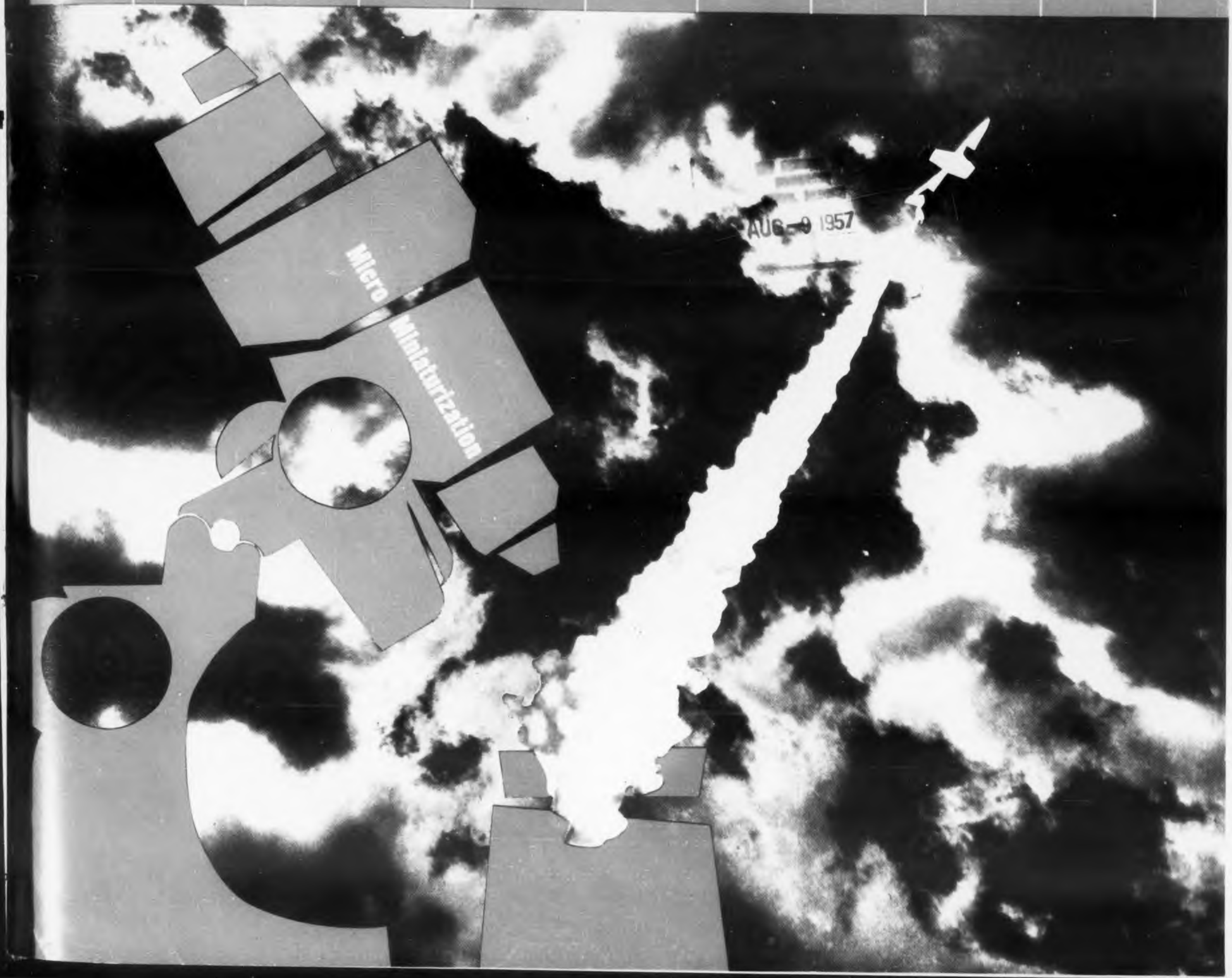
ELECTRONIC DESIGN

JULY 1, 1957



FREED

Offers for Immediate Delivery

MINIATURE COMPONENTS

(MEET MIL-T-27A SPECIFICATIONS)

MINIATURE AUDIO TRANSFORMERS

Catalog No.	Input	Coupling	Power Level	Balanced DC Current	Unbalanced DC Current	Impedance Ohms	
			DBM	MA	MA	pri.	sec.
PMA-1	V		+8	0	0	50/200/500	60,000 center tapped
PMA-2	V		+8	0	0	4/8	
PMA-3	V		+8	0	0	50/200/500	
PMA-4		V	+8	0	0	15,000	
PMA-5		V	+8	2	2	15,000	
PMA-6	V		+8	0	0	15,000	50/200/500
PMA-7	V		+8	2	2	15,000	
PMA-8	V		+8	2	.25	30,000 ct	
PMA-9		V	+8	0	0	60,000	
PMA-10		V	+8	0	0	50/200	

All units ±2 DB 30 to 20,000~; PMA 5 and 7 ±2 DB 200 to 10,000~. Case size 15/16"D x 1½" high, flanges 1½" long.

TRANSISTOR TRANSFORMERS

Catalog No.	200 to 15,000	300 to 15,000	Unbalanced DC Current	Max. Power Out	Impedance Ohms	
	DB	DB	MA	W.	pri.	sec.
TMA-1	±1		0	.25	500	500
TMA-2		±2	3	.25	50K	500
TMA-3		±2	3	.25	50K	6
TMA-4		±3	1	.25	100K	1.2K ct.
TMA-5	±2		3	.25	25K	1.2K ct.
TMA-6		±2	3	.25	50K	1.2K ct.
TMA-7	±1		4	.25	600/150	1.2K ct.
TMA-8	±2		3	.25	25K	600
TMA-9	±1		1	.25	4K ct.	600/150
TMA-10	±2		10	.25	2K	3.2
TMA-11	±1		1	.25	4K ct.	3.2
TMA-12		±2	4	.25	20K	50
TMA-13		±2	8	.25	1K	50
TMA-14		±2	0	.10	100K	1K
TMO-15		±2	1	.04	20K	50
TMO-16		±2	1	.04	20K	600
TMO-17		±2	3	.06	1K	50
TMO-18		±2	0	.10	100K	1K
TMA-19	±2		20	1.	1K	3.2

Case size 1"D x 1.5" high, flanges 1⅜". Specify TMO for open, TMC for encapsulated units.

MINIATURE HIGH Q TOROIDS

Cat. No.	Ind. MHY	Cat. No.	Ind. MHY	Cat. No.	Ind. MHY	Cat. No.	Ind. MHY
to 15 KC		10 to 50 KC		30 to 75 KC		50 to 200 KC	
F2050	1.	F2100	0.1	F2140	0.1	F2180	0.1
F2051	3.	F2101	0.2	F2141	0.2	F2181	0.2
F2052	5.	F2102	0.3	F2142	0.3	F2182	0.3
F2053	10.	F2103	0.4	F2143	0.4	F2183	0.4
F2054	15.	F2104	0.5	F2144	0.5	F2184	0.5
F2055	30.	F2105	1.0	F2145	1.0	F2185	0.6
F2056	50.	F2106	2.0	F2146	2.0	F2186	0.7
F2057	75.	F2107	3.0	F2147	3.0	F2187	0.8
F2058	100.	F2108	4.0	F2148	4.0	F2188	0.9
F2059	150.	F2109	5.0	F2149	5.0	F2189	1.
F2060	200.	F2110	7.5	F2150	7.5	F2190	2.
F2061	300.	F2111	10.	F2151	10.	F2191	3.
F2062	400.	F2112	15.	F2152	15.	F2192	4.
F2063	500.	F2113	20.	F2153	20.	F2193	5.
F2064	750.	F2114	30.	F2154	30.		
F2065	1,000.	F2115	50.	F2155	50.		
F2066	1,250.	F2116	75.	F2156	75.		
F2067	1,500.	F2117	100.	F2157	100.		
F2068	1,750.						
F2069	2,000.						

