58, Mass.

CIRCLE 68 ON READER-SERVICE CARD

## High Voltage Resins

### Withstand high temperatures

Impregnating and encapsulating Aritemp 215 and 221 epoxy resins pass the requirements for class H insulating compounds. Transformer coils impregnated with 221 and encapsulated in 215 will resist 8 kv for more than 1000 hr at temperatures to 200 C. Both resins are one component systems that require no mixing of catalyst and resin.

Aries Labs, Inc., Dept. ED, 45-33 Davis St., Long Island City 1, N.Y.

CIRCLE 69 ON READER-SERVICE CARD

## Commutators

**Have 50 channel capacity**

These solid state commutators have a 50 channel capacity and a 24 kc sampling rate. Called Radiplex's, they provide asynchronous operation and high common-mode noise rejection. Two models are available: a high level unit with a full scale input of ±10 v and a resolution of ±2 mv; and a low level unit with a full scale input of ±10 v and a resolution of ±10 μv. Both models have a self-contained power supply.

Radiation, Inc., Dept. ED, P.O. Box 37, Melbourne, Fla.

CIRCLE 71 ON READER-SERVICE CARD

## Power Transistors

**Have 25 amp dc collector current**

Power transistors 2N1162 through 2N1165 have a 25 amp dc collector current, 50 or 80 v collector to base voltage, and 35 or 60 v collector to emitter voltage. Maximum junction temperature is 90 C continuous and 100 C intermittent, and collector dissipation for mounting base temperature of 30 C is 50 w. The units are germanium pnp, alloy junction type with collector common to the case. Designed for high current switching and audio applications, they are hermetically sealed in a standard TO-3 package and meet MIL-T-19500A specifications.

Motorola Inc., Semiconductor Products Div., Dept. ED, 5005 E. McDowell Rd., Phoenix, Ariz.

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# NEW PRODUCTS

## Airborne Receiver Rack

### For telemetry

Airborne receiver rack ATR-100 contains four of the company's type 1403 crystal controlled phase-lock telemetry airborne receivers; one type SDU-203 spectrum display unit; and one type CSD-170 crystal storage drawer. The type 1403 receivers operate in the 215 to 260 mc range and offer a choice of two second i-f amplifiers of different bandwidths, one of 500 kc at the 3 db points with an attenuation of 60 db 500 kc each side of center frequency and the other of 100 kc with better than 60 db attenuation 250 kc each side of center frequency. They have a noise figure of less than 8 db.

Nems-Clarke Co., Dept. ED, 919 Jesup-Blair Dr., Silver Spring, Md.

CIRCLE 73 ON READER-SERVICE CARD

## High Power Isolator

### Provides 6 db isolation

Over its 350 to 400 mc frequency range, isolated model IUH2 provides over 6 db isolation. The unit has a maximum insertion loss of 1 db and can operate at average power levels above 10 kw. Peak power capacity is 10 mw. Without transitions, the isolator is 10 in. high, 27 in. wide, and 36 in. long.

Raytheon Mfg. Co., Special Microwave Device Group, Dept. ED, River Bldg. 2, Waltham 54, Mass.

CIRCLE 74 ON READER-SERVICE CARD

## K Band Magnetron

### For missile use

Built for missile applications, type M4154 fixed frequency K band magnetron delivers a minimum peak power of 20 kw. It withstands severe shock and 30 g vibration at 20 to 2000 cps.

Sylvania Electric Products, Inc., Special Tube Operations, Dept. ED, Mountain View, Calif.

CIRCLE 75 ON READER-SERVICE CARD

CIRCLE 76 ON READER-SERVICE CARD

## Transducers

### Converts frequency to voltage

Model SMC-15 Magacycler converts pulse rates of as low as 0 to 3 cps to linearly varying dc output. The SMC-5000 converts signals of 0 to 1250 cps up to 0 to 5000 cps to the desired linear dc output. The maximum frequency detected can be adjusted with a built-in attenuator through a more than 4 to 1 frequency detected can be adjusted with a built-in attenuator through a more than 4 to 1 frequency range. Full range linearity of better than 0.5% is standard while Red Line units are linear to as low as 0.1%. Standard temperature sensitivities are better than 100 ppm per degree C, with the Red Line units offering under 50 ppm from —60 to +100 C.

Pioneer Magnetics Inc., Dept. ED, 5858 Wilshire Blvd., Los Angeles 36, Calif.

CIRCLE 77 ON READER-SERVICE CARD

## Sonic Delay Line

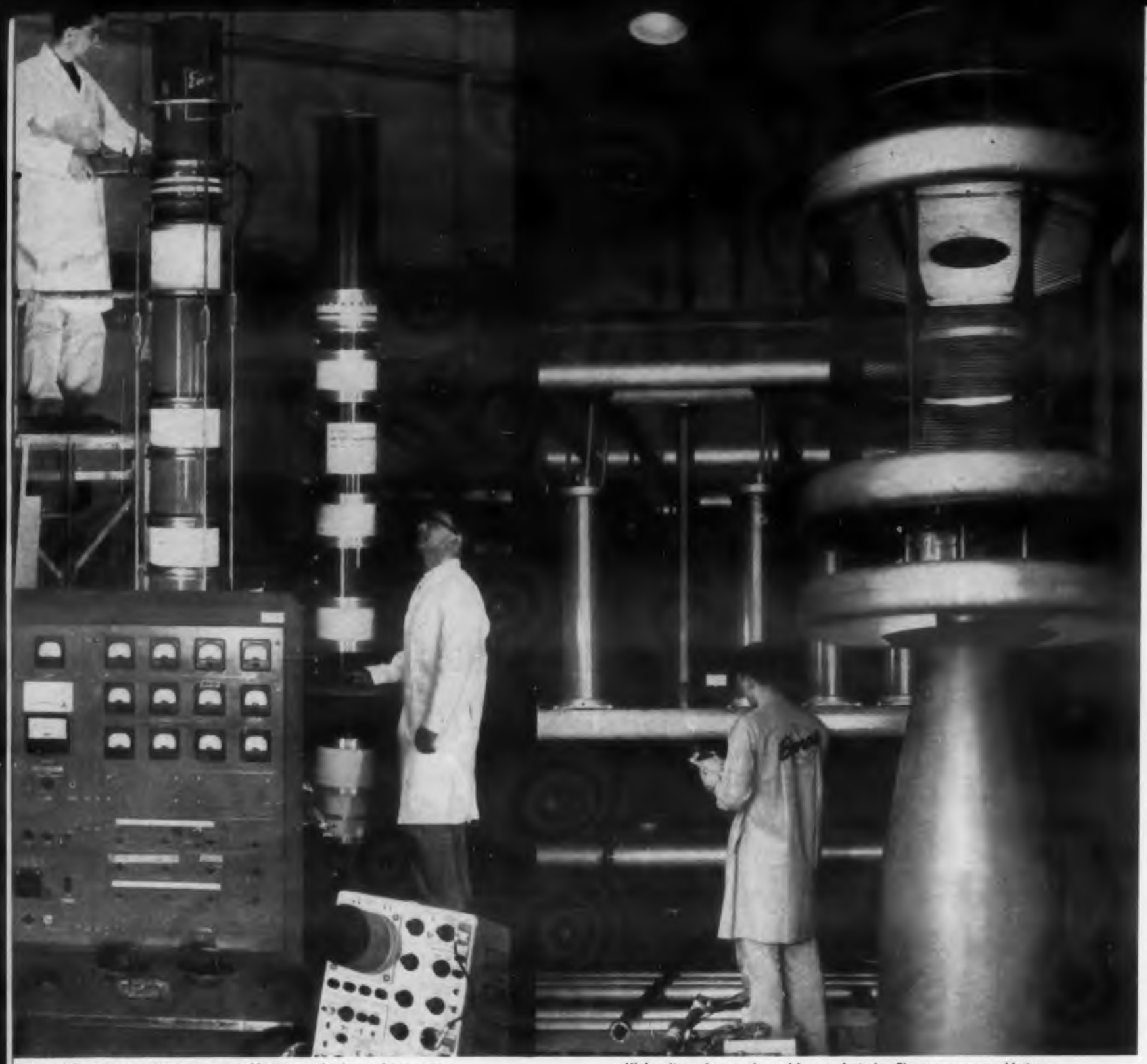
### Lag type

For use with signals in the sonic frequency range, the F344 lag type delay line has an impedance of 1100 ohms, a bandwidth of 15 kc, and a total delay of 76 μsec ±1%. Taps are provided at each 9.5 μsec, and loading is prevented by precision isolation resistors. Insertion loss is 0.2 db at 15 kc and 3 db at 30 kc; phase linearity is 1%; and vswr is 0.5 db. The unit can be used individually or cascaded for longer delays.

Control Electronics Co., Inc., Dept. ED, 10 Stepar Place Huntington Station, N.Y.

CIRCLE 78 ON READER-SERVICE CARD

CIRCLE 79 ON READER-SERVICE CARD ➤



ortion of Eimac's extensive super-power klystron production and test area.

High-voltage d.c. supply used in manufacturing Eimac super-power klystrons.

## SUPER-POWER UHF KLYSTRONS FOR SPACE RADAR NOW IN FULL PRODUCTION AT EIMAC

Tracking fast-moving ballistic missiles and satellites at great distances requires exceptionally powerful radar equipment. Eimac super-power amplifier klystrons, capable of one and one-quarter megawatt peak power and 75 kw average power at ultra-high frequencies, have made these new "space radars" possible. Development of these klystrons, the world's largest electron tubes, has been completed at Eimac and full power tubes have been delivered. They are now being manufactured in production quantities. In addition to radar, Eimac super-power klystrons can be used in linear accelerator and high-power tropo-scatter applications.

Production of these tubes is being carried on at the Eimac High-Voltage Laboratory in San Bruno, California, where development work was done. Complete facilities are available there for the fabrication, assembly, pumping and testing of these giant tubes. Two power supplies, each capable of producing 120,000 volts d.c. at two and four amperes are used in production and testing operations.

This success in developing and placing these tubes in full production in a relatively short time is indicative of Eimac's extensive experience in the field of high-power UHF electron devices. Other Eimac amplifier klystron types are used widely in military and commercial tropo-scatter networks throughout the world.

For high power at ultra-high frequencies investigate the many advantages of Eimac external-cavity amplifier klystrons.

**EITEL-McCULLOUGH, INC.**

Eimac San Carlos • California

# NEW PRODUCTS

## Thermoelectric Material

### For cooling small volumes

These thermoelectric bismuth telluride compositions cool or regulate the temperature of small volumes. Thirty grams of the material in a cooling junction with a temperature difference of 40 C can handle about 1/2 to 3/4 w heat load at its cold junction. With smaller temperature differences, this heat load can be considerably increased.

Merck & Co., Inc., Dept. ED, Lincoln Ave., Rahway, N.J.

CIRCLE 80 ON READER-SERVICE CARD

## Digital Voltmeter

### Has automatic range switching

The model 520 digital voltmeter has automatic range and polarity switching throughout its 0 to ±1200 v dc range. It also has a momentary, three-position lever switch which permits instant checking of both calibration and zero. This switch may be operated while the instrument is in use, thus providing an absolute check of any measurement. The unit can operate digital printers directly and has 0.1% full scale accuracy and 20 meg input impedance.

Franklin Electronics Inc., Dept. ED, Bridgeport, Pa.

CIRCLE 81 ON READER-SERVICE CARD

## VTVM

### Has dc to 1500 mc frequency range

The model 1041B vtvm has a frequency range from dc to 1500 mc and a frequency response that is flat to within ±0.2 db from 50 cps to 500 mc, or −0.5 to +3 db from 20 cps to 1500 mc. Its ranges are 25 mv to 300 v ac; 10 mv to 1 kv, dc; and 0.02 ohm to 500 meg. Center zero facilities are provided on all dc ranges.

Marconi Instruments, Dept. ED, 111 Cedar Lane, Englewood, N.J.

CIRCLE 82 ON READER-SERVICE CARD

CIRCLE 83 ON READER-SERVICE CARD

## Instrument Knobs

### Aluminum

With a special opening through which numbers or indications can be read, these aluminum instrument knobs unmistakably show their position. They are available in 12 colors.

Vemaline Products Co., Dept. ED, Hawthorne, N.J.

CIRCLE 84 ON READER-SERVICE CARD

## Q Meter

### Covers 1 kc to 300 mc

This Q meter covers 1 kc to 300 mc and measures Q from 5 to 1000. It provides accuracies of ±5% at 100 mc, ±12% at 200 mc, and ±20% at 300 mc. Delta Q controls are provided to facilitate batch testing. A complete range of accessories, including test inductors and series and dielectric loss test jigs is available.

Marconi Instruments, Dept. ED, 111 Cedar Lane, Englewood, N.J.

CIRCLE 85 ON READER-SERVICE CARD

## Klystron

### Rated at 1 kw cw

Model VA-802, 1 kw cw, air-cooled, 4-cavity klystron can be continuously tuned from 1700 to 2400 mc and is focused with a permanent magnet. Designed specifically for forward scatter communication systems, it is suitable for both fixed station and transportable service. Power gain of each tube is from 40 to 50 db. Power output into flat line for a vswr of 1.1 or less is 1000 w, and rf drive power—for maximum efficiency tuning—is 0.1 w max. Typical efficiency is 40%.

Varian Associates, Dept. ED, 611 Hansen Way, Palo Alto, Calif.

CIRCLE 86 ON READER-SERVICE CARD

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# NEW PRODUCTS

## Power Sources

### Have adjustable output power

Designed to permit accurate calibration of bidirectional power monitors and termination wattmeters, model 215 power sources have output power that is adjustable from 20 to 100% of rated power. Tuning is continuous over the frequency ranges. Four models are available covering 25 to 50, 50 to 150, 150 to 470, and 470 to 1000 mc. The units are self-contained including power supply and are supplied in bench cabinets or for rack mounting.

Sierra Electronic Corp., Dept. ED, 3885 Bohannon Dr., Menlo Park, Calif.

CIRCLE 88 ON READER-SERVICE CARD

## VHF Transceivers

### For local or remote control

Model 90C vhf transceiver and its remote control version, model 90CR, incorporate a 90 channel 118 to 127 mc transmitter and a tunable 108 to 128 mc receiver. They also contain a transistorized power supply and modulator. Shock mounted in a standard glove compartment opening, the units draw 2.2 amp at 28 v dc.

Dare, Inc., Dept. ED, Troy, Ohio.

CIRCLE 89 ON READER-SERVICE CARD

## X Band Magnetrons

### For missile and airborne use

Magnetron 2J42B and 6027H are fixed frequency X band devices designed especially for missile and other airborne applications. Minimum peak power outputs are 14 kw and 18 kw respectively. The tubes withstand 5 g vibration at 10 to 500 cps with less than 3 mc frequency shift and less than ±0.5 mc frequency modulation. They also withstand 50 g shock for 4 msec and may be operated up to 60,000 ft.

Sylvania Electric Products, Inc., Special Tube Operations, Dept. ED, Mountain View, Calif.

CIRCLE 90 ON READER-SERVICE CARD

◀ CIRCLE 91 ON READER-SERVICE CARD

## FM-AM Generator

### Low noise

An fm-am signal generator for narrow band mobile work, model 995A/4 covers 1.5 to 220 mc. It drifts less than 0.002% per 10 min and has both stepped and continuous incremental frequency controls. An internal fm noise of less than 25 cps enables it to measure 70 to 80 db adjacent channel rejection at 25 kc channel spacing.

Marconi Instruments, Dept. ED, 111 Cedar Lane, Englewood, N.J.

CIRCLE 92 ON READER-SERVICE CARD

## Oscilloscope

### Monitors up to seven channels

Designed for continuous function monitoring of up to seven channels simultaneously in one rack unit, the model 218A oscilloscope provides a means for viewing and evaluating complex voltages. Mainly for use with tape recording and data handling systems, it is suited for measuring and analyzing mechanical quantities through a transducer. Such quantities include stress, strain, vibration, pressure displacement, and acceleration.

Sierra Electronic Corp., Dept. ED, 3885 Bohannon Dr., Menlo Park, Calif.

CIRCLE 93 ON READER-SERVICE CARD

## Microwave Ferrites

### Low loss

These microwave ferrites are low loss magnesium manganese compounds. Type M-022, for general applications at C band frequencies and above, can be used in Faraday rotation and reciprocal phase shifting devices. Type M-032, for use in the S band and below, has low saturation moment and narrow line width. It can be used in resonance isolators and performs well in coaxial phase shifters down to several hundred mc.

Motorola, Inc., Solid State Electronics Dept., Dept. ED, 3102 N. 56th St., Phoenix, Ariz.