Case size: ¾"x11/32" x25/32h.

Encapsulated 1"dx⅞"h. When ordering hermetically sealed units add H, encapsulated units MR to Cat. No.

FOR PRECISION LABORATORY OR PRODUCTION TESTING

FREED

1110-AB INCREMENTAL INDUCTANCE BRIDGE AND ACCESSORIES

Accurate inductance measurement with or without superimposed D.C., for all types of iron core components.

- **INDUCTANCE** — 1 Millihenry to 1000 Henry
- **FREQUENCY** — 20 to 10,000 Cycles
- **ACCURACY** — 1% to 1000 Cycle, 2% to 10KC
- **CONDUCTANCE** — 1 Micromho to 1 MHO
- **"Q"** — 0.5 to 100
- **SUPERIMPOSED D.C.** — Up to 1 Ampere
- **DIRECT READING** — For use by unskilled operators.

ACCESSORIES AVAILABLE:
1140-A Null Detector 1210-A Null Detector - V.T.V.M. 1170 D.C. Supply and 1180 A.C. Supply.

FREED

NULL DETECTOR AMPLIFIER TYPE 1140-A

USES

A sensitive null indicator for bridge measurements, providing visual null indications or aural when used in conjunction with headphones. The unit may also be used as a high gain amplifier for general laboratory work.

DESCRIPTION

Functionally the instrument consists of a high gain linear amplifier with a 30 db. input attenuator in addition to the variable gain control. A four-inch panel meter provides visual null indications, the response of the meter circuit is approximately logarithmic over a 40 db. voltage range. Resonant circuits tuned to 60, 400 and 1000 cycles limit the amplifier transmission characteristics to the three audio frequencies commonly used for bridge measurements or it may be used as a non-selective amplifier with filter "off."

SPECIFICATIONS

Input Impedance: 1 megohm in parallel with 25 mmf. GAIN: 98 db. with 1 megohm load (6 mmf. shunt capacity), down 1.5 db. at 25,000 cycles, down 5 db. at 50,000 cycles, down 2 db. at 20 cycles. **Null Detector Sensitivity:** At 1 kc. 100 microvolts will give a 15% meter deflection.
Selective Amplifier: 26 db. second harmonic attenuation at 60, 400 and 1000 cycles.
Power Supply: 105-125 volts, 50-60 cycles, 35 watts consumption.
Dimensions: 13½" x 8½" x 10".

TELEMETERING COMPONENTS

BAND PASS FILTERS / DISCRIMINATORS

Catalog No. Z_o = 500 Ω	Catalog No. Z_o = 2,500 Ω	3DB Bandwidth per cent of F_o ± 9¾	3DB Bandwidth per cent of F_o ± 19½	Center Frequency F_o (KC)	Per cent Deviation of F_o 0½	Per cent Deviation of F_o 1%	Per cent Linearity 0.5	Per cent Linearity 1.0	Catalog No.
FBP-10	FBP-34	V		.4	V		V		DST-10
FBP-11	FBP-35	V		.56	V		V		DST-11
FBP-12	FBP-36	V		.73	V		V		DST-12
FBP-13	FBP-37	V		.96	V		V		DST-13
FBP-14	FBP-38	V		1.3	V		V		DST-14
FBP-15	FBP-39	V		1.7	V		V		DST-15
FBP-16	FBP-40	V		2.3	V		V		DST-16
FBP-17	FBP-41	V		3.0	V		V		DST-17
FBP-18	FBP-42	V		3.9	V		V		DST-18
FBP-19	FBP-43	V		5.4	V		V		DST-19
FBP-20	FBP-44	V		7.35	V		V		DST-20
FBP-21	FBP-45	V		10.5	V		V		DST-21
FBP-22	FBP-46	V		12.3	V		V		DST-22
FBP-23	FBP-47	V		14.5	V		V		DST-23
FBP-24	FBP-48	V		22.0	V		V		DST-24
FBP-25	FBP-49		V	22.0		V		V	DST-29
FBP-26	FBP-50	V		30.0	V		V		DST-25
FBP-27	FBP-51		V	30.0		V		V	DST-30
FBP-28	FBP-52	V		40.0	V		V		DST-26
FBP-29	FBP-53		V	40.0		V		V	DST-31
FBP-30	FBP-54	V		52.5	V		V		DST-27
FBP-31	FBP-55		V	52.5		V		V	DST-32
FBP-32	FBP-56	V		70.0	V		V		DST-28
FBP-33	FBP-57		V	70.0		V		V	DST-33

DISCRIMINATOR LOW PASS FILTERS

Catalog No.	Center Frequency F_o (cps)	Catalog No.	Center Frequency F_o (cps)	Catalog No.	Center Frequency F_o (cps)	Attenuation
OUTPUT						
LPO-10	6	LPO-19	81	LPO-28	790	.2 DB to 0.5 F_o; 7 DB at 1 F_o; 20 DB to 2 F_o; 30 DB from 2.5 F_o
LPO-11	8	LPO-20	110	LPO-29	900	
LPO-12	11	LPO-21	160	LPO-30	1,050	
LPO-13	14	LPO-22	185	LPO-31	1,200	
LPO-14	20	LPO-23	220	LPO-32	1,600	
LPO-15	25	LPO-24	330	LPO-33	2,100	
LPO-16	35	LPO-25	450	LPO-34	7,200	
LPO-17	45	LPO-26	600	LPO-35	10,000	
LPO-18	60	LPO-27	660			
Characteristic impedance of all = 330Ω						
INPUT						
LPI-10	400	LPI-17	3,000	LPI-23	14,500	.05 DB at 9¾% F_o; 30 DB at third Harmonics; 50 DB at fifth Harmonics
LPI-11	560	LPI-18	3,900	LPI-24	22,000	
LPI-12	730	LPI-19	5,400	LPI-25	30,000	
LPI-13	960	LPI-20	7,350	LPI-26	40,000	
LPI-14	1,300	LPI-21	10,500	LPI-27	52,500	
LPI-15	1,700	LPI-22	12,300	LPI-28	70,000	
LPI-16	2,300					
Characteristic impedance of LPI-10 thru 23 = 30,000Ω; of LPI-24 thru 28 = 5,100Ω						

Send for NEW 48 page transformer catalog. Also ask for complete laboratory test instrument catalog.

FREED TRANSFORMER CO., INC.

1727 WEIRFIELD ST., RIDGEWOOD, BROOKLYN 27, NEW YORK

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Hayden Publishing Company, Inc.
19 East 62nd Street
New York 21, New York

◄ CIRCLE 1 ON READER-SERVICE CARD

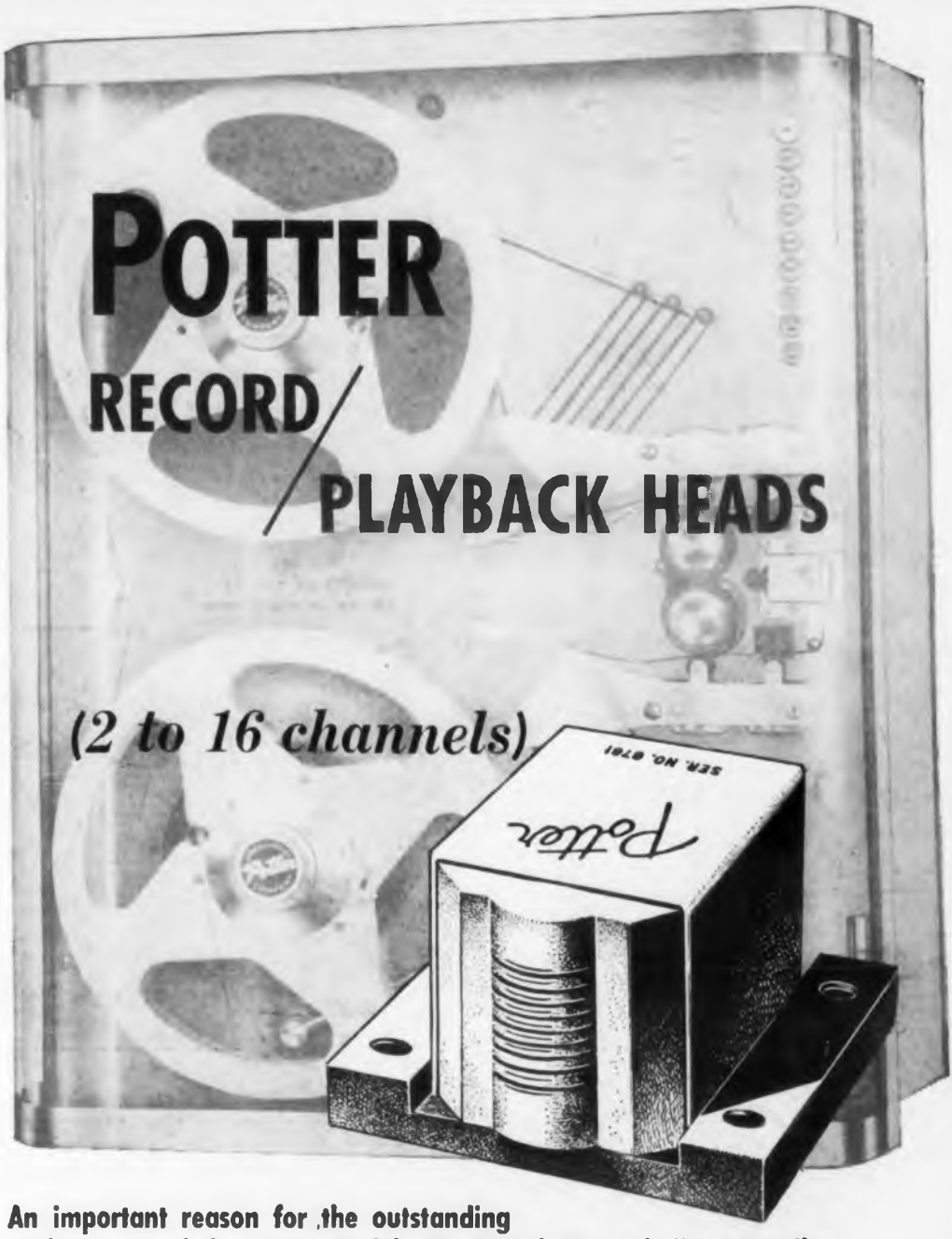
ELECTRONIC DESIGN

Contents

Vol. 5, No. 13

July 1, 1957

ELECTRONIC DESIGN is published semi-monthly by Hayden Publishing Company, Inc., 19 E. 62nd Street, New York 21, N. Y., T. Richard Gascoigne, President; James S. Mulholland Jr., Vice-President & Treasurer and David B. Landis, Secretary. Printed at Hildreth Press, Bristol, Conn. Acceptance under section 34.64 P. L. & R. authorized. 30,000 Copies this issue.



An important reason for the outstanding performance of the Potter Model 905 Digital Magnetic Tape Handler

Precision designed to meet highest standards of performance and reliability... *machined bronze... solidly constructed to close tolerances... high dimensional stability... full shielding between channels... precisely aligned gaps.*

Track width:	.020" to .031" ± .001"
Track spacing:	.050" to .078" ± .001"
Gap width:	.0005"
Gap alignment:	Within .0001"
Inductance:	Nominal 10 mhy for tube record amplifiers Nominal 1 mhy for transistor record amplifiers *(Available with both high and low impedance windings on each channel)*
Record Current:	10 mhy: 10 ma. 1 mhy: 30 ma. Rise time: 1 μ sec
Signal level:	Nominal 10 mv. for 10 mhy winding at 30 ips
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Gap, track width, track spacing and nominal inductance can be varied within reasonable limits for custom applications.

For more information, prices and delivery schedules on heads and tape handlers, write, wire or phone your Potter representative or the factory.