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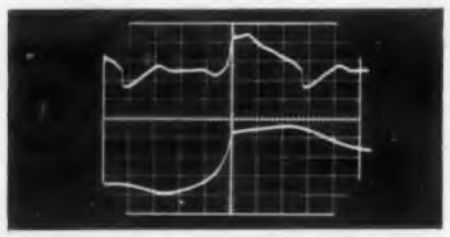
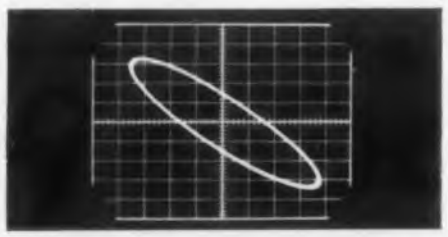
SHOWN IS M. SCHNEIDERMAN, PROJECT ENGINEER ON THE DUAL, USING HIS UNIT FOR ONE OF ITS MANY APPLICATIONS.



**DUAL-BEAM DISPLAY** — Outputs of the ultra-high-sensitivity deflection amplifiers of each channel are applied on identical time bases for clear and accurate comparison.



**EXPANDED TIME BASE DISPLAY** — With a signal from one channel applied on a calibrated time base, that same signal (or a different one) may be displayed on an expanded time base through the other channel. X5 expansion is available on either channel.



**ULTRA-HIGH-SENSITIVITY X-Y PLOTTING** — At the turn of a front panel control, outputs of the two deflection amplifiers may be applied to the X-Y axes of one channel, providing the most sensitive identical X-Y amplifier scope available. In this condition there is still an unused channel to display either of the above signals against time.

# AN ULTRA-HIGH SENSITIVITY DUAL-BEAM OSCILLOSCOPE OFFERING A GREAT VARIETY OF DISPLAYS

**The Du Mont DUAL (Type 411) is a dual-beam oscilloscope of high sensitivity embodying an unusually varied selection of displays. It is a true dual-beam scope employing a multi-gun cathode-ray tube. Each vertical channel may be operated independently of the other, with complete amplitude calibration facilities on both.**

## BRIEF SPECIFICATIONS

**SENSITIVITY** (both channels identical): Through amplifier, ac or dc—100 uvolts/major scale division (1 mv full scale).

**FREQUENCY RESPONSE:** dc to 100 kc

**SYNCHRONIZATION SOURCE:** External, power line or internal pickoff from either Y-amplifier; syncs on either polarity.

**SWEEP SPEEDS:** Calibrated sweeps, 19 fixed steps ranging from 1 sec/cm to 1 usec/cm in a 1-2-5 sequence. Uncalibrated sweep (through amplifier), continuously variable from 1 sec/cm to 2 usec/cm.

**SWEEP EXPANSION:** Up to five times full scale on either channel independently with no on-screen distortion.

**VERTICAL EXPANSION:** Up to three time full scale.

**VOLTS/DIVISION RANGES:** VOLTS PER DIVISION switch settings .001, .01, .1, 1 and 10 with MULTIPLIER switch settings x .1, x .5, x 1, x 2, and x 5.

**POWER SOURCE:** 115/230 volts ± 10%, single phase 50 — 400 cps. Transistorized heater regulation on all critical amplifier circuits.

**CATHODE-RAY TUBE:** 5 ARP-, operating at 2500 volts.

**MECHANICAL:** Size: Type 411, 17½" x 13½" x 23¼" overall. Type 411-R, 17½" x 19" (panel), 13½" (behind panel) x 21", 1¾" protrusion in front of panel. Weight approx. 70 pounds.

**HAND-CRAFTED WIRING THROUGHOUT**

**$995.00**

PRICE: Type 411 & 411-R
F.O.B. Clifton, N.J., U.S.A.

DU MONT® 411

*WRITE FOR COMPLETE INFORMATION*

INSTRUMENT DIVISION
**Allen B. Du Mont Laboratories, Inc. • 760 Bloomfield Ave., Clifton, N. J.**

# NEW PRODUCTS

## Tube Shield Liner and Shields

**Dissipates up to 50% of heat**

The Therma-flex liner with the NW type shield will reduce the bare bulb temperature of tubes by more than 50% and when used with the TR type shield will reduce the temperature by approximately 35%. They are available in shields for all standard size miniature tubes as well as some of the larger noval type tubes such as the 6094. The shields and liners have been designed to meet the requirements of MIL-S-9372, MIL-S-19786 and SCL6307/2.

International Electronic Research Corp., Dept. ED, 145 W. Magnolia Blvd., Burbank, Calif.

CIRCLE 96 ON READER-SERVICE CARD

## Switching Transistors

**High gain**

Power transistors 2N1136, A, and B; 2N1137, A, and B; and 2N1138, A, and B are designed for use in power switching and control circuits. They are provided in current gain ranges of 50 to 100, 75 to 150, and 100 to 200 at a collector current of 3 amp dc. Featuring a flat beta curve, they have a 5 amp maximum current rating and can switch power up to 400 w. Collector to emitter breakdown voltage ratings are 40, 70, and 80.

Bendix Aviation Corp., Red Bank Div., Semiconductor Products, Dept. ED, 201 Westwood Ave., Long Branch, N.J.

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## Converters

### Have 0.01% linearity

Model AC-1 manual ranging and AC-2 automatic ranging converters are designed for use with the company's digital voltmeters. They have a 30 cps to 20 kc range, 0.01% linearity, 0.02% stability, and 10 meg input impedance. Full-wave rectification provides an accuracy of ±0.1% and 2 digits on four ranges.

Cubic Corp., Dept. ED, 5575 Kearny Villa Rd., San Diego 11, Calif.

CIRCLE 105 ON READER-SERVICE CARD

## Transfer Function Analyzer

### Tests automatic control systems

Designed to test the frequency response of automatic control systems, this transfer function analyzer has a 0.5 cps to 10 kc range. It can deal with phase differences from 0 to 360 deg, amplitude differences to 70 db, and harmonic distortion to 100%. The equipment consists of the company's AD-880-A/1 two phase low frequency decade oscillator; AD-729-B/100 low frequency phasemeter; and AD-925-A tunable filter.

Muirhead Instruments, Inc., Dept. ED, 677 Fifth Ave., New York 22, N.Y.

CIRCLE 106 ON READER-SERVICE CARD

## Instrument Calibration Standard

### Has digital readout

A digital reading instrument calibration standard, the model 1294 supplies dc voltages from 1 mv to 2 kv in 12 full scale ranges; dc current from 10 μa to 30 amp in 12 full scale ranges; and ac voltages and currents over the same span with 14 full scale ranges for each function. Accuracy is ±0.1% for dc and ±0.3% for ac functions, and ac indication is true rms. Printed readout is available as an option.

Radio Frequency Labs, Inc., Dept. ED, Boonton, N.J.

CIRCLE 107 ON READER-SERVICE CARD

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# NEW PRODUCTS

## Taper Pin Connectors

### Dual row

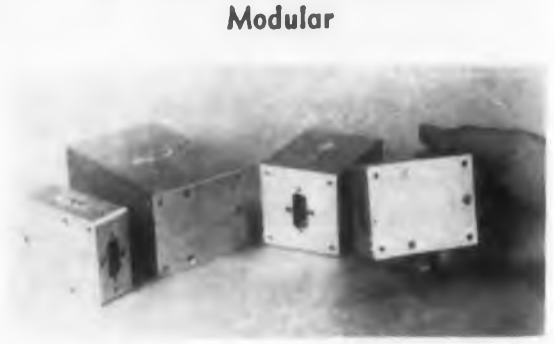
Type UPCC-FDTP printed card connectors have two rows of taper pin terminals linked mechanically and electronically for use with AMP 53 taper pins. Available with 7, 11, 15, 19, 23, or 32 contacts, they may also be obtained in custom configurations.

U. S. Components, Inc., Dept. ED, 454 E. 148th St., New York 55, N.Y.

CIRCLE 57 ON READER-SERVICE CARD

## Telemetering Equipment

### Modular



Transistorized airborne or ground based telemetering equipment for data acquisition. K-series modules can be supplied as systems or as individual units. The current line consists of: electronic commutators for time-division multiplexing of high level data signals; mechanical commutators for time-division multiplexing of high and low level signals; low level amplifiers for raising millivolt commutated inputs to the 0 to 5 v level; pulse width keyers for coding commutator outputs; and low voltage system power supplies. The units operate from —55 to +100 C and withstand 30 g, 5 to 2000 cps vibration and 200 g, 11 msec shocks.

Applied Science Corporation of Princeton, Dept. ED, P.O. Box 44, Princeton, N.J.

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## Static Inverters

### Have high stability

Model 12-115-60AC static inverters have non-saturating time-constant design which permits frequency stability over as much as ±60% of the input dc voltage. Efficiency up to 95% is obtained by elimination of zener diodes and other voltage regulation devices. Standard units have square-wave output, both sinusoidal output is available. The completely transistorized units are protected against overload and short circuit, and operating temperature range is —40 to +70 C. Input voltage: 12 v dc. Output voltage: 115 v ac, rms. And output power is 175 va continuous, 250 va intermittent.

Static Inverters Corp., Dept. ED, 2501 East 68th St., Long Beach, Calif.

CIRCLE 113 ON READER-SERVICE CARD

## Precision Potentiometer

### Noise free

A 4 w, multisection, wirewound potentiometer, model 158 provides noise free operation from —55 to +105 C. It is available in resistances up to 150 K and has an independent linearity of ±0.25%, resistance tolerance of ±5%, and resolution of 0.05%. Insulation resistance is 100,000 meg and life expectancy is 5 million revolutions. Special models are available with 0.2% independent linearity, ±1% resistance tolerance, 0.025% resolution, 500,000 meg insulation resistance, and a —65 to +150 C temperature range.

New England Instrument Co., Dept. ED, 320 Main St., Woonsocket, R.I.

CIRCLE 114 ON READER-SERVICE CARD

CIRCLE 115 ON READER-SERVICE CARD ➤

# NEW PRODUCTS

## Pulse-Waveform Generator

**Frequencies of 0.01 to 2000 cps**

Long calibrated pulses, sine, triangular and square waves can be generated with this unit. Signals are generated over a frequency range of 0.01 to 2000 cps. Pulse lengths are calibrated from 100 μsec to 10 sec, with an accuracy of ±3%. Constant duty cycle operation may be selected with calibrated pulse duty of 10 to 90% over the full frequency span. Maximum pulse amplitude is 50 v at 40 ma. Dial accuracy is ±2%, frequency stability ±1%, and output stability within 2%.

Kennedy Co., Dept. ED, 2487 E. Washington St., Pasadena, Calif.

CIRCLE 127 ON READER-SERVICE CARD

## Beam Switching Tube Tester

**Checks all ten positions**

Designed for the company's type 6700 and BD-301 beam switching tubes, the model 600 tester permits quick checking of all ten tube positions both statically and dynamically. It has an internal power supply, a spade voltage meter, a variable spade voltage control, a target current meter, and a built-in pin straightener. Other features include visual indication of beam position, manual or automatic cycling, and provision for monitoring cathode current externally and for monitoring and adjusting grid bias level.

Burroughs Corp., Dept. ED, P.O. Box 1226, Plainfield, N.J.

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CIRCLE 129 ON READER-SERVICE CARD

## Signal Generator

### Output of 4 to 410 mc

Model SG-54A standard signal generator has an output of from 4 to 410 mc. Incidental fm is less than 300 cps at 50% modulation of any rf or modulation frequency. vswr is less than 1.1 and frequency drift less than 0.001% over a 10 min period after warm-up. Output level is continuously variable from 0.1 to 100,000 mv. The carrier may be internally or externally sine wave modulated or externally pulse modulated. In pulse modulation, the rise time is better than 1 μsec from 6 mc to 120 mc and better than 0.5 μsec from 120 to to 410 mc. Frequency calibration is within 0.5% and resettability better than 0.05%. Modulated spectrum distortion is less than 3% at 50% modulation.

Trad Electronics Corp., Dept. ED, 101 First Ave., Asbury Park, N.J.

CIRCLE 130 ON READER-SERVICE CARD

## TWT Amplifier

### Provides 30 db gain

This twt amplifier provides a 30 db power gain from 12 to 16 kmc. It uses a permanent magnet twt weighing less than 5 lb and needs no electromagnet for focusing. Power supply regulation is 0.1%, ripple is 10 mv, and total weight is 55 lb.

Menlo Park Engineering Co., Dept. ED, 711 Hamilton Ave., Menlo Park, Calif.

CIRCLE 131 ON READER-SERVICE CARD

## Potentiometers

### 650 ohm to 100 K range

Series T single-turn potentiometers are 7/8 in. in diameter and have standard resistances ranging from 650 ohms to 100 K. Power rating is 1.2 w at 40 C, derating to zero at 125 C. The units have standard linearity tolerances of ±0.5 and ±0.2% and meet MIL-R-19 and NAS 710 specifications.

Beckman Instruments, Inc., Helipot Div., Dept. ED, 2500 Fullerton Rd., Fullerton, Calif.

CIRCLE 132 ON READER-SERVICE CARD
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# NEW PRODUCTS

## Miniature RF Filters

### Have 0 to 1250 mc cutoff frequencies

These lumped constant, low pass rf filters have cutoff frequencies from 0 to 1250 mc and provide sharp attenuation in the stop-band region. At a frequency of 1.2 times cutoff, attenuation is 20 db or higher; and at 1.5 times cutoff, it is at least 60 db. Units down to 100 mc cutoff are 3-1/2 in. long, including end connectors. Suited for the generation of signals for testing the frequency response of rf circuits, or in vswr measurements, the filters may also be used in transmitter or telemeter systems for missiles and aircraft. They are finished in nickel plated brass with BNC male and female end connectors. Input power is normally 10 w, maximum; impedance, 50 ohms.

Telonic Industries, Inc., Dept. ED, Beech Grove, Ind.

CIRCLE 121 ON READER-SERVICE CARD

## Voltage Regulator

### Has 115 v rated output

With a 150 w load and a constant frequency of 60 cps, the LVR-150 voltage regulator maintains an output voltage within ±0.5% of the rated 115 v through input variations between 95 and 130 v. With a 200 w load and 105 to 130 v input variation, the output is regulated to within ±2%. The unit can also regulate output voltage to within ±5% with rated load, 95 to 130 v input variation, and 50 to 63 cps frequency variation. The main assembly is housed in a 5 x 6 x 6 in. case with a four terminal input-output plug, and the diode bridge and associated components are mounted under a cover plate on the side of the main unit.

J. B. Rea Co., Inc., Electronics Div., Dept ED, 2202 Broadway, Santa Monica, Calif.

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# revolutionary G-E Controlled Rectifier

"Controlled rectifiers may revolutionize the electrical industry." This statement was made a year ago by a respected news publication. Since then samples have been studied by hundreds of firms. Many new circuits have been developed which promise important improvements in functions, reliability, simplicity, accuracy and lower cost. In just one year prices have been reduced 75 percent (see chart below). And now, the G-E Silicon Controlled Rectifier is a standard, production-line item, warranted in writing and available at sharply reduced prices.

This is the time for design engineers to exploit the inherent advantages of the Silicon Controlled Rectifier in their circuit designs. Many applications are proved . . . the firing circuits have been refined . . . the product line is stabilized . . . and it makes sound economic sense. Call or write your G-E Semiconductor Sales Representative for complete details. The Controlled Rectifier is also available from many local G-E Distributors.

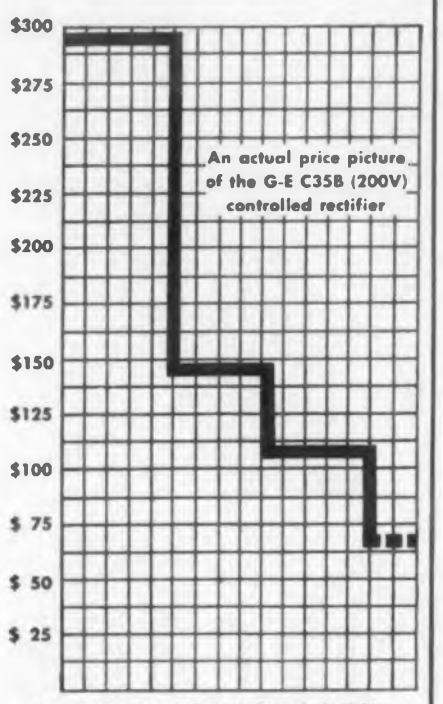

**HOW THE G-E CONTROLLED RECTIFIER WORKS.** The Silicon Controlled Rectifier is a three junction semiconductor device for use in power control and power switching applications requiring blocking voltages up to 400 volts and load currents up to 16 amperes. Series or parallel circuits may be used for higher power applications.

The G-E Controlled Rectifier's reverse characteristic is similar to a normal silicon rectifier in that it represents essentially an open circuit with negative anode to cathode voltage. The forward characteristic is such that it will block positive anode to cathode voltage below a critical break-over voltage if no signal is applied to the gate terminal. However, by exceeding the forward break-over voltage or applying an appropriate gate signal the device will rapidly switch to a conducting state and present the characteristically low forward voltage drop of a single junction silicon rectifier.

**DETAILED NOTES** are available on the application of the G-E Silicon Controlled Rectifier, plus reprints of articles that have appeared in technical journals. Write to Section S25359, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

**STEADY PRICE DROP.** Since its introduction one year ago, the price of the typical G-E Controlled Rectifier has dropped more than 75 percent. This results from improved manufacturing techniques and volume production. The G-E Controlled Rectifier is now a production-line item, warranted in writing for one year and subjected to the same quality control tests imposed on all General Electric transistors and rectifiers.