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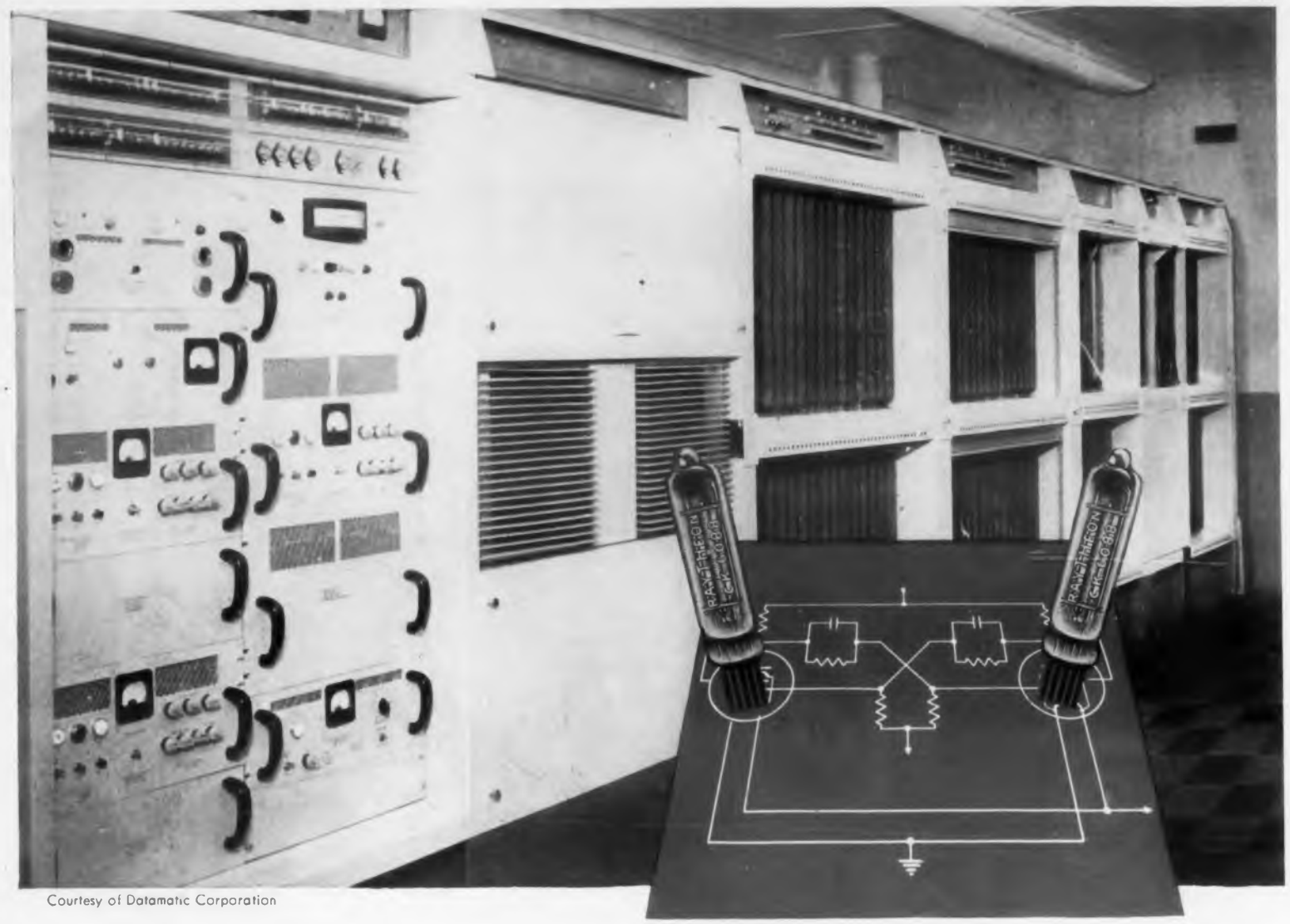


Courtesy of Datamatic Corporation

Editorial

Make It Smaller!

The cry being heard almost everywhere in engineering departments these days is: "Make it smaller." This request, along with demands for greater reliability, higher and lower temperature operation, high impact and vibration resistance, and tolerance to other environments as well, challenge the design engineer as never before. Few formal courses of study offer any help. Engineers are mostly on their own.

This issue of ELECTRONIC DESIGN is dedicated to the concept of *thinking small*. The designer must condition himself to think initially in terms of millionths of an inch instead of thousandths, hundredths, and tenths. It is wasteful to redesign a standard-size package of electronic gear to miniaturize it when it can be foreseen in advance of initial design that it will be needed in the smaller form.

We initially called our readers' attention in our Dec. 15, 1956 Editorial to the need to study watchmaking techniques in design of electronic components and systems. In this issue we present two articles by watchmakers themselves which might be considered the first step in conveying the thinking of this industry "under a micoscope" to electronic engineers. We hope to present more specific design suggestions from them and others working in the field from time to time.

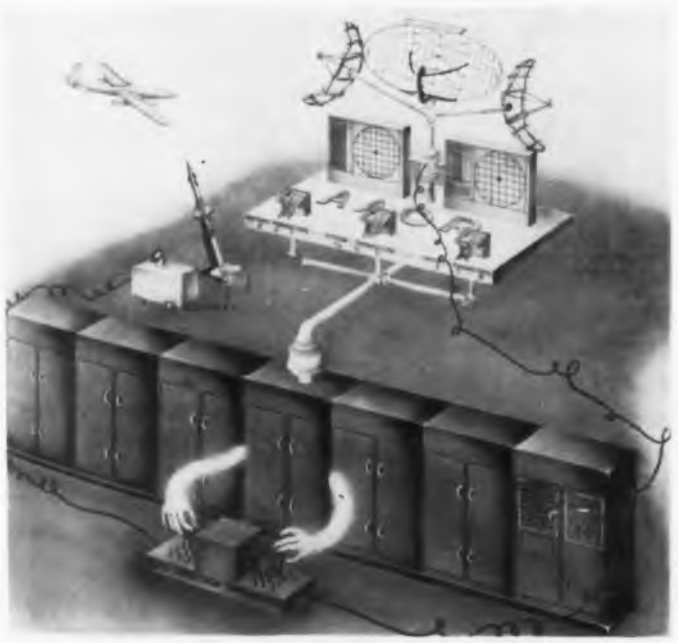
Look to this issue for a beginning in your study of the micro-miniaturization trend. Then follow ELECTRONIC DESIGN in the months ahead for a well-rounded program of articles and announcements of new products necessary for designers in their quest for ways to *make it smaller*. E.T.E.

Looks good, Bill . . . But remember, our Packaging Engineers have to squeeze it into a vest pocket!

Courtesy, Stromberg-Carlson Div., General Dynamics Corp.

Engineering Review

For more information on developments described in "Engineering Review," write directly to the address given in the individual item.



MATABE, a computer system to be used by anti-aircraft control centers, makes possible the quick decision of tactical problems that might arise during a defense situation. The computer acts upon information derived from routine observations, possible tactical compromises, as well as from the immediate data of a given defense situation.

Tactical Computer for Air Defense

A control system capable of performing 136,000 mathematical steps in less than a second has been developed to assist anti-aircraft operation centers in organizing defense against enemy aircraft. The equipment, officially called the Multi-weapon-Automatic Target and Battery Evaluator (MATABE), was conceived by the Army Signal Engineering Labs., Ft. Monmouth, N.J., and was developed by the Burroughs Corp. in Paoli, Pa.

The system is a result of the need to aid anti-aircraft officers to calculate quickly the information needed to make the most favorable use of their weapons in the destruction of aircraft.

The problem which must be solved in organizing a defense pattern is a complex one. The common sense solution, namely that of evenly spacing weapons around the area to be defended and assigning a given sector of defense to each weapon, is not necessarily the best solution. Too many variables are involved, such as anti-aircraft batteries that may be placed partially out of action, and the relative importance of each of the attacking planes. For instance, it might well be disastrous if the plane carrying the bomb became the total responsibility of one anti-aircraft battery, simply because the plane happened to be entirely within that particular battery's sector. Defense at such a moment would be greatly strengthened if another battery, which might be temporarily unoccupied in its own sector, were called in for assistance.

MATABE will give such information as the time it takes a missile to get from the battery to its bursting point; how much time a battery needs to carry out its assignment; the point of intercept; whether a target is within effective range; the kill probability of a battery-target assignment; percentage of total bomb damage attacking planes are capable of inflicting; and military value of a target according to strategic goals or the target priority of a group of attacking planes. Computations are based on data fed into the system derived from routine observations and strategic compromises.

The system is capable of analyzing both air attacks and defense plans. Its evaluations can lead to major tactical changes in specific attack or defense plans, and minor alterations in the position or type of batteries in a defense system. The system is 29 feet long, over seven feet high and consists of seven cabinets housing the electronic equipment. It can be controlled from two panels and is cooled by a nine-ton air conditioning unit.