**The G-E Controlled Rectifier is also available at even less cost (ZJ39L series) for use at 100°C and below, with currents up to 10 amperes.**




**MAXIMUM ALLOWABLE RATINGS (Resistive or Inductive Load)**

| | C35U | C35F | C35A | C35G | C35B | C35H | C35C | C35D |
|---|---|---|---|---|---|---|---|---|
| Continuous Peak Inverse Voltage (PIV) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 volts |
| Transient Peak Inverse Voltage (Non-Recurrent<5 millisec.) | 35 | 75 | 150 | 225 | 300 | 350 | 400 | 500 volts |
| RMS Voltage ($V_{RMS}$), Sinusoidal | 17.5 | 35 | 70 | 105 | 140 | 175 | 210 | 280 volts |
| Average Forward Current ($I_F$) | Up to 16 amperes | | | | | | | |
| Peak One Cycle Surge Current ($I_{surge}$) | 150 amperes | | | | | | | |
| Peak Gate Power | 5 watts | | | | | | | |
| Average Gate Power | 0.5 watts | | | | | | | |
| Peak Gate Current ($I_G$) | 2 amperes | | | | | | | |
| Peak Gate Voltage ($V_G$) (forward) | 10 volts | | | | | | | |
| Storage Temperature | −65°C to +150°C | | | | | | | |
| Operating Temperature | −65°C to +125°C | | | | | | | |

| CHARACTERISTICS (At Maximum Ratings) | C35U | C35F | C35A | C35G | C35B | C35H | C35C | C35D |
|---|---|---|---|---|---|---|---|---|
| Minimum Forward Breakover Voltage ($V_{BO}$) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 volts |
| Maximum Reverse ($I_R$) or Forward ($I_S$) Leakage Current (Full Cycle Average) | 6.5 | 6.5 | 6.5 | 6.5 | 6.0 | 5.5 | 5.0 | 4.0 ma |
| Maximum Forward Voltage ($V_{F\ AVG}$) | 0.86 volts (Full Cycle Average) | | | | | | | |
| Maximum Gate Current To Fire ($I_{GF}$) | 25 ma | | | | | | | |
| Maximum Gate Voltage To Fire ($V_{GF}$) | 3 volts | | | | | | | |
| Typical Gate Current To Fire ($I_{GF}$) | 10 ma at +1.5 volts (Gate to Cathode Voltage) | | | | | | | |

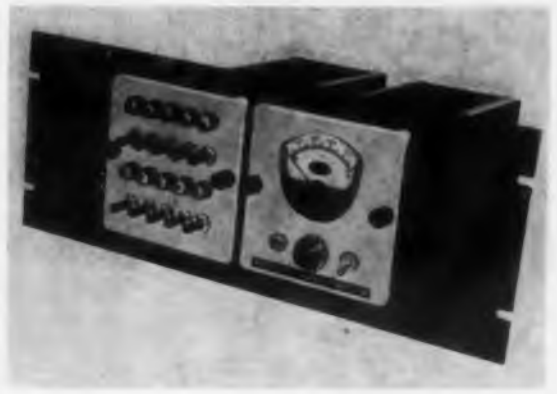
**ZJ39L Series—lower cost series with ratings similar to above, but for use up to 100°C maximum, with forward current ratings up to 10 amperes.**
**ZJ50 Series—a high-current series now in development, and available on a prototype-sample basis.**

GENERAL ELECTRIC

CIRCLE 123 ON READER-SERVICE CARD

## Temperature Monitoring System

### Multipoint



This continuous temperature monitoring system consists of monitor modules, each of which receives inputs from 10 thermistor probes, and an alarm indicator module. Up to 10 modules, 100 points, can be handled by one alarm indicator module, and all points are monitored simultaneously. No scanning devices are used. Designed to detect and furnish warning when the temperature at any protected point reaches a preselected high or low limit, the system can provide protection for processing equipment and all types of industrial installations. It monitors temperatures from −25 to +600 F.

Fenwal Inc., Dept. ED, Ashland, Mass.

CIRCLE 124 ON READER-SERVICE CARD

## Large Waveguide Window

### For multimegawatt applications

This large waveguide window is designed for multimegawatt applications with the company's WR-2100 waveguide. It provides good radio frequency continuity and a standing wave ratio of 1.03 over a 10% band.

I-T-E Circuit Breaker Co., Dept. ED, 1900 Hamilton St., Philadelphia 30, Pa.

CIRCLE 125 ON READER-SERVICE CARD

## Variable Speed Drive

### Has 10 turn vernier dial

For exact adjustment to any speed setting or for duplication of previous speed settings, this 2 in. square Servotran variable speed drive can be furnished with an accurately calibrated vernier 10 turn dial. The unit can provide output shaft speeds infinitely variable from 0 to 1200 rpm, forward and reverse. It is available with motors in the 1/100 to 1/40 hp range. Other models for applications requiring between 1/1000 and 1/10 hp are also available.

Humphrey, Inc., Humphrey Products Div., Dept. ED, 3794 Rosecrans St., San Diego 10, Calif.

CIRCLE 126 ON READER-SERVICE CARD

# NEW PRODUCTS

## Precision Potentiometer

### Operates at 230 C

The series 42 wire-wound precision potentiometer is designed to operate at temperatures up to 230 C, with a wattage rating of 0.25. Resistance change after 255 hr at 230 C is less than 0.1%. Insulation resistance is 10,000 meg min. Resistance tolerance is ±5% from 1 to 100,000 ohms. Independent linearity is ±0.5% and noise is less than 5 μv. It has screw terminals for simple and positive connections and comes with bushing type mounting, although servo type can be furnished.

Clarostat Mfg. Co., Inc., Dept. ED, Dover, N. H.

CIRCLE 117 ON READER-SERVICE CARD

## Decoder Modules

### For binary coded decimal information

Decoder modules type BCD-8421 and BCD-4221 are designed to take the respective binary coded parallel information directly to the input of a beam switching tube and display the equivalent decimal information on a Nixie in-line indicator tube. The beam switching and Nixie tube combination has an access time of 1 μsec and an inherent memory. The modules are plug-in, printed circuit type and have display repetition rates in excess of 1 kc.

Burroughs Corp., Electronic Tube Div., Dept. ED, Box 1226, Plainfield, N.J.

CIRCLE 118 ON READER-SERVICE CARD

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Circle 119 for Allied ▶
Circle 120 for Texas ▶

# NEW PRODUCTS

## Transistorized Power Inverter

**Dc to sine wave ac**

Model 591-J transistorized power inverter is designed to insure maximum performance from ac gyros and motors. No excess heat is created because the output waveshape, being sinusoidal, avoids the heat-producing harmonics. Unit is fully encapsulated and hermetically sealed. Nominal input voltage: either 24, 26 or 28 v dc. Output voltage: 26 and 115 v ac standard. Output frequency of 400 cps is standard, with 1200, 1500 and 2000 cps available. Output power: 40 va; operating temperatures: —55 to +71 C.

Arnold Magnetics Corp., Dept. ED, 4613 W. Jefferson Blvd., Los Angeles 16, Calif.

CIRCLE 134 ON READER-SERVICE CARD

## Receiving System

**For low-level beacon signals**

A complete receiving system, the Microlock model 90208-2 receives low-level beacon signals from missile or satellite borne transmitters, permitting accurate measurements of position and velocity as well as recording of telemetered information. Sensitive to signals down to —150 dbm, the system is designed for use with an interferometer antenna system and operates on a phase-locked-loop principle. Angular position can be determined to an accuracy of 1 mil. The system is mounted in a standard relay rack and is furnished with power supplies and alignment and monitoring equipment.

Resdel Engineering Corp., Dept. ED, 330 S. Fair Oaks Ave., Pasadena, Calif.

CIRCLE 135 ON READER-SERVICE CARD

## Hybrid Tees

### For large waveguides

This hybrid Tee, which can be used as either test equipment or as a functional part of a system, is made in both plain and folded types. Waveguide sizes range from WR770 through WR2300, covering a uhf frequency range of 320 to 1450 mc. Among applications are: power dividers; balanced mixers; sideband modulators; power discriminators and phase detectors.

I-T-E Circuit Breaker Co., Dept. ED, 1900 Hamilton St., Philadelphia 30, Pa.

CIRCLE 136 ON READER-SERVICE CARD

## Insulation Testers

### Portable

Portable Hipot testers S2, DC, S5 DC, and S10 DC cover 0 to 2, 0 to 5, and 0 to 10 kv dc, respectively. They incorporate a 4 in. meter for direct indication of leakage current; a direct reading, 4 in. kilovoltmeter connected directly across the output; and a dead front safety grounded control panel. They are protected against overloads and surges and provide a continuously adjustable output voltage from zero to maximum. The units can be used to measure leakage current, for breakdown testing, or as high voltage power supplies where a few milliamperes of current is adequate. They measure 8 x 14 x 8 in. and weigh 20 lb.

Peschel Electronics, Inc., Dept. ED, RFD 1, Patterson, N.Y.

CIRCLE 137 ON READER-SERVICE CARD

◀ CIRCLE 870 ON READER-SERVICE CARD

# NEW PRODUCTS

**POCKET ADDING MACHINE AND SLIDE RULE.**—This 13-scale log-log slide rule has a 5 in. scale length and a six digit adding machine on its reverse side. A P scale makes it possible to find any sine and cosine of an angle without determining the angle.

Harrison Home Products Corp., Dept. ED, 565 Fifth Ave., New York 17, N.Y.

CIRCLE 139 ON READER-SERVICE CARD

**LIGHTHOUSE TRIODE.**—General purpose model GL-6771 is a high mu, metal ceramic unit for use in grounded grid service as a radio frequency amplifier, oscillator, or frequency multiplier. As a cw oscillator, it can be used at frequencies to 4000 mc.

General Electric Co., Power Tube Dept., Dept. ED, Schenectady 5, N.Y.

CIRCLE 140 ON READER-SERVICE CARD

**MINIATURE INSTRUMENT NUTS.**—Miniature turned nuts in a range of types, shapes, and sizes for use in precision instruments and miniaturized equipment. Supplied to customer specifications with standard or special threads in diameters down to 1/8 in. hexagon. Lengths and diameters are held to +0.000 and −0.005 in.

Fischer Special Mfg. Co., Dept. ED, 422 Morgan Ave., Cincinnati 6, Ohio.

CIRCLE 141 ON READER-SERVICE CARD

**TUBE SOCKET SAVERS.**—These rugged units are designed for 7, 8, and 9 pin miniature sockets in electron tube testers.

Forway Industries, Inc., Dept. ED, 122 Green Ave., Woodbury, N.J.

CIRCLE 144 ON READER-SERVICE CARD

**SOLID STATE POWER SUPPLIES.**—Miniature Transpac short-circuit and transient proof power packs cover 5 to 60 v dc in fixed and adjustable voltage types. Available in ratings to 200 ma, they operate from an input source of 105 to 125 v ac, 60 or 400 cps.

Electronic Research Associates, Inc., Dept. ED, 67 Factory Place, Cedar Grove, N.J.

CIRCLE 145 ON READER-SERVICE CARD

**CHASSIS LATCH.**—The 35L is designed for engaging, disengaging, and carrying equipment filled drawers from electronic racks. It has a pushbutton release mechanism on the locking device which permits quick release of multiple pin connectors commonly used with plug-in chassis. Adequate mechanical advantage is provided to engage connector plugs with forces of 400 lb.

Camloc Fastener Corp., Dept. ED, 61 Spring Valley Rd., Paramus, N.J.

CIRCLE 146 ON READER-SERVICE CARD

**GEAR SET VERNIER.**—Automatically provides vernier calibration settings to an accuracy tolerance within 1/1000 in. regardless of human errors in reading and lining up a vernier to the hairline marker and inaccuracies in the manufacture of the vernier dial.

Jos. Gelb Co., Dept. ED, 52 Arlington St., Newark 2, N.J.

CIRCLE 147 ON READER-SERVICE CARD

**ULTRASONIC CLEANING TANK.**—Series TH Sonogen ultrasonic cleaning tank-transducers have an integral heater, dual thermostatic control, and twim-wall costruction. Available in eight standard sizes with 1 to 32 gal tank capacity and transducer input from 65 to 1000 rf w.

Branson Ultrasonic Corp., Dept. ED, 40 Brown House Rd., Stamford, Conn.

CIRCLE 148 ON READER-SERVICE CARD

**ELECTRICAL RESISTANCE PROBE.**—Highly sensitive to environmental changes, this probe measures corrosion and hard-to-detect liquid and gaseous contaminants. It can detect the slightest change in humidity, ozone concentration, or water content in a nonaqueous liquid. In missile systems, it can detect corrosive conditions which may harm delicate electromechanical components long before any actual corrosion occurs.

Crest Instrument Co., Div. of Magna Products, Inc., Dept. ED, 11808 S. Bloomfield Ave., Santa Fe Springs, Calif.

CIRCLE 149 ON READER-SERVICE CARD

**HIGH CURRENT TERMINAL BLOCKS.**—Types T and U, respectively rated 125 and 250 amp at 750 v, have tubular type terminals for connecting wire leads without lugs. Type T accommodates AWG 6 to 1/0 wire and has 1 to 6 terminals per block. Type U has socket head screws in its terminals and accommodates AWG 4 to 250 MCM wire. Types L, O, and S, designed for the connection of leads with lugs, are rated at 750 v for 100, 125, and 225 amp, respectively, and handle up to 1, 1/0, and 4/0 AWG.

Curtis Development and Mfg. Co., Dept. ED, 3250 N. 33rd St., Milwaukee 16, Wis.

CIRCLE 150 ON READER-SERVICE CARD

**PRESSURE SENSITIVE TAPE.**—Thermal curing type TGV Teflon impregnated fiberglass tape has a temperature range of −100 to +500 F and adheres to any dry, clean surface. For both mechanical and electrical applications, it is available in 18 yd rolls and 1/2, 3/4, 1-1/2, and 2 in. widths.

The Connecticut Hard Rubber Co., Dept. ED, 407 East St., New Haven 9, Conn.

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# NEW LITERATURE

### RF Chokes 154

A new rf choke coil technical data sheet contains a detailed description of the electrical parameters for the complete line of chokes which are available in a 100,000 to 1 inductance range, said by the manufacturer to be the widest range available in a small size, high-reliability line. The entire standard line of Essex chokes is described by the data sheet which lists parameters for 123 different units with inductance values from 0.1 h to 10 mh. The units shown include the logarithmic series as well as the preferred series. The data sheet announces that all Essex encapsulated choke coils are nonflammable, and it explains the company's ability to produce, on special order, choke coils with inductance values rather than the 123 standard preferred and logarithmic series listed. Essex Electronics, Berkeley Heights, N.J.

### Converter-Inverters 155

A 4-page, 2-color data file describes company's Transidyne line of converter-inverters. The data file shows pictures of the various case styles and lists features and specifications of the four basic series. For your free copy of Data File 701, write Spectrol Electronics Corp., 1704 South Del Mar Avenue, San Gabriel, Calif.

### Communication Accessories 156

Twenty-four page catalog covers toroidal coils, laminated transformers, filters, magnetic amplifiers and dc to dc converters. Basic catalog 858 includes graphs, pictures, dimensions of units, electrical characteristics and a price list. Communication Accessories Co., Lee's Summit, Mo.

### PTFE Tubing 157

A new, three-color, four-page brochure contains prices, tolerances, sizes and application information on PTFE (polytetrafluoroethylene) tubing. A gate-fold chart lists electrical, mechanical, chemical and thermal properties of the high temperature tubing, opposite a full page of purchasing information such as price, color packaging and terms. Cross-reference charts are provided for "Super-Thin", "Thin-Wall" and "ASTM Wall" PTFE tubings by AWG size and footage. Another chart lists dimensional tolerances for all PTFE tubings by AWG size. Irvington Div., Minnesota Mining and Manufacturing Co., 900 Bush Avenue, St. Paul 6, Minn.

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### Cathode Ray Tubes 160

A new booklet lists the characteristics of television picture tubes and cathode ray tubes for specialized commercial, industrial and military applications. The 42-page booklet constitutes a complete reference to all popular tube types of American manufacturers, and characteristics and mechanical dimensions of most EIA-registered tubes. Tubes listed in the new Sylvania booklet are grouped under two general headings depending on whether they employ magnetic or electrostatic focus. Within these groups the tubes are listed numerically-alphabetically. Essential data such as maximum ratings, heater voltages, typical operations information, and bulb dimensions can be readily determined where individual data sheets are not available. Special sections on phosphor characteristics and proper tube handling highlight the presentation. Sylvania Electric Products Inc., 1740 Broadway, New York 19, N.Y.