Solar Bats in Army's Helmet: Clusters of solar cells placed on either side of helmet supply the necessary power for keeping the Signal Engineering Laboratory's helmet-radio alive. Use of the solar cells in combination with rechargeable nickel-cadmium batteries is expected to provide power for many months, possibly a year or more. With the dry cells formerly used in the helmet-radio, battery life was less than a day if used continuously, which placed considerable limitation on the helmet-radio as a practical piece of equipment.

Problems were encountered in raising the 4.5 v output of the solar-battery combination to the 50 v needed for the transmitter-receiver. However, careful design produced a transistorized converter small enough to fit, with the nickel-cadmium cells, in the aluminum housing already designed for the dry batteries previously used in the helmet-radio. Even with the solar cells, power converter and nickel-cadmium batteries, the sun-powered version of the radio is as light as the dry battery set, which weighs slightly less than a pound.

Engineering Review

Inertial Guidance

The inertial guidance system was demonstrated recently at Cambridge, Mass., where much of the fundamental research had been accomplished by an M.I.T. group. It was revealed for the first time at that conference that on Feb. 8, 1953, the device had guided a U.S. Air Force B-29 from Bedford, Mass., to Los Angeles, Calif., with an error of only 10 miles at the final destination. Since the system does not depend in any way on information received from an outside source, it has the obvious advantage of not being able to be jammed or otherwise affected by enemy or other interference.

Engineers describe it in the simplest terms as the system that knows where it is because it knew where it was and where it's going. The system keeps track of its position in space by counting to itself units of acceleration in horizontal North-South and East-West directions. This counting process is continually integrated. The system, therefore, can tell itself at any time how far, how fast and in what direction it has come from its starting place.

The Aeronautical Division of Minneapolis-Honeywell Regulator Co. is in production on several of the components such as inertial hermetic integrating gyroscope that can detect infiinitesimal rates of movements and a pendulous gyro accelerometer. Other components of the system include analog computers and gyro stabilized platform for the accelerometers.

This model of the inertial guidance system was shown at an MIT conference, during which it was revealed that a comparable system had guided a B-29, in 1953, from Bedford, Mass., to Los Angeles, Calif., with an error of only 10 miles.

Food Preservation with Radar

Radar is being used to preserve fresh and cooked foods so they can be stored on a kitchen or grocer's shelf at room temperature indefinitely without refrigeration. Still in the experimental stage at the Raytheon Mfg. Co. Food Lab., Waltham, Mass., the new process is expected to make available normally perishable meats, fish, fruits and vegetables in unfrozen form the year round without loss of flavor, texture or nutrient value. Beef, shrimp, strawberries and other foods have been successfully preserved by this technique.

In recent flavor evaluations at MIT, panel members found no significant difference between the experimentally processed food and the cooked fresh product used as a control.

The preserved food weighs only a fraction of the fresh product. From 70 to 95 per cent of the fresh food's weight is water, removed in processing by applying microwave energy while the food is held under vacuum at below freezing temperatures. About 70 to 75 per cent of steak is water; shrimp is 80 per cent; and strawberries, about 90 per cent.

When food is needed, it is restored to its original fresh condition in minutes simply by immersing in water. The food soaks up the water and may then be cooked in any ordinary way.

Changing Usage of High Frequency Power

A different utilization of high frequency electric power was predicted in a paper at the Summer General Meeting of the AIEE. Vernon C. Geckler, of General Motors Corp., Bristol, Conn., stated that with some exceptions, automation and integration lines will dictate the use of smaller size generating units located and sized specifically for a particular production line. Generating units used for these integrated lines would not be direct connected units but V-belt driven units on which the belts may be changed to vary the generator speed to gain a different frequency. This means a greater number of units to maintain but the end results of integration would warrant the application of these small units.

In the not too distant future it was thought possible that there would be developed an electronic unit which would be sufficiently small in size as to be installed on a machine tool, and have the ability to vary its frequency within the range requirements of the machine. High frequency, is expected to have continued application for internal grinding, portable tools for high production lines, woodworking machines and commercial and industrial lighting. The last two would include auditoriums, gymnasiums, large store areas and large manufacturing floor.

The use of high frequency is not new, but has been used satisfactorily to a limited degree for 50 years, although at that time little was known about its application. General Electric developed the first large industrial application for high frequency power in 1904 by utilizing 150 cps at Bristol, Conn.

Engineering Review

Ferromagnetic Garnets

A group of ferromagnetic materials called garnets promise to extend the increased efficiency which ferrites give to radar and similar transmissions into lower transmission bands, by increasing the lower limit down to 100 mc. This implies considerable advantages in systems where power is limited, for example in airplanes and missiles. Presently under study by Professor C. Lester Hogan of Harvard University's Div. of Engineering and Applied Physics, these man-made ferromagnetic garnets have the same crystal structure as the gem stone but have been chemically modified so that they are ferromagnetic. Previous ferrites which Hogan and others have developed have doubled the efficiency in the range above 1000 mc.

Ordinary broadcast antennas are wasteful of signal power because they tend to reflect part of the outgoing signal back in the direction of the oscillator. To combat this reflection, which can throw the oscillator out of phase, large resistances must be introduced between the antenna and the signal source. Garnets and other ferrites have the unique property of passing microwaves in one direction only, blocking them if they attempt to return. When introduced into a communications system between the oscillator and the antenna, garnets and other ferrites eliminate the need for large resistances, and make increases of about 100 per cent of the signal power possible without increasing power input at the oscillator.

The one-way property of garnets and other ferrites, is explained in terms of the spin of the electron. Since the electron possesses charge, it produces a magnetic field when it spins. This act of spinning also gives the electron the properties of a tiny gyroscope. When disturbed, electrons precess. The axis of precession for the top and for the electron is determined by the axis of the magnetic force-field acting upon them. When microwave radiation enters the garnet or ferrite in one direction, its direction agrees with the direction of the electron's precession. But if the wave is reflected in the other direction, its direction disagrees with the electron's precession and the wave is blocked. The characteristic of garnets which permits their use at lower frequencies is their long relaxation time, the time it takes for the precession of its electrons to become damped and disappear. Some garnets have relaxation times as long as 1 μsec, whereas other ferrites have relaxation times in the vicinity of 0.01 μsec.

Garnets and other ferrites are produced by powder metallurgy techniques. A powdered mixture of the ingredients is compressed under high pressure and fused in a high temperature furnace. *They are*

dark, heavy materials with a high dielectric strength (nearly perfect insulators) but are strongly magnetic. Manufacture of garnets for experimental purposes is carried on in the ferrite preparation laboratory at Harvard's McKay Laboratory.

Recently, Dr. Harry Suhl of Bell Telephone Labs. has proposed a new type of microwave amplifier which would use single crystals of these garnets. This amplifier promises to be the lowest noise amplifier yet which will operate at room temperature.

Picture Tube for Battery TV

A new cathode-ray tube that will enable television receiver designs to operate from batteries when using a combination kit of transistors and tubes has been developed by Multi-Tron Lab., Inc., 4624 W. Washington Blvd., Chicago, Ill. This tube is a further application of the patented pure-signal cathode-ray tube design which permits direct operation from diode or transistor output, thus eliminating the video amplifier in home receivers. It is not expected, however, that the industry will complete circuit and component development for production of the battery TV receiver prior to the first quarter of 1958.