### Potentiometer and Bridge Instruments 161

A new 64-page edition of Bulletin P1245-A, covers complete specifications of company's potentiometer and bridge instruments in indicating, recording, and controlling models. Information concerning rack mounting instruments, high-speed and multipoint instruments, and miniature instruments is included, in addition to descriptions of standard round-chart and strip-chart instruments. One section of the bulletin is devoted to sensing elements and attachments for use with Dynamaster instruments. Resistance bulbs, magnetos, photocells, conductivity cells, frequency converters, computing, totalizing, and digital read-out attachments are among those listed. A section describing the incorporation of Dynamaster instruments into other manufacturers' equipment is also included. Request Bulletin P-1245-A from The Bristol Co., Waterbury 20, Conn.

### Transformer Catalog 162

"Pulse-Transformers", a 24-page catalog, is designed to assist engineers in the application of transformers to their specific needs. Complete with many tables, charts, and schematics this manual covers a brief history of low-level pulse transformers, their measurements, specifications, applications, interchangeability, dielectric ratings, manufacturing, and other data. Also included is information on some 2000 standard design transformers (available from stock), as well as case types and specifications data to aid the engineer who requires transformers of custom design and manufacture. "Pulse Transformers" is available on request by writing PCA Electronics Inc., 16799 Schoenborn St., Sepulveda, Calif.

# Editorial Critique

*Electronic Design* is getting a thorough going over . . . The scene above is typical of the editorial conference held after each issue goes to press. These special meetings, called by Edward E. Grazda, Editor, help to improve editorial standards by constructive self-criticism. Editors exchange points of view, make suggestions, comment on clarity and conciseness; discuss technical points. These discussions are aimed, as always, toward making your magazine more interesting, useful, and informative. Your own reactions, ideas, and comments are often mentioned here – all helping to keep the magazine more closely tuned to the main current of reader needs and interests.

# NEW LITERATURE

### Semiconductor Preforms 165

Bulletin A-68, a 4-page illustrated technical bulletin describing high purity semiconductor preforms used in making alloy junctions in germanium and silicon devices, include information on analyses of alloys, specifications and tolerances of discs, spheres, and washer preforms, along with previously unpublished phase diagrams of semiconductor alloys. Bulletin A-68 shows typical analyses of semiconductor elements such as lead, antimony, indium, gold, gallium, cadmium, indicating the importance of minimal impurities. In addition to metallurigical information, Bulletin A-68, lists specifications and tolerances on high purity preforms produced from these alloys. Bulletin A-68 also shows company's unique facilities for the production of high purity preforms. Accurate melts, analyses their own alloys, rolls and forms these alloys, and by maintaining their own tool and die facilities can rapidly tool up to produce either small or very large production runs. Inspection facilities depicted in the bulletin show a system of close control on size and weight of preforms by mechanical, optical, and electronic methods. Accurate Specialties, Inc., 37-11 57 St., Woodside 77, N.Y.

### Alternators 166

A new, four-page illustrated folder, detailing its dramatic new line of alternators, features silicon rectifiers in lieu of standard selenium rectifiers. According to the literature, the new type alternators provide infinite operating life and vastly reduced maintenance. The folder graphically illustrates how the new silicon rectifier because of its considerably smaller size, has been successfully combined with the basic alternator, thus providing an alternator system with only two components instead of the previous three (the alternator, the rectifier, and the regulator). More than 30 illustrations highlight design and application features. The literature also contains detailed specifications and operating information. Copies may be obtained from the Leece-Neville Co., 1374 East 51st St., Cleveland 3, Ohio.

### Test Equipment 167

A new data folder, providing specifications and prices for transistorized digital test equipment describes 10 of the firm's standard building blocks which can be used in a wide variety of test setups, through use of patch cords. Digital Equipment Corp., Maynard, Mass.

Don't miss an issue of *ELECTRONIC DESIGN;* return your renewal card.

### Guide to Silicones 170

Latest additions to the Dow Corning Silicone line include three brochures which detail the growing use of different silicone products in their respective fields of application. "1959 Guide to Dow Corning Silicones" is a 16-page illustrated brochure discussing new materials to improve products and reduce costs. Nature, properties, and applications of adhesives through water repellents are described. The four-page leaflet, "Nothing Sticks to Paper with Syl-Off Silicone Coatings" discusses the advantages of this product. "Silicones in Missile Design" is an illustrated folder describing rigid materials, rubbery materials, fluid materials, and dielectric materials for electrical and electronic systems in missile and support equipment. Dow Corning Corp., Midland, Mich.

### Pushbutton Switches 171

This two-page data sheet covers a new series of "One-Shot" Switches. The unit consists of a pushbutton switch assembly with an electronic circuit which produces a single, microsecond length pulse with each operation. Data sheet includes photo, dimension drawing, specifications, circuit schematic, pulse curve oscillagraphs and application information. Micro Switch, Division of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

### Electronic Components 172

Catalog 558, a 12-page two-color brochure, lists Hitachi electronic receiving tubes and transistors. Also included are several types of capacitors, resistors and audio equipment. Electronic Utilities Co., Division of the Sampson Co., 2244 S. Western Ave., Chicago 8, Ill.

### Batteries 173

"A Reusable Primary—The Yardney PB Silvercel® Battery," is a technical bulletin describing this recently developed battery which combines the recyclability of the secondary battery, the fast activation of the primary and the high power output of the silver-zinc system. The illustrated brochure explains the PM Silvercel battery's outstanding characteristics—highest specific power, highest specific energy and longest activated stand life yet achieved by a primary, reusability and fast activation. It compares the battery's energy and power with other battery systems, and discusses its applications, electrical characteristics (energy, power discharge rates), construction, charging, fast activation, wet stand, recycling, soaking time and other technical data. Yardney Electric Corp., 40-50 Leonard St., New York, N.Y.

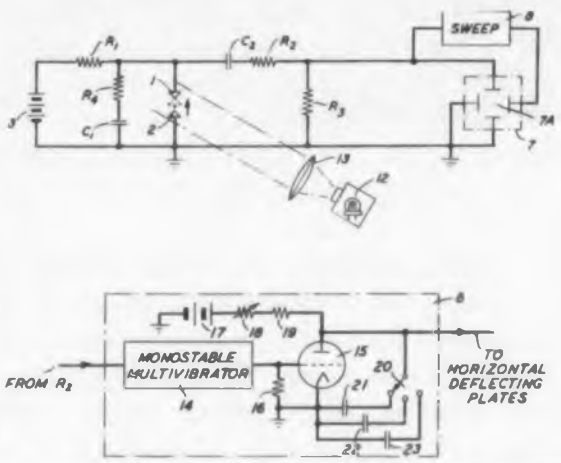
# PATENTS

### Velocity Measurement of Relay Contacts

*Patent No. 2,864,054. Willard S. Boyle and James L. Smith. (Assigned to Bell Telephone Labs., Inc.)*

Rate of closure of contacts is measured by displaying, on a calibrated oscilloscope, the time interval from arc discharge across the contacts to the time of actual contact. For fixed voltage and pressure, the spacing for arc discharge is obtained from Paschen's law; actual contact is the instant a storage capacitor discharges.

Initially, capacitor $C_1$ charges fully and ultraviolet lamp *12* illuminates the contact spacing with photoelectrons to insure reproducibility of the spacing for the arc. As contacts *1* and *2* move together, capacitor $C_1$ discharges at the time the arc initiates and the crt sweep *3* is triggered. Capacitor $C_1$ recharges as the contacts move closer and the second discharge of the capacitor, when the contacts touch, precisely marks the time of closure $T$ on the oscilloscope display.



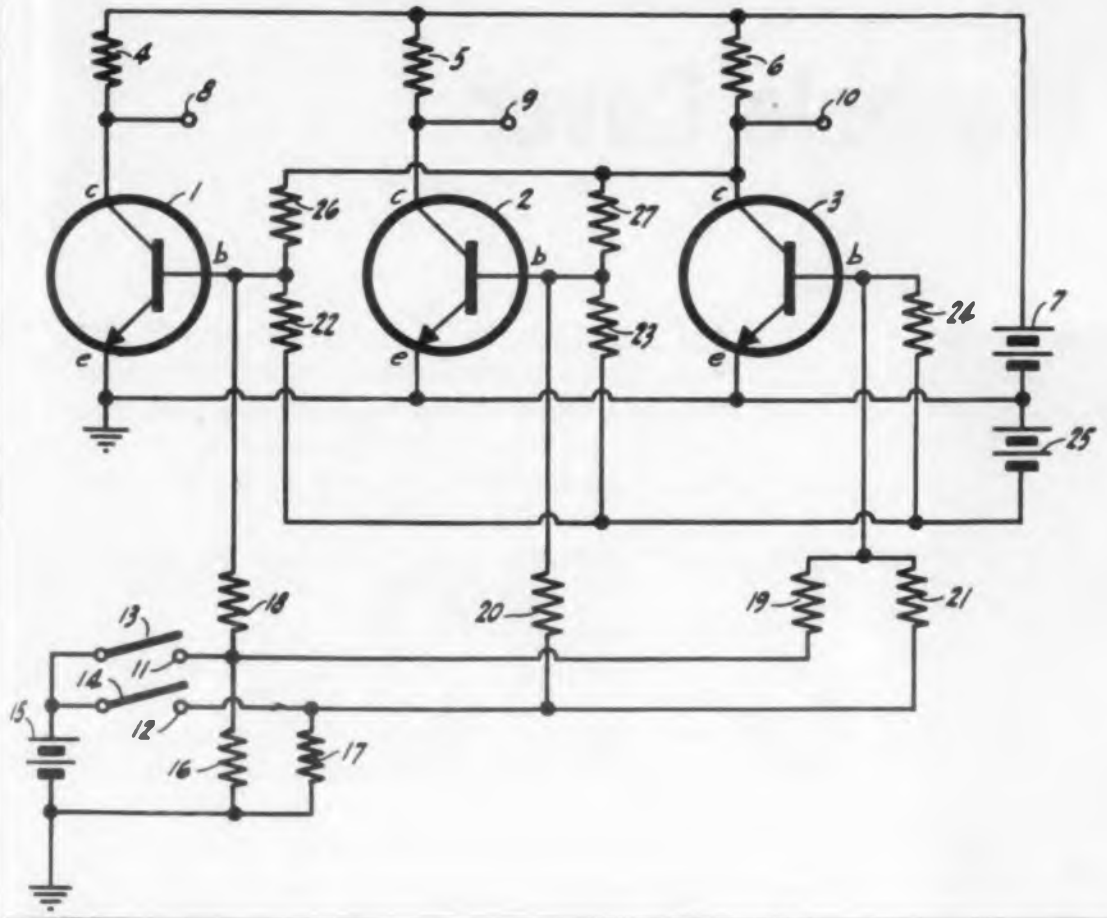

### System for Selectivity Energizing One of Three Circuits Responsive to Variation of Two Conditions

*Shih C. Chao. (Assigned to International Business Machines Corp.)*

Individual signals gate selected circuits while the signals simultaneously exclusively gate another circuit.

Battery *25* sets the pnp transistors beyond cut off. Closing switch *12* permits only transistor *1* to conduct and closing

switch *14* causes only transistor *2* to conduct; for both instances, resistors *19* and *21* divide the input signals to hold the third transistor cut off. However, when switches *12* and *14* close together, these voltage divider resistors are shorted, transistor *3* conducts and the output voltage is fed back to cut off transistors *1* and *2*.



# Radio Frequency Manhole Cover

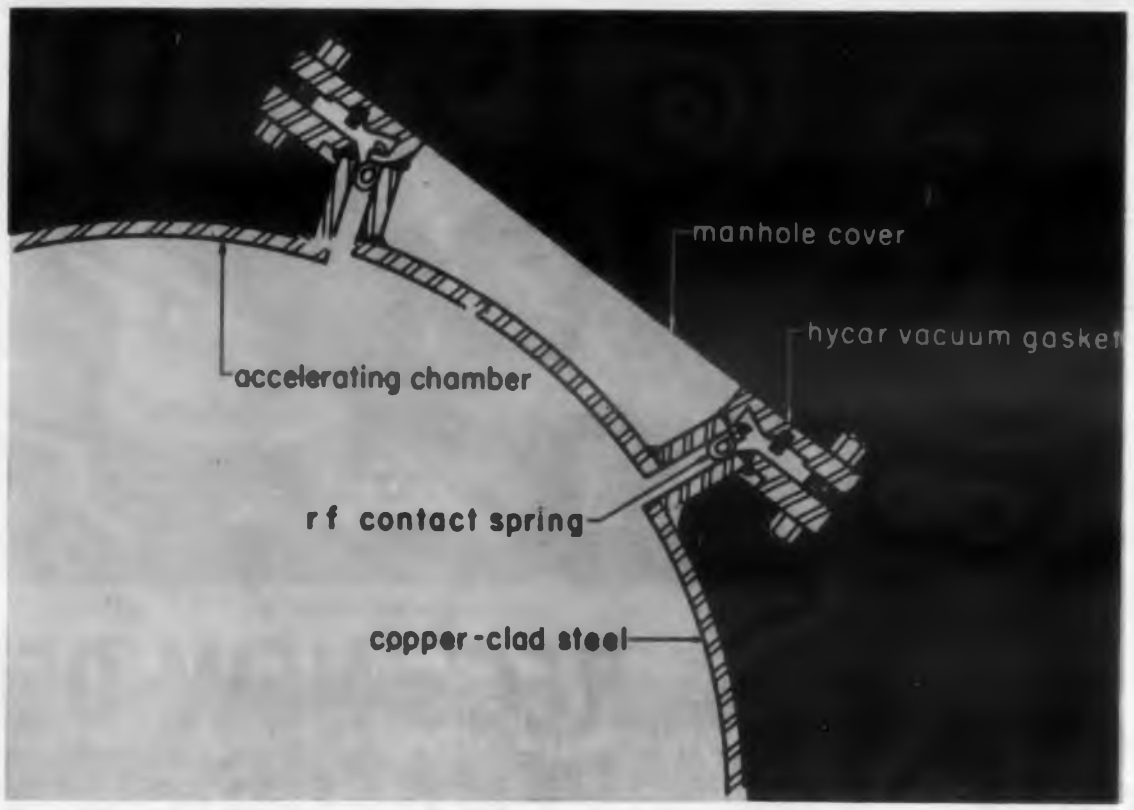



**Fig. 1.** Cross section of an accelerating chamber of the HILAC, showing a manhole cover and rf-contact spring.

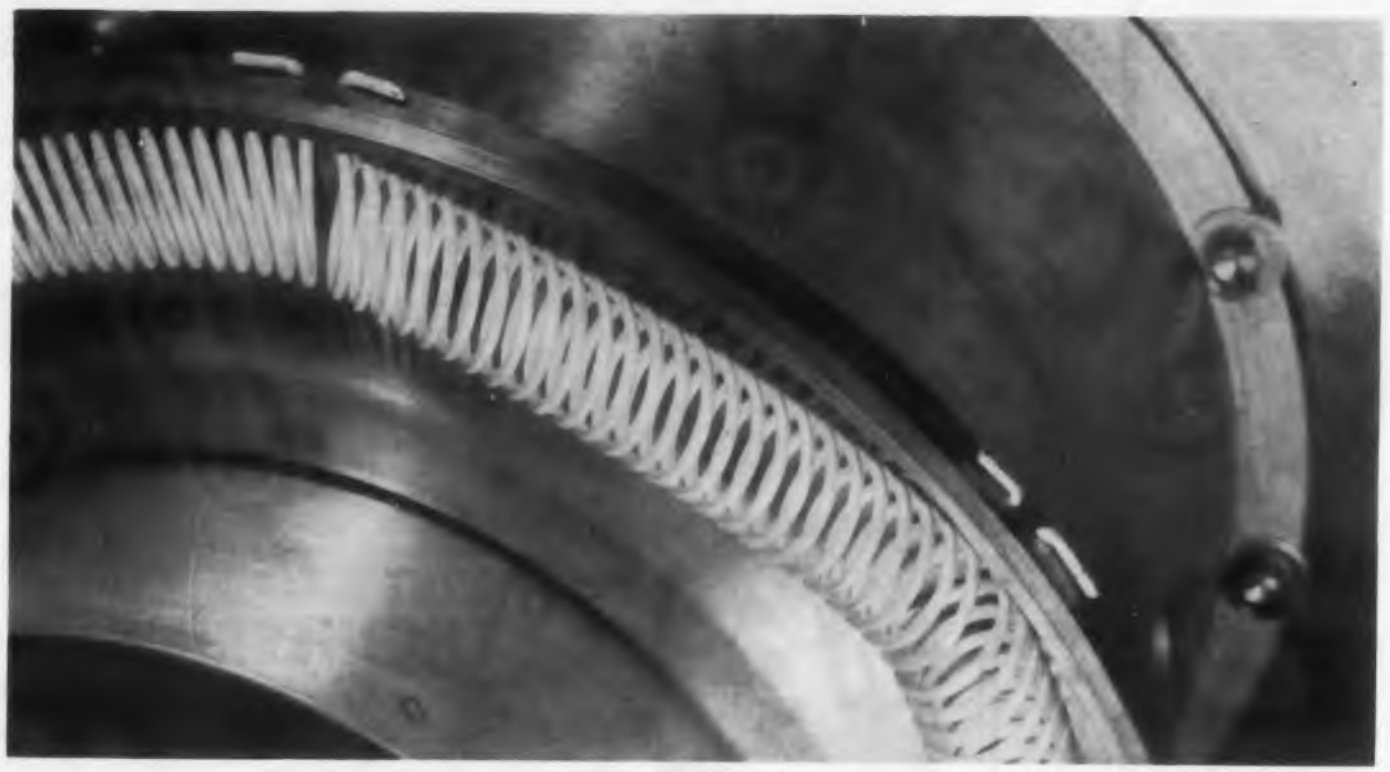


**Fig. 2.** Radio frequency contact for a transmission-line joint of the HILAC.

IN THE heavy-ion linear accelerator (HILAC) the accelerating chambers are made of copper-clad steel. The rf and vacuum cavities are integral; opening one cavity simultaneously opens the other. Therefore, all covers must have both a vacuum gasket and an rf contact.

To facilitate entry it is desirable to use only one set of clamping bolts for making both the rf contact and the vacuum seal.

An arrangement which has proved successful for the manhole covers of the HILAC is shown in Fig. 1. The unique element of this is the rf contact spring. This spring is designed so that the contact force rises to a maximum with a deflection of only 1/16 in., even though the spring diameter is 1 in.

The contact force remains almost constant with further deflection. Because of this, the spring can accommodate large surface roughness and still give a successful rf contact that can be reused indefinitely.

The HILAC has been operating for nearly two years at rated power (70 mc, 42 amp rms on a 3 per cent duty cycle) and there have been no spring replacements due to burnout. One spring section had to be replaced because of mechanical damage, but the circumstances only proved the ruggedness of the design.

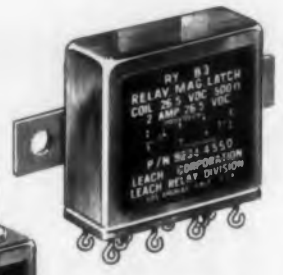
One of the manhole covers was accidentally dropped when it was about a foot above the hole. The rf contact spring piloted the 400 pound cover into the hole and absorbed enough shock so that nothing was damaged except one 6 in. spring section. It took only a minute to clip off the ends of the damaged spring, insert the ends of a new one, and bend them over.

Although this design has been used only in the HILAC, it is apparent that it could be applied to other situations. For instance, in a variable-volume resonator where it is necessary to have an rf contact between a sliding piston and a cylinder wall, this spring might prove ideal.

The work on the manhole cover was done under auspices of U.S. Atomic Energy Commission.

*Luther R. Lucas, Lawrence Radiation Laboratory, University of California, Berkeley, Calif.*

TYPE 9234-4550 2PDT, 2AMP, MAGNETIC LATCH RELAY




(BRACKET MOUNTING. SOLDER HOOK TERMINALS, HERMETICALLY SEALED)

TYPE 9200-5091 2PDT, 2AMP, RELAY


(STUD MOUNTING, SOLDER HOOK TERMINALS, HERMETICALLY SEALED)

TYPE 9200-5072 2PDT, 2AMP, RELAY


(PLUG-IN OR PRINTED CIRCUIT MOUNTING, HERMETICALLY SEALED)

# LEACH SUBMINIATURE CRYSTAL CAN RELAYS

(SHOWN ABOVE...ACTUAL SIZE)

## torture-tested to perfection for big relay performance

These sensitive Leach subminiature relays deliver big relay performance... in a crystal can size that makes them ideal for use in missile control circuits in airborne or ground equipment and in computer and printed circuits.

Torture-tested to perfection in the Leach Production Reliability Center, these subminiatures are designed to meet the critical extremes of vibration, shock and other stringent environmental requirements in military and commercial applications.

They meet the specifications of both MIL-R-25018 and MIL-R-5757C—as well as MIL-R-6106C, *including the minimum current test requirements.* Uniform contact pressure and overtravel are guaranteed for the life of these balanced-armature relays. They are available in a wide range of socket, stud and bracket mountings to meet specific customer requirements.

*Write today for Leach Crystal Can Relay Brochure containing specifications, typical ratings and other information on these subminiatures! Or contact your nearest Leach sales representative to discuss your specific subminiature relay requirements.*

RELIABILITY

**LOOK TO LEACH**

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CIRCLE 181 ON READER-SERVICE CARD

# IDEAS FOR DESIGN

## Optical Gaging Cuts Costs Improves Efficiency

In microwave tube assembly, accurate physical measurements are essential. Bomac Laboratories, Inc., an important company in the microwave tube field, has found great economies through the use of a Kodak Contour Projector.

This instrument, shown in the photo, is used for rapid, accurate inspection of incoming material, in-process part measurements, and statistical quality evaluation.

During incoming inspection, multiple hole alignment on flat surfaces, angles of blind holes (via surface illumination), and decreasing angle slopes are but a few of the ways Bomac uses optical gaging. In many cases, components cannot readily be inspected by other means.

Furthermore, it is possible to check several dimensions of a part simultaneously with contour projection. Some of the general types of measurements include: thread forms, angles, hole locations, and the relationship between two or more parts of subassemblies.

One of the beauties of this method is that there is no wear to a light beam, no matter how often it is used. Hence, wear allowances need not be considered.

**Contour projection** allows for precise measurement of intricate parts.

## Shaft Turns, Syncs Scope

We needed to generate a synchronizing signal from a rotating shaft to trigger a scope. The shaft was on a "Servo Breadboard." A trigger was needed to relate mechanical and electrical rotation.

A mechanical brush contact was tried. This worked, but the contacts tended to float, at higher rpm's, giving an erratic trigger.

A simple method of generating the desired pulse is shown in Fig. 1. A 1N469 phototransistor is used in a simple amplifier circuit. The light source is a prefocused GE224 "Penlite" bulb. Both transistor and light are mounted by their leads in the positions shown. Fig. 2 shows the amplifier circuit.

The output trigger is approximately one to two v (depending on how critically the light source is adjusted). The rise and fall time is constant, at approximately 90 μsec, over a motor speed of 500 to 4000 rpm.

*Philip L. Writer, Engineer, Computers & Controls Div., Litton Industries, Beverly Hills, Calif.*

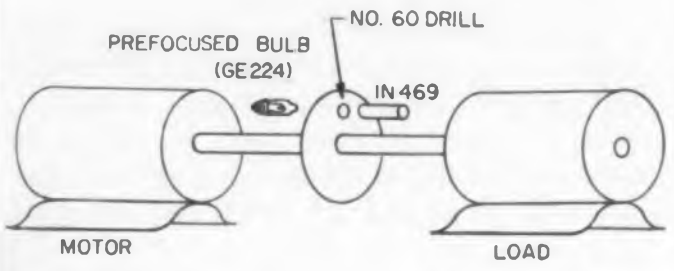



**Fig. 1.** The disk, mounted on the rotating shaft, provides a sync signal everytime the small hole allows light to strike the phototransistor.

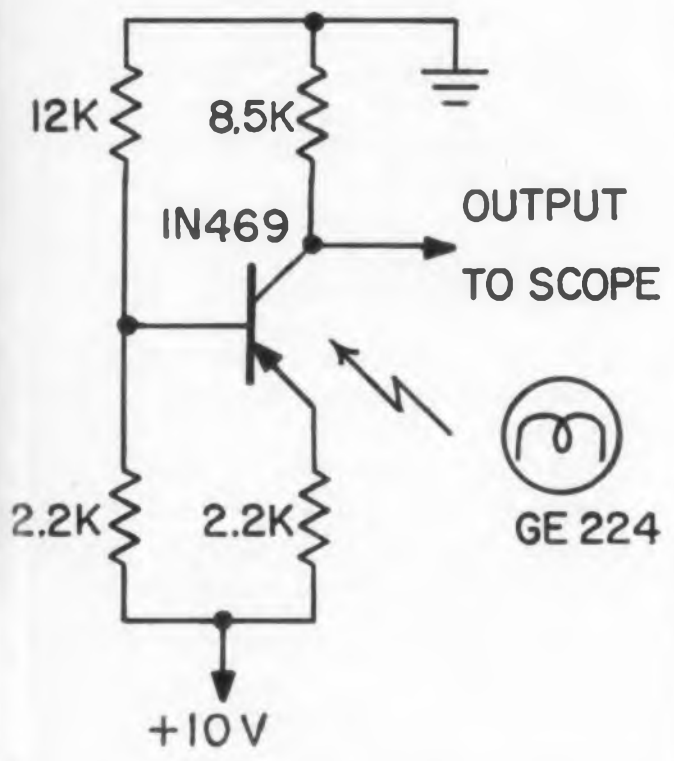



**Fig. 2.** Phototransistor circuit to provide scope sync.

# IDEAS FOR DESIGN

## Ten Minute Interval Timer

A need recently arose for an interval timer which would allow another piece of equipment to be activated from 5 sec to 1 minute, then turn this equipment off and accurately wait anywhere from 3 minutes to 10 minutes. Both intervals were to be adjustable.

Since such long intervals demand very large capacitors, especially in transistorized equipment, the new and small GE Tantalytic capacitors were used.

The circuit, shown in Fig. 1, works as follows. Assume that at $t = 0$, 30 v is applied to the circuit. Immediately the zener diode assumes a reference voltage, but at the same time *C*, which is 2300 μf, is thrown across the zener diode terminals through *R1*, the charge resistance. This heavy load causes the diode to go out of regulation. Therefore, *C* starts to charge essentially from zero. Eventually, the zener diode regains regulation and the capacitors start to charge asymptotically to the zener's terminal voltage with a time constant as determined by *R1* and *C*.

As *C* charges, the voltage across *C* is used to supply bias current to the base thru *R4* and *R6*. Thus, as the base current increases, so does the collector current until the "pull in" current has been reached in the relay. At this point, (1) the controlled circuit is disconnected (pin *1* of relay),

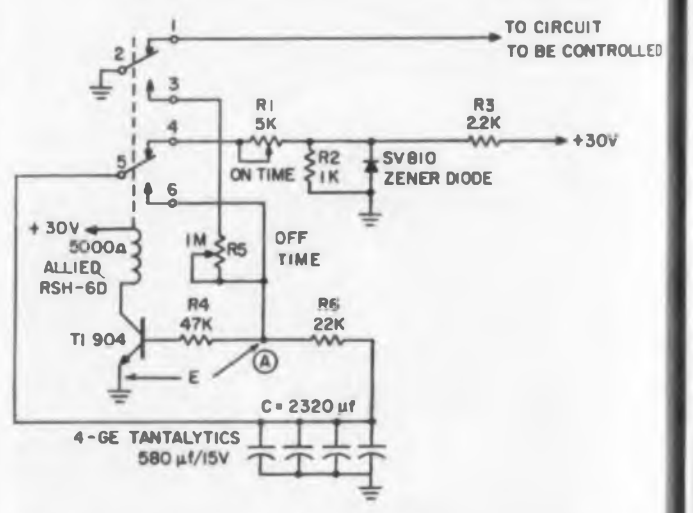



**Fig. 1.** Long interval timer takes advantage of large capacity available in small size tantalum capacitors.

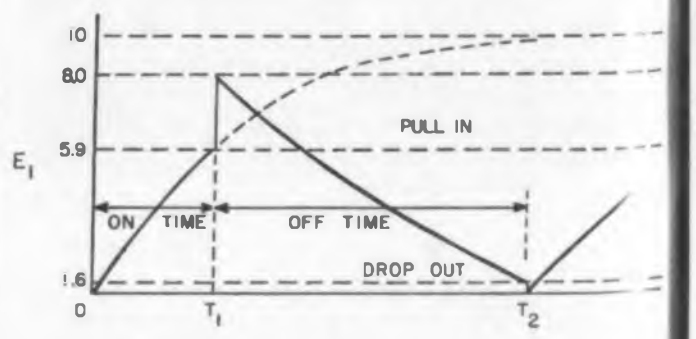



**Fig. 2.** Voltage at point *A* as a function of time.

(2) a resistor *R5* is connected to ground, (3) resistor *R6* is shorted out. Event 3 has particular significance, for it causes the full charged voltage of the capacitors to be used as base bias.

Fig. 2 is a plot of the voltage appearing at point *A*. At *t*1, *E*1 rises 2 v higher, and this adds greatly to the time interval. The capacitor then starts to discharge exponentially until at *t*2, insufficient bias current flows to maintain the relay energized. The process then repeats itself.

With the values shown, the *on* time can be varied between 3 sec to over a minute, and the *off* time can be varied from less than a minute to 5 minutes. With *R5* removed, a time of almost 10 minutes has been obtained.

*Gerald Wilner, Development Engineer, ITT Laboratories, Nutley 10, N. J.*

## TV Antenna for Radio

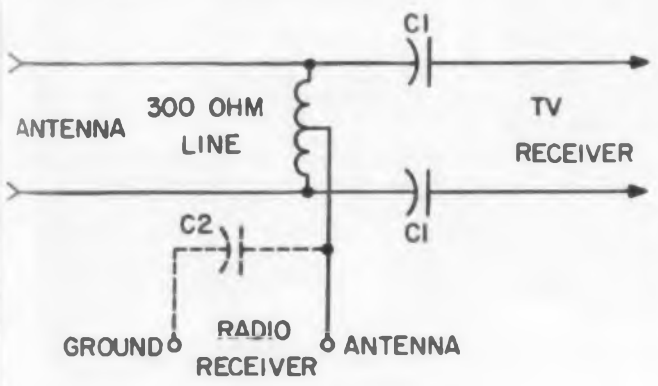
Because of its location, an outdoor TV antenna constitutes a good radio antenna, too. And its connection to the radio receiver can tremendously improve reception. However, it is bothersome to connect and disconnect the ribbon every time one wants to switch from TV to radio.

A permanent installation is easily made and well worth the trouble. The accompanying diagram shows all that is needed is a coil and two capacitors. They can be inserted anywhere in the line, generally right at the connection to the TV receiver. However, if the ribbon passes near the radio receiver, it can simply be cut at the nearest point.

A small terminal strip is used to support the coil and capacitors. The coil is but a choke to block the high TV frequencies. It can be made by winding 40 turns of hookup wire on a 1/4 in. diameter form, and is not critical. A center tap is provided.

The capacitors *C1* block the low radio frequencies. They can have a value of 20 to 50 μμf. To obtain a good match at the radio input, it may be necessary to connect a capacitor *C2* between antenna and ground terminals. Its value should be around 100 μμf.

*Dr. A. V. J. Martin, Carnegie Institute of Technology, Pittsburgh 13, Pa.*




**TV Antenna** for radio.

# STANDARDS AND SPECS

**Sherman H. Hubelbank**

### Magnetic Materials

MIL-P-55034, Stability of Powdered Magnetic Materials (Molded) for Cores (for use in Electrical and Electronic Parts), 19 September 1958

Covered in this spec is the evaluation of the uniformity and the stability under environmental conditions of molded, powdered magnetic materials for use as cores in such electrical and electronic parts as coils, transformers, etc. The cores covered by this spec are intended for use in applications where uniformity and stability of electrical and magnetic characteristics under adverse environmental conditions is a prime requisite. Specific performance of cores is not covered in this spec.

### Composition Resistors

MIL-R-94B, Variable Composition Resistors, Amendment 1, 24 November 1958

A requirement was added to Acceleration and Shock that movement in the arm incurred during these tests shall not result in a resistance change greater than 10 per cent. Test procedures have been modified. The requirements of Method 205 of MIL-STD-202 have been added for shock testing.

### Flanges, Waveguides, Fittings

MIL-F-3922, Flanges, Waveguides, and Associated Fittings, Supplement 1A, 15 November 1958

Improved versions of the old flanges, incorporating a modified gasket groove, have been added. The new flanges and gaskets are completely interchangeable with the old versions.

### Aircraft Microphones

RTCA 258-58/DO-91, Minimum Performance Standards for Aircraft Microphones, November 1958

Covered in this standard are the minimum performance standards for the sound pressure-electrical current transducer, the connector cord, and other components which form a part of the microphone such as switches, connector plugs, and amplifiers. Inasmuch as the measured values of radio performance characteristics may be a function of the method of measurement, standard test

conditions and methods of test are recommended. Copies of this standard are available from the Radio Technical Commission for Aeronautics, Room 1072, Building T-5, 16th & Constitution Avenue, N.W., Washington 25, D.C. for $0.25 per copy.

### Aircraft Headsets and Speakers

RTCA 257-58/DO-90, MINIMUM PERFORMANCE STANDARDS FOR AIRCRAFT HEADSETS AND SPEAKERS, NOVEMBER 1958

Equipment covered by this standard includes the electrical current-sound pressure transducer, the connector cord, and other components which form a part of the headset or speaker assembly such as headbands, ear plugs, enclosures, connectors, amplifiers, and attenuators. Also included are standard test conditions and standard methods of test. Copies of this standard are available from the Radio Technical Commission for Aeronautics for $0.25 each.