3001 Ft. Per Sec: A spin pit, constructed by the Aluminum Co. of America, whirls parts at nearly three times the speed of sound in order to test their strength. The company reports that parts have been spun at peripheral velocities of 3000 ft. per sec without rupture. The weights of parts to be investigated range up to nearly a ton, and speeds exceed 100,000 rpm. Aluminum parts, bolted to an air-driven turbine, are spun in a vacuum so that air resistance will not impede them. According to one witness, as the speed increases, the turbine emits a sound like a police siren which soon dies away only to be reinforced at successive intervals by other harmonics.

Engineering Review

Operation Moonwatch

Keeping track of the earth satellite is expected to pose somewhat of a problem. Since the satellite's batteries will run down within a few weeks, scientists will depend on visual observation to locate the man-made moon. This has created a demand for observation posts across the country; a demand which is already in the process of being fulfilled.

The first post to be financed by private enterprise is located on the rooftop of the Valley National Bank in Phoenix, Ariz. The equipment on top of the 12-story building includes a 24-ft T mast, 12 sighting benches, an equal number of wide-angle telescopes, shortwave radio, tape recorder, and even coffee-making facilities for use on cool mornings. Scientists expect the sphere to cross over Southwestern skies during the first dawn following its release into space. Actually, the satellite will make 15 globe-girdling trips during every 24-hour period but it will only be visible at twilight. At other times, the satellite will be lost in the night sky or in the daylight brilliance.

The hope that other private enterprises would follow suit in the support of Operation Moonwatch has been partly fulfilled. Business firms in over a score of American cities have agreed to finance comparable stations. At the present over half of the 200 posts originally proposed are in the process of being constructed, and a majority of the remainder are in the planning stage.

Surplus Seachlight Provides Solar Furnace

Tungsten arc or carbon resistor furnaces have commonly been employed in the past for high temperature studies, but with the disadvantage that the crucibles, electrodes, or resistors contaminate the reaction and give false indications.

As a solution to this problem, the National Bureau of Standards has acquired a new research facility in the form of a furnace. Producing temperatures up to 3500 C, the furnace will melt refractory materials in a controlled environment free of contaminating agents.

The furnace was converted from a surplus Army searchlight with a 5-ft diameter parabolic mirror. It collects the sun's rays and focuses them into an intensely hot spot about 1/4 in. in diameter. Heating occurs only at this small spot, and the experiment is carried out here. This area can be isolated by closed glass tubing, which can be evacuated or filled with gas of the experimenter's choice. The glass enclosure is not affected by the sun's rays since the image of the sun is unfocused where the light passes through the enclosure and no local heating of the glass results.

The curved mirror faces a flat mirror, about 8 ft sq., which is directed at the sun and reflects the light

into the furnace. This is attached to a searchlight mount, which is controlled by an assembly of photocells and other appropriate electronic equipment to follow the sun's apparent motion.

Besides study of the properties of refractory materials, the solar furnace can be used in the zone refining of oxides of zirconium, thorium, or uranium to produce extremely pure samples of those compounds. Another possible use of the furnace would be to aid in growing single crystals of these and similar materials for laboratory studies.

Magnetic Laminators Installed

Four film processing laboratories have been equipped to laminate magnetic sound tracks to 8 and 16 mm motion picture film. Most recent applications for the laminated sound tracks have been in television news coverage where the film can now be stripped prior to exposure and used in the new sound-on-film cameras which record magnetically. Primary advantage of the magnetic track over conventional optical tracks is in greatly improved fidelity of sound while maintaining top picture quality. Installation of the magnetic laminators was announced by the Minnesota Mining and Manufacturing Co., St. Paul, Minn.

Sodium-Cooled Reactor Fired

On April 25, self-sustaining nuclear fission was achieved in the Sodium Reactor Experiment, a small-scale experimental civilian atomic power project being developed near Los Angeles, Calif., by Atomics International, a division of North American Aviation, Inc. This is the first sodium-cooled reactor to produce a sustained nuclear chain reaction. It uses neutrons moderated with graphite to sustain the fission process, and liquid sodium is circulated through the reactor core to remove heat produced by the atomic fission. During the initial start-up test, the reactor operated at a power level of about 1 kw of heat. No electricity was generated. The design capacity of the reactor is 20,000 kw of heat.

Meetings

Aug. 1: Deadline for papers proposed for the Oct. 31-Nov. 1 conference of the **Professional Group on Electronic Devices, IRE,** in Washington, D.C. Abstracts should be submitted to the program chairman, W. M. Webster, RCA Semiconductor Div., Somerville, N.J. Subject matter should concern developmental techniques and devices, such as electron tubes and transistors, rather than basic research or circuit applications.

Aug. 20-23: Wescon (Western Electronic Show and Convention)

Cow Palace, San Francisco, Calif. Sponsored by the San Francisco and Los Angeles Sections representing the Seventh Region IRE and West Coast Electronic Manufacturers Association. For more information write to Don Larson, Business Manager, 342 N. LaBrea Ave., Los Angeles 36, Calif.

Sept. 4-6: Special Technical Conference on Magnetic Amplifiers

Penn Sheraton Hotel, Pittsburgh, Pa. Sponsored by the AIEE and the IRE. The program's four sessions will deal with New Circuits and Techniques, Analysis and Design, and Applications. For more information, write to D. Feldman, Bell Telephone Labs.

Sept. 9-13: Twelfth Annual Instrument-Automation Conference and Exhibit

Cleveland Auditorium, Cleveland, Ohio. Sponsored by the ISA. Organized under the unifying theme, "Instrumentation for Systems Control," the conference will open with formal sessions devoted to data handling and instrument terminology. Following these there will be individual workshop sessions in limited discussion groups covering such topics as aircraft and missiles (excluding propulsion), wind tunnels, flight propulsion systems, process industries, power generation and distribution, meteorological, nuclear, medical, geophysical exploration and general industrial laboratories. Some 100 papers will be presented at the technical sessions. There will be about 500 exhibits. For details of the technical program write to Herbert S. Kindler, Director of Technical Programs, ISA, 313 Sixth Ave., Pittsburgh, Pa.

Sept. 17-18: RETMA Symposium on Numerical Control Systems for Machine Tools

Ambassador Hotel, Los Angeles, Calif. For details write to RETMA, Room 650, 11 W. 42nd St., New York 36, N.Y.

Oct. 16-18: 1957 IRE Canadian Convention and Exposition

Automotive Building, Exhibition Park, Toronto, Canada. Sponsored by the Canadian Sections of the IRE. For information write to Grant Smedmor, IRE Canadian Convention, 745 Mt. Pleasant Rd., Toronto 7, Canada.

Oct. 31-Nov. 1: Third Annual Technical Conference of the Professional Group on Electron Devices, IRE.

Shoreham Hotel, Washington, D.C. Those interested in submitting papers should check the paper deadlines at the end of this section. For more information, write W. M. Webster, RCA Semiconductor Div., Somerville, N.J.

Nov. 11-13: Third Annual Instrumentation Conference

Biltmore Hotel, Atlanta, Ga. The theme of this conference will be "Instrumentation for Data Handling" with special symposiums on electronic instrumentation as applied to medicine and the sales and purchasing aspects of electronic instrumentation. Papers should be submitted to Lamar Whittle, Federal Telecommunications Lab., 1389 Peachtree St., N.E., Atlanta, Ga. For more information write B. J. Dasher, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Ga.