### Airborne Receiving Equipment

RTCA 222-58/DO, MINIMUM PERFORMANCE STANDARDS FOR AIRBORNE ILS GLIDE SLOPE RECEIVING EQUIPMENT, OCTOBER 1958

Minimum performance standards under both standard test conditions and environmental test conditions are established by this standard. Also included are standard test conditions and methods of test. Copies of this standard are available from the Radio Technical Commission for Aeronautics, Room 1072, Building T-5, 16th & Constitution Avenue, N.W., Washington 25, D.C. for $0.30 per copy.

### Screws

ASME B18.6.4, SLOTTED AND RECESSED HEAD TAPPING SCREWS AND METTALIC DRIVE SCREWS, 1958

Covers thread-forming screws, thread-cutting screws, and metallic-drive screws. Details given include boundry diameters, body dimensions, thread classifications, thread length, point design, chamfers, and fillets. General specs cover quality, finish, tolerances, limits, and other pertinent information. Also included is a conversion chart to identify ASA, manufacturers' and Federal Service's designations and tapping screw nomenclature. Copies of this publication are available from the Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y., for $4.00 per copy.

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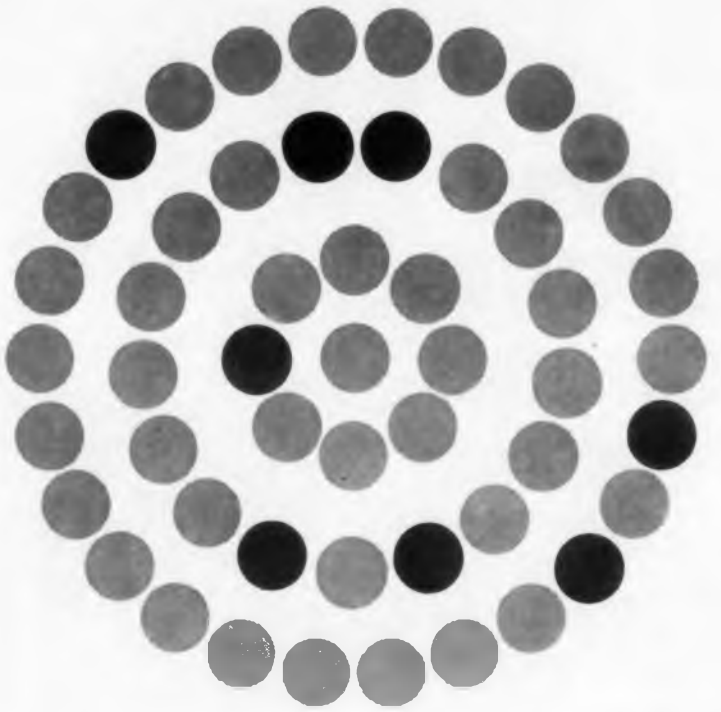

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CIRCLE 871 ON READER-SERVICE CARD

# Nonlinear and Parametric Phenomena in Radio Engineering

**Part 17**

**A. A. Kharkevich**

(Translated by J. George Adashko)

**Chapter 2**

## Generation of Oscillations

### 28. Microwave Oscillators

The oscillator circuits already described are not suitable for the generation of microwave frequencies. This is due first to the fact that at microwave frequencies the parasitic parameters of the circuit and of the tube begin to play an important role.*

By changing the method of wiring and the construction of the parts, and in particular by using special tubes that differ greatly from ordinary tubes, it is possible to generate frequencies up to 500 mc with customary circuits. Secondly, at microwave frequencies it becomes necessary to allow for the transit time of the electron in the space between the tube electrodes, since the time becomes comparable with the oscillation period.

This results, in the case of the conventional generator, in insurmountable difficulties of basic character. But, on the other hand, the same cir-

*Parasitic parameters are those not taken into account in the first-approximation basic circuit, namely, lead capacitance, capacitance between individual circuit elements, capacitances to ground, inductance of leads, etc.

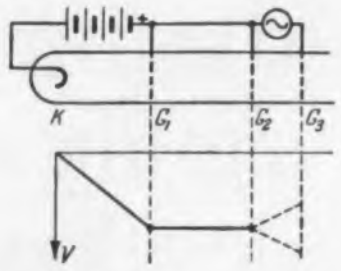


**Fig. 98.** The cathode end of a klystron tube and its voltage diagram.

cumstance can be used to construct many types of oscillators, in which the finite transit time of the electrons serves as the very basis for the oscillation mechanism.

In modern microwave practice, use is made of essentially three types of oscillators: (1) the klystron oscillator, (2) the magnetron oscillator, and (3) the backward-wave oscillator.

We shall not deal with the theory of these oscillators. However, to gain an idea of certain principles underlying the use of the finite electron velocity for the generation of microwaves, we present a brief qualitative description of the phenomena that take place in a klystron.

Klystron operation is based on velocity modulation of an electron beam with subsequent automatic conversion of the velocity modulation into density modulation of the electron beam. The term modulation is used here simply in that sense, that a certain parameter is varied by means of an applied signal.

Let us examine Fig. 98, which shows, for the time being, only a portion of the klystron. In addition to the cathode $K$, there are three other electrodes in the form of grids. Grid $G_1$ serves as the accelerating electrode, and is positive relative to the cathode. An alternating voltage is applied between grids $G_2$ and $G_3$. The corresponding potential diagram is shown in the lower half of Fig. 98.

The electrons emitted by the cathode are accelerated in the region $K$-$G_1$ and travel through region $G_1$-$G_2$ at a uniform speed, at which they enter the space $G_2$-$G_3$. This region is under the influence of an alternating field, which either decelerates or accelerates the electrons. The electron beam that leaves the region $G_2$-$G_3$ is thus velocity modulated, i.e., the electrons move at different velocities. As a result, the faster electrons overtake the slower ones in the space to the right of $G_3$, and electron bunches, i.e., regions with increased electron density, are produced.

It is easy to see that the bunches are periodic along the klystron axis and form a traveling density wave. The length of this wave, i.e., the distance between neighboring bunches, is

$$\lambda = v/f$$

where $v$ is the average velocity prior to modula-

## RUSSIAN TRANSLATIONS

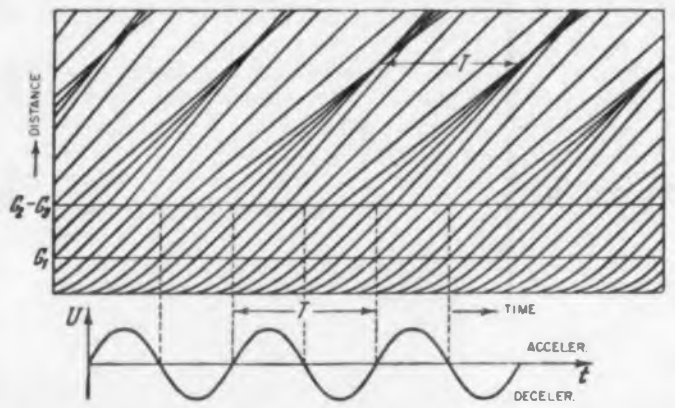


**Fig. 99.** This drawing shows how bunching takes place in the klystron.

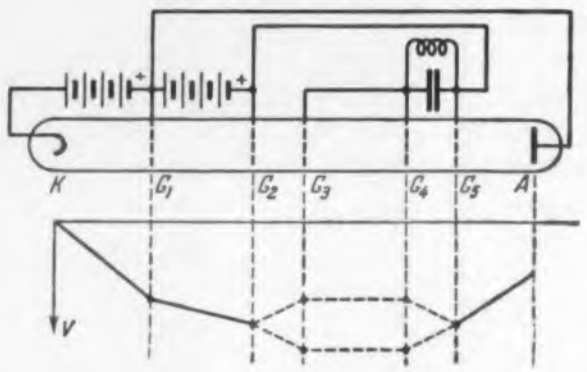


**Fig. 100.** The klystron oscillator.

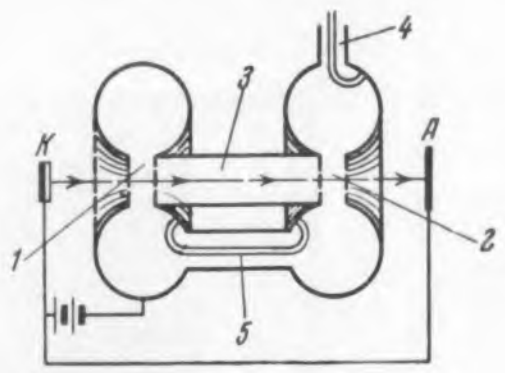


**Fig. 101.** A klystron with two resonant cavities. *1* and *2* represent toroidal cavity resonators. The bunching space *(3)* is in the form of a tube as is the feedback loop *(5)*. The ac pickoff is at *4*.

tion and $f$ is the modulation frequency. This process is called bunching, and the combination of grids $G_2$ and $G_3$ is called the buncher. The space in which the bunches are formed is called the bunching space or the drift space.

The bunching process is explained by Fig. 99, the lower half of which shows the time variation of the alternating buncher voltage. The upper portion of the diagram shows, in distance-time coordinates, the motion of the electrons. For simplicity it is assumed that the electrons leave the cathode at equal time intervals.

Upon acquiring equal velocities after passing



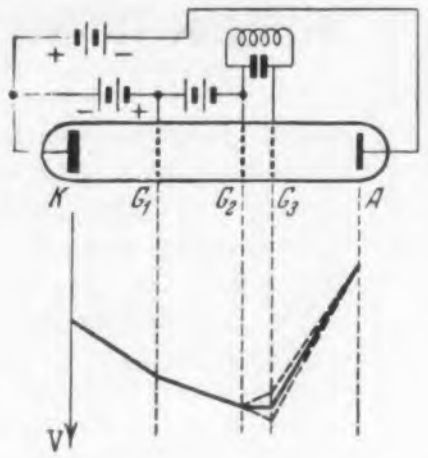


**Fig. 102.** The reflex klystron and its voltage diagram.

through the accelerating field, the electrons enter the buncher $G_2$-$G_3$, where the electron velocity is either increased or decreased, depending on the sign of the buncher voltage (see sinusoidal curve in the lower portion of the diagram). The motion of the electrons leaving the buncher is represented by straight lines with different slopes. The steeper lines correspond to the faster electrons.

It is seen from the diagram that thanks to the different slopes, the straight lines that represent the motion of the electrons form converging beams. This is a graphic explanation of the formation of electron bunches.

The variable-density electron beam formed in the bunching space can be used to induce a current in an external circuit. For this purpose, use is made of two additional grids $G_4$ and $G_5$, to which we connect a tank circuit tuned to the proper frequency. If the voltage is now picked off the tank circuit and fed back to the buncher, we obtain the klystron oscillator of Fig. 100.

The spent electrons fall on the collector *A* and flow through it to the cathode. The combination of grids $G_4$ and $G_5$ is called the catcher. To excite the system, a suitable adjustment of the phase of the feedback is necessary. For a specified construction and fixed distance between the buncher and the catcher, the phase of the feedback can be regulated by varying the accelerating voltages on $G_1$ and $G_2$.

The construction of a klystron with two resonators is shown in Fig. 101, where *1* and *2* denote toroidal cavity resonators (shown in cross section). The buncher and the catcher are formed by pairs of perforated disks, which serve as capacitive inserts in the resonators. The bunching space is made in the form of a tube *3*. Still another tube contains the feedback loop *5*. Loop *4* serves to pick off the alternating voltage.

The reflex klystron is the most widely used. It differs from the system just considered in that the buncher and the catcher are combined. After passing through a pair of grids, which comprise the buncher, the electron beam is retarded by a nega-

## RUSSIAN TRANSLATIONS

tive field and turns back, passing again through the same pair of grids which now serve as the catcher. The diagram of the reflex klystron and a corresponding potential diagram are shown in Fig. 102.

The bunching process in the reflex klystron is explained in Fig. 103. This diagram differs from Fig. 99 in that the lines representing the motion of the electrons that leave the buncher are not straight but parabolic (corresponding to the motion in an accelerating field of opposite direction). The electrons return to $G_2$-$G_3$. Bunches are formed as a result of the difference between the initial velocities.

It is obviously necessary to tune the system in such a way that the bunches are formed in the $G_2$-$G_3$ zone. It should be noted that there is no separate feedback loop in the reflex klystron, and the feedback is effected through the electron beam. The reflex klystron can be tuned not only by varying the accelerating positive potentials on $G_1$ and $G_2$, but also by varying the negative potential on the reflecting electrode $A$.

### 29. Relaxation Self Oscillations

So far we have considered generators of oscillations that are nearly sinusoidal. Such self oscillations are called nearly-harmonic. However, in electronics we employ also self oscillations with waveforms that differ greatly from sinusoidal.

Such self oscillations, which sometimes feature abrupt jump-like changes in current or voltage, or jump-like changes in the rate of variation of these quantities (graphically represented by oscillograms in the form of broken lines) are called relaxation self oscillations.

The essential difference between the waveforms of nearly-harmonic and relaxation self oscillations is due to the difference in the arrangement and operation of the generators of these types of oscillations.

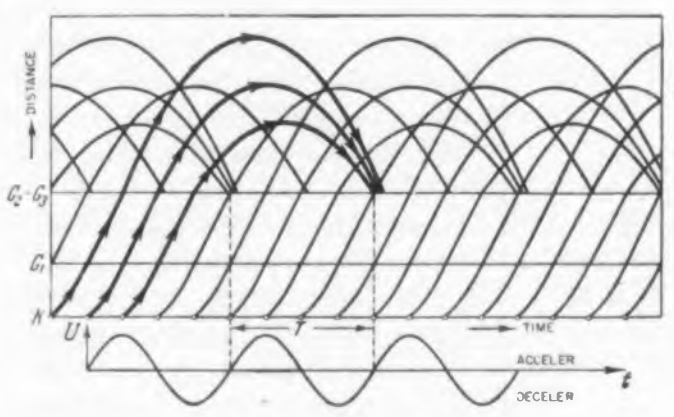


**Fig. 103.** The bunching process in the reflex klystron.

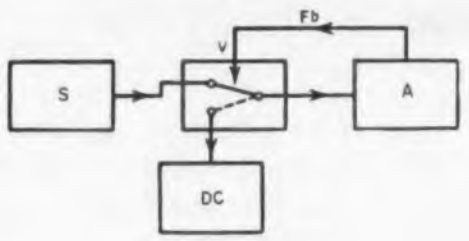


**Fig. 104.** The mechanism of a relaxation oscillator. *S* is the energy source, *A* an accumulating (storage) element, *V* a valve, $F_b$ a feedback connection, and $D_c$ a discharge circuit.

The generator for nearly-harmonic oscillations usually contains an *LC* tank circuit (or an equivalent *LC* circuit), i.e., an oscillating system containing (at least) two reactance elements capable of energy storage. From the energy point of view, oscillations occur in the tank circuit, because the energy stored in the tank circuit is alternately concentrated entirely either in the magnetic field of the coil or in the electric field of the capacitor. This energy transfer takes place periodically.

If there are no losses, the oscillation is strictly sinusoidal. In the presence of losses the amplitude diminishes with time exponentially because the stored energy diminishes continuously. On the other hand, if the energy losses are replenished from a source, as they are in every oscillator, the oscillations are undamped, and their waveform differs from sinusoidal only in as much as this is dictated by the nonlinearity that limits the amplitude.

The mechanism of a relaxation oscillator is different. It is characterized by the fact that there is a single (in the simplest case) energy storage element. The periodic process in a relaxation oscillator consists of having the energy storing element accumulate an increasing supply of energy, until a certain definite upper level is reached. Then a certain valve discharges the accumulating element through a discharge circuit, until the energy reserve reaches a definite lower level. Now the valve operates again and makes the accumulating element resume charging.

This is explained in the block diagram of Fig. 104, in which *S* is the energy source, *A* the accumulating element, *V* the valve, $F_b$ the feedback connection, and $D_c$ the discharge circuit. It follows from this general description that the relaxation oscillator is characterized by the presence of a valve that can assume two fixed positions, one of which corresponds to charging the accumulating element, and the other to discharging.

The valve is controlled by feedback from the accumulating element. The feedback serves to operate the valve when two fixed energy levels are reached, an upper one and a lower one. It follows

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that the swing of the relaxation oscillations does not depend on the energy balance, but is determined only by the difference between the two levels at which the valve operates.

All these general properties of relaxation oscillators can be readily understood by examining the simplest case, that of a relaxation oscillator with a gas discharge tube. The oscillator is shown in Fig. 105.

The energy source is the battery $E$ which charges, through resistor $R$, and capacitor $C$ which serves as the accumulating element. The valve employed is the gas discharge tube $T$, which also serves as the circuit into which the accumulating element discharges. The oscillator operates as follows.

When the battery is connected, the capacitor starts charging. When its voltage reaches a value $U_2$, the "firing voltage" of Tube $T$, the gas in the tube ionizes and the tube resistance, which up to then was quite large, is sharply reduced to a small value $r$. The capacitor starts discharging rapidly into this resistance. When the voltage drops to a Value $U_1$, at which the ionization ceases, the resistance of the tube again rises sharply, and the capacitor-charging process is repeated.