Nov. 13-14: Mid-America Electronics Convention

Municipal Auditorium and Hotel Muehlebach, Kansas City, Mo. Sponsored by the Kansas City Section of the IRE. There will be exhibits and twelve technical sessions. Approximately thirty papers will deal with medical electronics, airborne electronics, instrumentation, engineering management, electronics in nucleonics and a diversity of other subjects. Persons who want to submit papers should contact the Technical Papers Chairman, MAECON, 5109 Cherry St., Kansas City 10, Mo. The deadline for submissions is Aug. 15. For more information write Richard L. Clarke, 425 Volker Blvd., Kansas City 10, Mo.

Nov. 13-15: Eighth National Conference on Standards

St. Francis Hotel, San Francisco, Calif. Sponsored by the American Standards Association. Emphasis will be on standards as a key to progress and profits. Sessions will cover radiation exposure, electronics, industrial preparedness, motion pictures and television, purchasing, company standards, technical communications, government standards and safety. For more information, write to D. E. Denton, ASA, 70 E. 45th St., New York 17, N.Y.

Washington Report

Herbert H. Rosen

Pay-See TV Legal Says FCC

Under pressure from Congress and part of the electronic industries, the Federal Communications Commission has finally decided that it "has statutory authority to authorize the use of television broadcast frequencies for subscription television operations." The decision was reached after receiving some 25,000 comments from industry and the public. The Commission also received proposals for three different systems for encoding and decoding the TV signals: "Phonovision," sponsored by Zenith and TECO, Inc.; "Subscriber-Vision," by Skiatron Electronics and Television Corp. and Skiatron TV; and "Telemeter," by International Telemeter Corp.

But the FCC is not yet willing to give the green light to Pay-See TV. In spite of the many comments and detailed proposals, there is still some question as to whether the system would "be in the public interest." Consequently, the FCC is now in receipt of more comments on the "manner in which subscription television would operate in actual practice." Obviously, a proportion of the first 25,000 comments was opposed to the idea. Their main argument is that the airways are free and that subscription TV would "seriously impair the capacity of the present system to continue to provide advertiser-financed programming. . . ."

By now, the FCC will have its staff finding out if a trial demonstration is feasible. In fact, the Commissioners feel that the trial is indispensible in determining "acceptability to the public." They will have been given views on which cities should be used in the test. Whether single stations or networks of stations should be employed. The time needed in planning and preparing for a series of tests. The number of hours thought necessary for a true test. And the hours of the day that they should be run. What operating and performing restrictions should be imposed. And a guess of what the impact on the public will be.

If the analysis of the current crop of comments proves that inadequate information has been supplied, the FCC will conduct oral hearings on specific issues. Ultimately, standards will be developed that will call for one or more encoding and decoding systems.

First Grants for Over-Horizon TV Transmission Made

AT & T and Florida Micro Communications, Inc. are the first companies authorized by the FCC to

relay TV programs by the tropospheric scatter technique. A 180-mile link will be established between Florida and Cuba in the uhf portion of the radio spectrum. AT & T will operate on 840 and 880 mc and will use the link to supplement its submarine telephone cables across the Florida Strait.

Florida Micro Communications, operating on 800 mc, initially, will use the link as a one-way relay for monochrome or color TV signals from Miami to Cuba. Later, the system will be made two-way.

Airways Plan Faces Rocky Road

A Federal Airways Modernization plan now before Congress looks like it may have some trouble before passage and implementation. First of all, there are some Congressmen who feel it too ambitious a program and too radical in approach. The plan, proposed by E. P. Curtis, Special Assistant to the President, calls for the establishment of a temporary Airways Modernization Board to lay down policy and be responsible for bringing the nation's airways and airports up to date. The AMB would be replaced in three years by the Federal Airways Agency, a permanent, independent organ that would attempt to keep the airways system abreast of aviation developments—jets, helicopters, turbos, atomic energy, etc.

But the major obstacle to success of the plan is the absence of the electronic equipment to do the job called for. By 1975 the total air traffic will be approximately two times what it is today. This requires a tenfold increase in capacity of the air traffic control systems to serve the users. It also means greater use of automatic radar systems, better flight control and detecting instruments, more automatic and reliable communications, and a tremendously expanded application of computers and storage devices.

Mr. Curtis foresees the airplane pilot sitting up in the cockpit of his plane using his inbred judgment, but doing little else about flying it. Take-off and landing will be largely electronic-automatic. In-flight control will be dictated by controllers—human and electronic—that know immediate position and tell what the next position should be. Even portions of SAGE and VOLSCAN have deficiencies that would prohibit their use in 1975.

There seems to be every indication that Congress will authorize the establishment of at least the Air Modernization Board. When that happens, the functions of the old ANDB will be absorbed and more authority will be issued. This means that studies will be started on what equipment will have to be developed to bring the antiquated airways system up to at least 1960 levels. The AMB will also have the authority to start some development programs in this area. But the ultimate success of the program will be heavily dependent on what the electronic industries can come up with to speed the handling and control of military and civil aircraft.

Micro-Miniaturization

Introduction

ELECTRONIC DESIGN would define "micro-miniature" in its pure sense as *technology under a microscope*. In this sense it is new to our thinking because it requires tools of fabrication generally unknown to the electronic industry. To design for it requires thinking smaller than ever before. We cannot be satisfied, either, with redesigns of standard-sized equipment by "experts" in micro-miniaturization such as watchmakers. Electronic designers must think "micro-miniature" at the outset of a design that must eventually be produced "under a microscope." Any other approach is wasteful of precious design effort; and warmed-over designs are rarely as good either economically or functionally as fresh, straightforward designs based on end use.

Miniaturization, sub-miniaturization, and micro-miniaturization are all terms now in our electronic language book. Yet, we would be in error to assume any sharp line of demarcation between the three concepts. We suggest, for instance, that "micro-miniaturization," from a practical standpoint, is just smaller subminiature or extremely small miniature. The trend will continue. What is micro-miniature today may only be subminiature tomorrow. The ultimate may be complete electronic systems fabricated in the solid state without need for interconnecting leads and with virtually 100 per cent efficient use of space. Printed wiring may become as obsolete as the rotary spark gap.

The concept of this special "status report" on micro-miniaturization was born following the excellent orientation symposium on this subject at the recent IRE National Convention in New York. The articles by Messrs. Henry A. Stone, Dr. Cledo Brunetti et al, W. W. Hamilton, and John R. Moore, are based on papers they read at this symposium.

In order to get the concept of "thinking small" before electronic designers at the earliest possible moment, time did not permit an exhaustive survey of every electronic firm that might have information to contribute to the subject. Illustrations shown and information presented should only be considered examples of the trend—not in any sense a complete summary of what is available either in micro-miniature components or equipment. Better examples could undoubtedly have been given, but only at the expense of delaying presentation of vital material of timely importance.

Electronic Design solicits further articles and new examples of micro-miniaturization from any and all sources. Further reports on this subject will be forthcoming.

E.T.E.

Component Development for Micro-miniaturization

Henry A. Stone, Jr.
Bell Telephone Laboratories
Murray Hill, N. J.