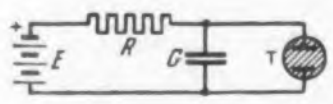
The course of the phenomenon is shown by the oscillogram in Fig. 106, which shows time variation of the capacitor voltage. The swing of the oscillations depends only on the voltage difference $U_2$-$U_1$. As to the frequency, it depends on the time constants of the charge and discharge circuits, and also on the supply voltage.

Let us evaluate the oscillation period. It consists of two sections $\Delta t_1$ and $\Delta t_2$, of which the first determines the charge time and the second the discharge time. For the charge process we have

$$U = E\left(1 - \epsilon^{-\frac{t}{\tau_1}}\right)$$

where $\tau_1 = RC$ is the time constant of the charge circuit. We can write the following two equations

**Fig. 105.** The simplest relaxation oscillator uses a gas tube.



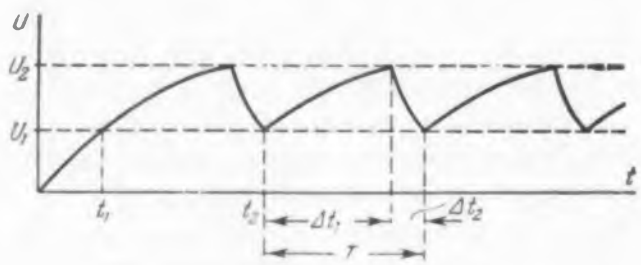




**Fig. 106.** Voltage variations on the capacitor in the relaxation oscillator of Fig. 105.

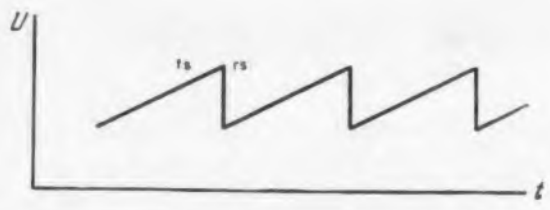



**Fig. 107.** A sawtooth voltage derived from a relaxation oscillator if the charge time is very large, and the discharge time very small. The letters on the figure represent the forward sweep and the return sweep.

$$U_1 = E\left(1 - \epsilon^{-\frac{t_1}{\tau_1}}\right),\ U_2 = E\left(1 - \epsilon^{-\frac{t_2}{\tau_1}}\right)$$

(see Fig. 106) from which we find

$$t_1 = \tau_1 \ln \frac{E}{E - U_1},\ t_2 = \tau_1 \ln \frac{E}{E - U_2}$$

and hence also the charging time

$$\Delta t_1 = t_2 - t_1 = RC \ln \frac{E - U_1}{E - U_2}$$

This expression shows that the greater the value of $E$ at given values of $U_1$ and $U_2$, the smaller the difference between unity and the quantity under the logarithm, and the smaller the charging time. The charging process is given by the formula

$$U = U_2\, \epsilon^{-\frac{1}{\tau_2}(t - t_2)}$$

where $\tau_2 = rC$ is the time constant of the discharge circuit. When $t = t_3$ a voltage value $U = U_1$ is reached. We obtain

$$U_1 = U_2\, \epsilon^{-\frac{1}{\tau_2}(t - t_2)} = U_2\, \epsilon^{-\frac{\Delta t_2}{\tau_2}}$$

hence

$$\Delta t_2 = r\,C \ln \frac{U_2}{U_1}$$

We now obtain the oscillation period by adding $\Delta t_1$ and $\Delta t_2$.

$$T = \Delta t_1 + \Delta t_2 = C\left(R \ln \frac{E - U_1}{E - U_2} + r \ln \frac{U_2}{U_1}\right)$$

We see that the oscillation period depends on the time constants of the discharge and charge circuits, i.e., on the values of $RC$ and $rC$, on the ratio of the firing and extinction voltages $U_2$ and $U_1$, and on the supply voltage $E$.

If $E$ and $R$ are taken sufficiently large and $r$ and $C$ sufficiently small, the waveform approaches that shown in Fig. 107. A voltage of such form is called a sawtooth voltage and is extensively used in radio engineering as a sweep voltage in cathode-ray oscilloscopes, in television, radar, etc.

The sweep voltage usually must meet rather stringent requirements as to linearity on the forward sweep (*fs* on Fig. 107) and minimum dura-

## RUSSIAN TRANSLATIONS

tion of return sweep (*rs*). The simplest circuit of Fig. 105 which we have analyzed does not satisfy these two requirements. The linearity of the forward sweep can be improved considerably by replacing the resistor $R$ with a current limiter, such as a saturated diode. However, to generate a sawtooth sweep voltage it is preferable to use special, more highly developed relaxation oscillators.

### 30. Relaxation Oscillators

One of the earliest relaxation oscillators circuits is the symmetrical multivibrator,* which has retained its value to this day. The diagram of a symmetrical multivibrator is shown in Fig. 108. Both halves of the circuit can be considered as two separate generators, interconnected in such a way that one of the generators serves as the valve that controls the operation of the other.

To describe the operation of the circuit, we shall start with such a state, in which the currents and the plate circuits of the two tubes are exactly equal. This is an equilibrium state, which, however, is unstable. In fact, let the current of the first tube increase somewhat.

In this case the tube voltage becomes smaller than the initial value, and the capacitor $C_1$ starts discharging. The discharge current, flowing through resistor $R_{g2}$, produces a negative voltage on the grid of the second tube. Consequently the voltage on the plate will increase and the plate current will diminish.

Owing to the increased plate voltage, capacitor $C_2$ will start charging. The charging current, flowing through resistor $R_{g1}$, will produce a positive voltage on the grid of the first tube, and consequently a further increase in current of the first tube.

This analysis shows that the initial state we considered, in which the currents and the voltages of

*This is an oscillator capable of generating many frequencies (in the sense of having a rich spectrum). The multivibrator was used in its time to calibrate wave meters, with the harmonic frequencies serving as reference points.

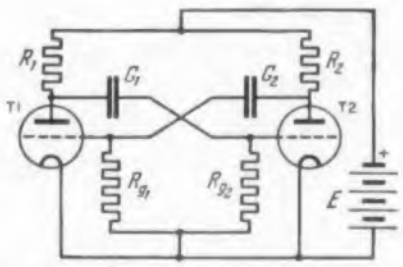



**Fig. 108.** The symmetrical multivibrator.

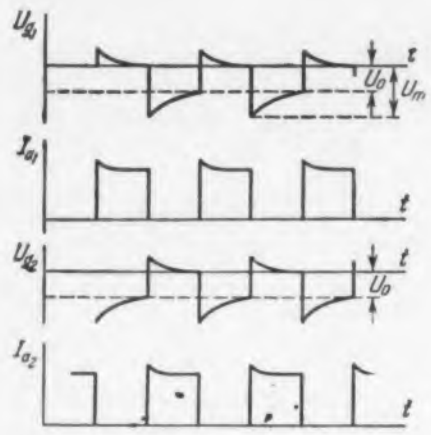



**Fig. 109.** Grid voltages and plate currents in the symmetrical multivibrator of Fig. 108.

both halves of the circuit are equal, is really unstable.

The increase in the current of the first tube and the increase in the negative voltage on the grid of the second tube are both very rapid. As a result, the first tube becomes saturated, and the second becomes blocked by the large negative voltage. Now capacitor $C_1$ continues to discharge through $T_1$ and $R_{g2}$; the discharge current, and with it the negative grid voltage of $T_2$ decreases until $T_2$ starts conducting.

During the instant that the voltage across it drops, capacitor $C_2$ starts discharging, and the currents and voltages change abruptly, as described above, but with the roles of two halves of the circuit interchanged.

The time variations of the plate currents and grid voltages of both halves of the circuit are shown in Fig. 109. Owing to the symmetry of the circuit, the durations of the plate current pulses are the same in both halves. Thus, the waveform of the plate current in each tube is nearly rectangular. Incidentally, by changing the parameters, it is possible to obtain also a nearly triangular form. The form of the oscillation depends on the charge and discharge time constants.

It is seen from the circuit of Fig. 108 that the time constant for charging is

$$\tau_c = C\left(R_g + \frac{R_i R}{R_i + R}\right)$$

and the time constant for discharging

$$\tau_d = C\left(R + \frac{R_g r_g}{R_g + r_g}\right)$$

where $C$ is the capacitance, $R$ the resistance in the plate circuit, $R_i$ the tube resistance (from the cathode to the anode), $R_g$ the resistance in the grid circuit, and $r_g$ is the tube resistance (cathode-grid).

Usually $\tau_c \gg \tau_d$. In this case the waveform of the oscillations is never rectangular. Knowing the time constant, it is possible to find the oscillation period. During one half of the period, the grid volt-

# RUSSIAN TRANSLATIONS

age diminishes from the maximum value $U_m$ to the cutoff value $U_o$. Thus

$$U_o = U_m \epsilon^{-\frac{1}{2}\frac{I}{\tau_f}}$$

hence

$$T = 2\,\tau_f\, ln\, \frac{U_m}{U_o}$$

The cutoff voltage is a parameter of the tube. As to $U_m$, at the start of the discharge, i.e., directly after the current jump, it has a value.

$$U_m = E\,\frac{1}{1 + \frac{R_i}{R} + \frac{R_i}{R_g}}$$

The period thus depends on the tube parameters, on the circuit parameters, and on the supply voltage.

Another example of a relaxation oscillator is the blocking oscillator used principally to obtain various brief pulses (of duration down to fractions of a microsecond). The blocking oscillator circuit is shown in Fig. 110. It consists of a triode and a transformer, which couples the plate and grid circuits. The tank circuits are formed by the winding inductances and their distributed capacitances, whose equivalents are shown dotted in the diagram.

The circuit of Fig. 110 can be considered as a degenerate ordinary oscillator with tuned grid and plate circuits. It is characterized by the fact that the processes that take place in the circuits are aperiodic in character and occur in intermittent sharp jumps. These jumps, called "blocking" in foreign literature are the reason for the name of this oscillator.

We shall examine the operation of this circuit from the instant when the capacitor $C_o$ is charged and the grid is negative relative to the cathode, so that the tube is cutoff. Capacitor $C_o$ is discharged through resistance $R_g$. The time constant of the discharge is $R_gC_o$. When the voltage reaches a value $U_o$, the tube starts conducting and plate current flows.

Owing to the strong positive feedback, a positive voltage will appear on the grid, causing a further rapid rise in the plate current. This process, which is very fast, causes the anode voltage to drop almost to zero (which is the "blocking"). When the resultant grid voltage (which equals the

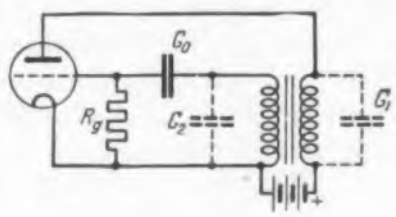



**Fig. 110.** A basic blocking oscillator.

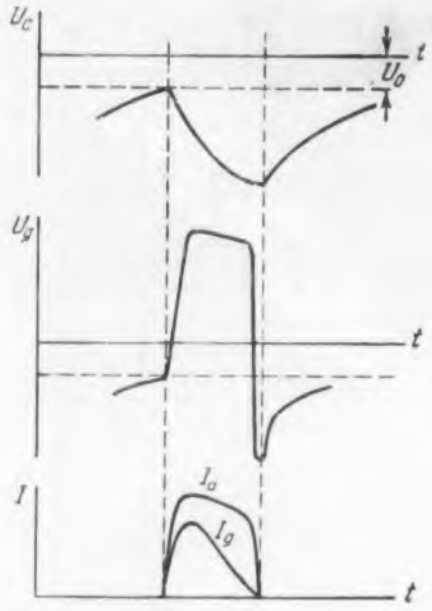



**Fig. 111.** Voltage and current variations in the blocking oscillator circuit.

sum of the negative voltage across $C_o$ and the positive voltage induced by the feedback) drops to zero, grid current appears and the capacitor starts charging rapidly through the grid-cathode space, with a time constant $C_o\, r_g$.

At this stage of the process the grid voltage is positive and a voltage appears on the plate. The tube has a small transconductance at this instant and changes in the grid voltage do not affect the plate current noticeably.

But later on, after the grid voltage reaches a maximum and starts diminishing, the transconductance increases. Finally, conditions favorable for the next jump are reached. The reduction in the grid voltage causes a reduction in the plate current, which causes a further reduction in the grid voltage, and the tube is cut off at very high speed. The cycle then repeats. Fig. 111 shows the time variation of the capacitor voltage $U_c$, of the grid voltage $U_g$ and of the grid and plate currents $I_g$ and $I_a$.

The self excitation condition of the blocking generator can be written in the following form (provided $C_1$ and $C_2$ are very small compared with $C_o$):

$$k\,S_a - \frac{1}{n\,R_i} - \frac{n}{R_g} - n\,S_g + \frac{1}{r_g} > 0$$

where $S_a$ and $S_g$ are, respectively, the transconductances of the plate and grid circuits, $R_i$ and $r_g$ are the internal cathode-plate and cathode-grid resistances, $n$ is a transformation ratio and $k$ the coupling coefficient (close to unity in our case). The minimum duration of the pulses depends on the leakage inductance of the transformer and on the parasitic capacitance $C_1$. The pulse repetition rate is determined essentially by the time constant for charging capacitor $C_o$, and is $T \cong R_g C_o$.

*(This concludes Chapter 2. Chapter 3 starts in the next issue.)*

## GERMAN ABSTRACTS

E. Brenner

# Attenuation in the Passband of Filters

FILTERS which are designed on a pure-reactance basis have attenuation in the passband due to the losses in the reactive components, generally the coils. When high $Q$ elements are used and attenuation constant $\alpha_d$ can be related to the phase function $\beta$ ($\omega$) through the equation

$$\alpha_d = \frac{\omega}{2Q}\,\frac{d\beta}{d\omega}$$

Eq. (1) is a good approximation only when all the elements in the filter have a $Q$ which is nearly the average value used in that equation. The use of equal $Q$ elements does not result in the best design because the quality which is required of each element is not the same at all frequencies, i.e. it depends on the frequency band in which the element is effective. Moreover, Eq. (1) applies only to filters in which coils and capacitors are used. When other components, such as quartz crystals, are employed, it does not apply.

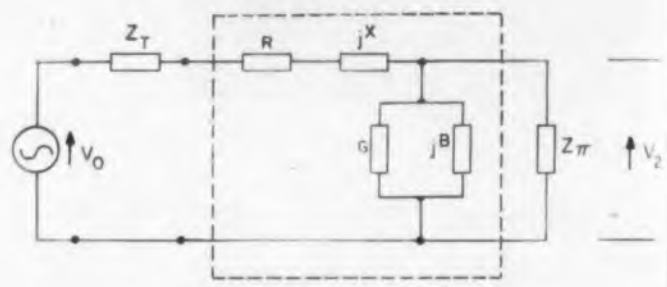



**Fig. 1.** Image terminated half section. The image transfer function, $ln\ (V_0/2V_2)$ is calculated using for $Z_T$ and $Z\pi$ the image impedances of the lossless ($R=G=0$) two port.

# Time Delays in P-N Junctions

WHEN p-n junction diodes are used in the sinusoidal steady state with large amplitude currents, two time delay effects are observed. When the diode is forced from the conduction into the nonconduction region, the current collapses $\alpha/\omega$ μsec after it has passed through zero. The approximate waveform is shown in Fig. 1. This time delay is due to a capacitive effect which occurs because of a storage of charge in the path regions of the junction. In the conducting direction, it is observed that the peak current amplitude, for constant impressed voltage, decreases with increasing frequency.

Denoting the life time of the charge carriers by $\tau$, the charge in the diode can be calculated assuming that for sufficiently large amplitudes the current waveform during conduction is sinusoidal, as shown in Fig. 1, when the voltage across the diode is sinusoidal.

The differential equation of the charging process can be written as

$$\frac{dQ}{dt} = I_m \sin \omega t - Q/\tau$$

and, subject to the initial condition $Q(O) = O$ has the solution:

$$Q(t) = \frac{I_m\,\tau}{\omega\tau + \frac{1}{\omega\tau}}\left(e^{-t/\tau} + \frac{\sin \omega\tau}{\omega\tau} - \cos \omega\tau\right)$$

Hence the charge at $\omega t = \pi/2$, denoted by $Q_d$ and the charge at $\omega t = \pi$, denoted by $Q_o$ can be calculated as a function of frequency. The result is shown in Fig. 2. The curve for $Q_d$ is confirmed by the experimental observation that the admittance in the conducting direction decreases with increasing frequency. Moreover, it follows that the corresponding time constant ($L/r$) can be approximated by $\tau$.

The charge $Q_o$ controls the time delay for transition to the zero current state. Solving Eq. (1) on a new time scale, subject to the initial condition $Q(O) = Q_o$ and replacing $Q$ with $-Q$, one can solve for $\alpha$. The result is

$$exp\,[-(\pi+\alpha)/\omega\tau] = \frac{\sin \alpha}{\omega\tau} - \cos \alpha$$

Experiments indicate that the value of $\alpha$, as given by Eq. (3), is too large, probably because the diode is not fully discharged when the current flow ceases.

The total charge $Q_c$ which is collected is given by

$$Q_c = I_m\,\tau\,\frac{1 - \cos \alpha}{\omega\tau}$$

and its frequency dependence is also shown in Fig. 2. The difference $Q_o - Q_c$ is the charge lost by recombination during the "reverse" time.

It can be shown that for the image terminated half section, shown in the Fig. 1, the image transfer function for high $Q$ elements results in the attenuation constant $\alpha_d$ where

$$\alpha_d = \frac{1}{2}\,(R/Z_T + G\,Z_\pi)$$

where $Z_T$ and $Z_\pi$ are the image impedances of the half section if the losses are ignored. In terms of the $Q$'s of the coils, it can be shown that Eq. (2) has the form

$$\alpha_d = \frac{k_1}{Q_1} + \frac{k_2}{Q_2} + \frac{k_3}{Q_3} \ldots \qquad (3)$$

where $k_1$, $k_2$ ... are frequency dependent "weighting factors" which are determined by the element values.

The original paper includes an elaborate example dealing with a quartz crystal filter as well as a discussion of the numerical evaluation of the weighting factors from the frequency dependence of image and driving point impedances.

*Abstracted from an article by J. Boehse,* Frequenz, *Vol. 12, No. 12, December 1959, pp 380-383.*

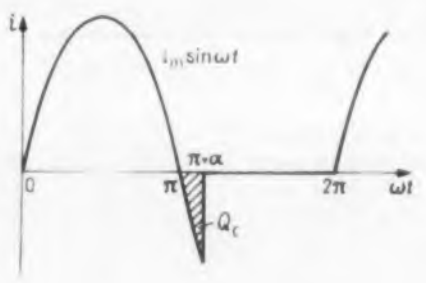



**Fig. 1.** Approximate current waveform for the p-n junction diode.

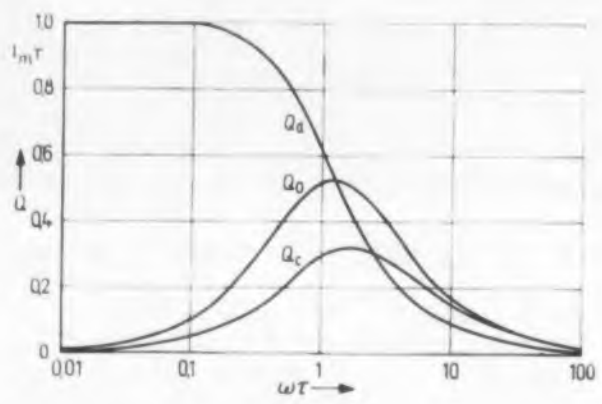



**Fig. 2.** Stored charge at the time $\omega t = \pi/2$, $Q_d = Q(\pi/2\omega)$, at the instant $\omega t = \pi$, $Q_0 = (\pi/\omega)$, and net charge $Q_c$ as a function of (normalized) frequency.

*Abstracted from an article by W. Heinlein,* Archiv der Elektrischen Uebertragung, *Vol. 12, No. 11, November 1959 pp 510-514.*

# MEETINGS

**May**

- 3-7 Symposium on Electrode Processes, Philadelphia, Pa.
- 4-6 11th National Aeronautical Electronics Conference (IRE), Dayton, Ohio
- 4-8 85th Society of Motion Picture and Television Engineers Convention, Fontainbleau Hotel, Miami Beach, Fla.
- 5-7 URSI Spring Meeting (PGI, PGIT, PGGT), Washington D.C.
- 5-7 7th National Conference on Electro-Magnetic Relays, Stillwater, Okla.
- 6-8 1959 Electronics Components Conference (IRE, AIEE, EIA, WCEMA), Philadelphia, Pa.*
- 6-8 7th Regional Technical Conference and Trade Show (IRE), Albuquerque, N. Mex.
- 11-12 Symposium on Industrial Uses of Radioisotopes, Atlanta, Ga.*
- 11-13 National Power Instrumentation Symposium, Kansas City, Kan.
- 11-13 National Symposium (PGMT, IRE), Boston, Mass.
- 11-13 2nd Annual Joint Conference on Automatic Techniques, Chicago, Ill.*
- 11-13 Radio Technical Commission for Marine Services Assembly Meeting, Mt. Royal Hotel, Montreal, Canada
- 12-14 Annual Frequency Control Symposium, Signal Research and Development Laboratory, Fort Monmouth, Berkeley-Carteret Hotel, Asbury Park, N.J.
- 18-20 5th Annual National Symposium on Instrumental Methods of Analysis, Houston, Tex.
- 18-20 Electronics Parts Distributors Show, Chicago, Ill.*
- 18-20 Fifth National Symposium on Instrumental Methods of Analysis, Instrument Society of America, Hotel Shamrock Hilton, Houston, Tex.
- 19-21 AIEE Middle Eastern District Meeting, Baltimore, Md.
- 20-22 National Spring Meeting, Society for Stress Analysis, Sheraton Park Hotel, Washington D.C.
- 25-27 National Telemetry Conference (IAS, ISA, AIEE, ARS), Denver, Colo.*
- 25-29 International Convention on Transistors and Associated Semi-Conductor Devices, London, England*

**1959 Electronic Components Conference, May 6-8**

Benjamin Franklin Hotel, Philadelphia, Pa. Sponsors: IRE, EIA, AIEE, WCEMA. Theme: New Concept for Space Age. Contact *John E. Hickey, Jr., The Chilton Co., 56th & Chestnut Sts. Philadelphia 39, Pa.*

**Symposium on Industrial Uses of Radioisotopes, May 11-12**

Georgia Tech Campus, Atlanta, Ga. Sponsors: Georgia Tech., Office of Isotopes Dev. (AEC), and Lockheed Aircraft Corp. This symposium is designed to serve an eleven-state area and will show industrialists the many ways in which they can use isotopes to save time. For further information contact: *Richard Wiegand, Director, Short Courses & Conferences, Georgia Institute of Technology, Atlanta, Ga.*

**Second Annual Conference on Automatic Techniques, May 11-13**

Pike Congress Hotel, Chicago, Ill. Sponsored jointly by ASME, AIEE, and IRE. The meeting

will avoid the complex engineering problems usually associated with automation. It will cover instead, progress now being made in automatic controls and ways in which they may be applied to any industry. For further information contact: *F. D. Snyder, c/o Westinghouse Electric Corp., 40 Wall St., New York 5, N.Y.*

**Electronic Parts Distributors Show, May 18-20**

Conrad Hilton Hotel, Chicago, Ill. An expanded educational program for distributors designed to bring further benefits to the industry will be a special highlight of the show.

**National Telemetry Conference, May 25-27**

Brown Palace and Cosmopolitan Hotel, Denver, Colo. Sponsored annually by the American Rocket Society, IAS, AIEE, and ISA. Theme: Investigation of Space. Twelve Sessions are tentatively scheduled for the meeting including such subjects as: Special Telemetry Techniques for Satellites and Space Vehicles; Sub-miniaturization; Telemetering of Bio-Medical Information from Man in Space; Transistorization and Data Processing. For information contact *Ralph Schmidt, AVCO Mfg. Co., 201 Lowell St., Wilmington, Mass.*

**International Convention on Transistors and Associated Semi-Conductor Devices, May 25-29**

To be held in London, this convention has been organized by the radio and telecommunication section of Britain's Institution of Electrical Engineers to mark the tenth anniversary of the transistor. It will be the most comprehensive ever held on transistors and will cover design, manufacture, basic theory, characteristics, measurements, applications, and equivalent circuits. To provide the widest possible interest, the International Transistor Exhibition will be held at the same time. For details contact *Industrial & Trade Fairs Ltd., Drury House, Russell Street, London, W. C. 2, England.*

### Paper Deadlines

**May 10:** Deadline for receipt, in triplicate, of a 100-200 word abstract and a 500-word summary of papers for the **1959 National Symposium on Telemetering** to be held in San Francisco, **September 28-30. July 10** is deadline for receipt of full-length papers on specially provided master sheets. Submit papers as early as possible on significant work in telemetry and related fields, such as space vehicle communication systems, satellite instrumentation, data processing equipment, new developments in telemetry equipment, and flight test electronics. Further inquiry should be directed to: *George L. Larse, Program Chairman, Lockheed Aircraft Corporation, Missile Systems Division, Sunnyvale, Calif.*

# REPORT BRIEFS

## Noise Sources in Radio Receivers

Considered in this study were problems of standard noise sources in a radio receiver, calibration of secondary standards, and their use in measuring receiver noise factors—problems which are associated with the use of the receiver in radio astronomy where noise is the intelligence measured. A review of figure of merit concepts and receiver measuring practices using gas-discharge noise sources led to formulae which are said to reduce computations to simple additions of excess noise temperature and attenuations. Hot-body noise sources were used as standards in development and calibration of gas-discharge noise sources. Studies of calibrations and source design problems disclosed sources of errors, useful design features, and special techniques valuable for receiver measurements and calibrations. *Fundamentals in Noise Source Calibrations At Microwave Frequencies, J. E. Sees, Naval Research Laboratory, Jan. 1958, 24 pp, $0.75. PB 131367 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

## Electronic Materials Rated

Electronic transformer materials which appear best suited for use at 500 C and under intense nuclear radiation, the severe environmental combination in which future military electronic equipment may be expected to operate, are identified in a report of recent research for the Air Force. The broad evaluation of transformer basic materials showed mica paper, glass-served silver wire, and grain-oriented silicon steel to have best properties after aging for 1000 hours. The materials were also shown to perform together as transformers. For mechanical moisture protection of transformers, an encapsulating technique using a thin ceramic coating in conjunction with a stainless steel mesh was found feasible. Tests under combined high temperature and radiation tentatively indicated that effects on both materials and transformers were primarily caused by temperature. An exception appeared to be in the dielectric breakdown strength of air. Evaluation results were expected to form a basis for a tentative design practice for construction of transformers and inductors tolerant to the severe environment. Two volumes of the research appear in a single report. *Ultra High Temperature Miniaturized Power Transformers and Inductor Materials, Volumes 1 & 2, H. B. Harms, J. C. Fraser, General Electric Company for Wright Air Development Center, U. S. Air Force, May 1958, 476 pp, $6.00. Order PB 151141 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

### Target Data Processing Systems

This report studies the human capabilities in tasks assigned to operators of target data processing systems using manual detection and tracking. Two aspects of detection and tracking task design are discussed. First, the type and number of tasks which can profitably be assigned to an operator are reviewed. The second discussion offers some suggestions for facilitating performance of the basic tasks of detection, tracking, and monitoring. The information is said to be particularly applicable to semiautomatic systems in which electronic data storage is provided. *Some Problems in The Design of Human-Operated Target Data Processing Systems, T. J. Coonan, Naval Research Laboratory, Sept. 1958, 7 pp, $0.50. Order PB 151113 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

### Visual Coding Dimension

An investigation was conducted to determine whether the flash rate of a flashing light was a suitable coding dimension for the presentation of information. Results showed that no more than five discriminable steps of flash rate could be used for encoding information. The report states that the investigation showed that flash rate was not a good information code for cathode ray tube displays, but it might be a very useful code for exterior lighting displays on aircraft or on the ground. *Flash Rate As A Visual Coding Dimension For Information, J. Cohen, A. J. Dinnerstein, Antioch College for Wright Air Development Center, U. S. Air Force, May 1958, 13 pp, $0.50. Order PB 151185 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

### Aircrew Fatigue Problems

Outlined in this report is a plan for an experimental program designed to determine the effects of confinement stresses of a five-man crew. These men would be isolated in a flight station for 120 hours. The experimental crew compartment is described and illustrated. Performance tasks, programming and recording instruments, together with the laboratory techniques planned for use in the experiment, are explained. *Aircrew Fatigue Problems During Extended Endurance Flight: Phase 1—Planning. O. S. Adams, Lockheed Aircraft Corporation for Wright Air Development Center, U. S. Air Force, May 1958, 86 pp, $2.25. Order PB 151189 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

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# REPORT BRIEFS

### Sensory Capacity as Data Source

A general survey of what is known about man's ability to make use of his sensory capacities for gathering information is presented. Some comparisons between different sense modalities are made and the problem of sensory interactions is discussed. Use of some of the subordinate sensory channels is also examined. *Man's Senses As Informational Channels, G. H. Mowbray, J. W. Gebbard, Applied Physics Laboratory, Johns Hopkins University, for U.S. Armed Forces, May 1958, 71 pp, $2.00. Order PB 151160 from OTS, U. S. Department of Commerce, Washington 25 D.C.*

### Vanguard Satellite Receiver

An earth satellite command receiver was developed for use in Vanguard and other United States satellites. This receiver turns on the satellite instrumentation upon command from a ground-based Minitrack station. It is a vhf double-superheterodyne type utilizing a small portion of the 108-Mc Minitrack transmitter power as the first local oscillator. The basic design of the various components provides for economical use of satellite battery power and at the same time a reasonable degree of security against accidental interrogation from unauthorized sources. *Project Vanguard Report No. 35: Minitrack Report No. 6—The Vanguard Satellite Command Receiver, D. S. Hepler, U. S. Naval Research Laboratory, Sept. 1958, 11 pp, $0.50. Order PB 151112 from OTS, U. S. Department of Commerce, Washington 25, D. C.*

### Radio Stars for Vanguard Tracking

The Mark II Minitrack System, whose function is primarily the tracking of artificial satellites, was also designed for the tracking of radio stars. A means of external calibration of the system by tracking these radio-noise sources is described and illustrated. Results obtained by this method are presented and compared with results obtained by the complex but more precise method used in calibrating Prime Minitrack stations. It is reported that the tracking of radio stars does in fact provide an adequate system calibration if sufficient data are taken. The system is described briefly and an operational analysis is made. *Project Vanguard Report No. 33: Minitrack Report No. 7—Calibrating the Mark II Minitrack System with Radio Stars as Signal Sources, V. R. Simas and G. C. Kromiller, Jr., U. S. Naval Research Laboratory, Oct. 1958, 28 pp, $0.75. Order PB 151163 from OTS, U. S. Department of Commerce, Washington 25, D. C.*

## Vibration Manual

The Vibration Manual for Engineers, a Navy publication containing formulas useful to design engineers in minimizing mechanical vibration difficulties, was prepared by the Structural Mechanics Division of the Navy's David Taylor Model Basin. It updates an earlier manual having the same title (1944). The revised edition has the main purpose of expediting calculations required by the practicing engineer. Most formulas conform with a notation based on the inch-pound-second systems of units. They are presented in case form and are illustrated and explained. *A Vibration Manual for Engineers (Second Edition), R. T. McGoldrick, Structural Mechanics Division, David Taylor Model Basin, U. S. Navy, Dec. 1957, 32 pp, $1.00. PB 131785 from OTS, U. S. Department of Commerce, Washington 25, D.C.*

## Audio Filter

Design of an active, low frequency, bandpass filter is described. The synthesis technique made use of RC elements with transistor negative impedance converters to obtain complex poles. Very steep skirt selectivity and 20 db of transmission gain were achieved, but the variation of filter properties with temperature limits this particular filter to use in an environment such as might be encountered normally in a laboratory. It is felt that this limitation is not fundamental and could be substantially alleviated by the use of different transistor types. *Audio Filter, P. Z. Grayum, Philco Corp., 5 Dec. 56, 29 pp, microfilm $2.70, photocopy $4.80. Order PB 135512 from Library of Congress, Washington 25, D.C.*

## Theory of Systems

The first three of the five sections present complete developments of theories followed in current engineering practice. Section one discusses the tasks that can and cannot be performed by digital control systems and digital computing systems. Sections two and three contain developments of theories of discrete and of continuous mechanisms. The final two sections are specialized. One discusses weighting functions for continuous mechanisms from the point of view of functional analysis. In the last section, an important class of mechanisms known as finite automata is analyzed using algebraic techniques. *Fundamental Concepts In The Theory of Systems, University of Chicago for Wright Air Development Center, U. S. Air Force, Nov. 1957, 137 pp, $2.75, Order PB 151242 from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.*

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### April 29, 1959



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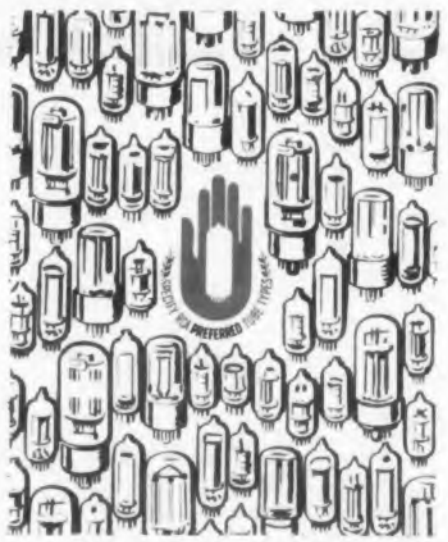

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