A Definition

Micro-miniaturization is defined by Henry A. Stone, Jr. of Bell Telephone Laboratories, Murray Hill, N. J. as "miniaturization of electronic equipment carried to the ultimate degree." According to Mr. Stone, available subminiature components have volumes as small as 0.01 cu in., but this is still not small enough for increasingly complex air and missile borne systems nor for equipment which will be worn or carried by personnel.

"Micro-miniaturization challenges the component engineer to realize the utmost performance from the materials at his disposal, and the highest degree of control in the processes of manufacture. To a greater degree than ever before the chemistry and physics of materials, and their behaviour in components, must be understood on the basic level. Automation and automatic process testing are essential to insure the quality and uniformity demanded by increasingly stringent goals in reliability."

MICRO-MINIATURIZATION has been described as "the ultimate in miniaturization" so small that further size reduction is of no practical interest. Since some day someone is certain to want a two-way color television set built into a wristwatch, it can be assumed that micro-miniaturization will allow plenty of scope for engineering ingenuity and imagination.

The objective of this article is to review the history of miniaturization as it has applied to various passive components and to assess present trends and some of the approaches to micro-miniaturization for designers.

Inductors and Transformers

The most obvious aid to miniaturization is provided by materials with improved electrical characteristics, which can be directly substituted for older materials. Ferrites, as used in inductors and transformers, represent a recent and glamorous example of miniaturization by direct substitution. At *A* Fig. 1 is shown a high-Q filter inductor using a Molybdenum permalloy core; at *B* is a subminiature ferrite core coil for similar applications in transistor circuits. By direct substitution it is not implied, of course, that the sizes and shapes of the cores in these coils are the same, but it does mean that both designs were derived from the same kind of mathematics. In both cases the parameters were permeability, loss factor, modulation, etc. and mechanical handling qualities. No new technological concepts were involved.

Chronological development of core materials since about 1917 is illustrated in Fig. 2. The "Q" represents a quality factor of importance in inductors. Each increase in Q has been accompanied by size reduction in coils. It is a rather obvious extrapolation that new magnetic materials having higher Q's will permit still further size reduction. Recent developments in the ferrite field indicate that not only will Q's be improved, but better ferrites suitable for higher frequencies will make it possible to substitute magnetic core coils where much larger air core coils must now be used.

But even without waiting for new materials, there is the possibility of micro-miniaturized inductors for some applications. The coil shown in Fig. 1C is a working model that was used recently in a laboratory model of a broadband coaxial amplifier.[1]

Although not a commercial item, it illustrates the inherent possibilities in currently available ferrites.

Capacitors

Often it is not so much new materials that are needed as it is ingenuity in the use of the old. The development of metallized paper and, later, of stripped lacquer film capacitors, illustrates this point. Some history of size reduction in foil paper capacitors is illustrated in Fig. 3. Almost all of the space saving represented by these successively smaller capacitors was due to direct substitution of new materials, or at least to new developments in material technology. In each case the size reduction followed the development of thinner foils and thinner paper. The smallest capacitor shown uses paper about 0.00025 in. thick and aluminum foils of about the same thickness.

This about represents the end of that particular road. The foils and the paper in these units are self-

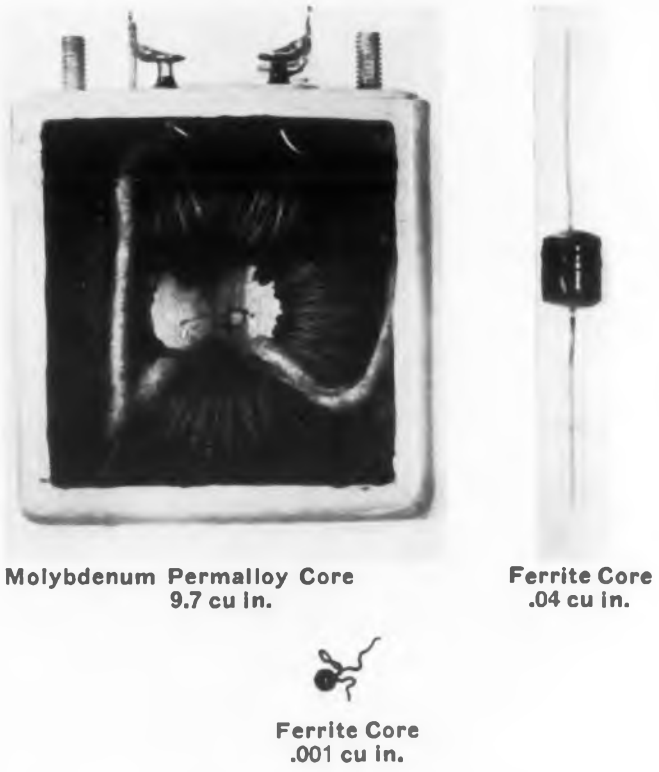


Fig. 1. Evolution of inductors. (upper left) Early molybdenum permalloy toroid; (upper right) currently available subminiature ferrite coil; (lower) micro-miniature ferrite coil now in the laboratory.

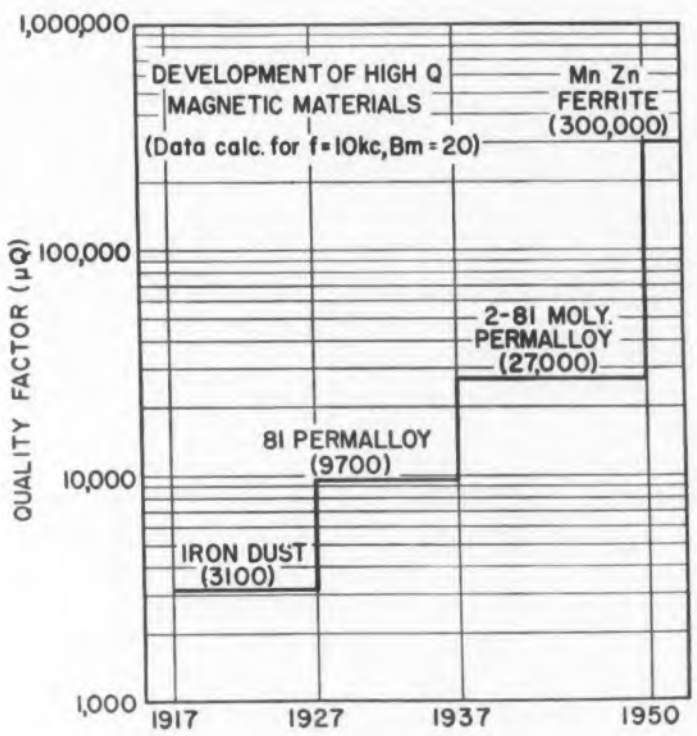


Fig. 2. Improvements in quality (μQ) of magnetic materials over the years. Advance has been especially rapid since 1950.

Micro-Miniaturization

supporting so that they can be handled and wound into capacitors. The further size reduction, illustrated in Fig. 4A, could not have come about through continuing substitution of still thinner foils. It had to depend on new ways of using materials. First there was a new concept; why should the paper and the metal foil both be self-supporting? Why not just coat the paper with a thin film of metal? The now familiar metallized paper capacitor resulted from this kind of thinking. By now it is an old story that metallizing not only got rid of most of the bulk occupied by discrete metal foils, but because of its self-healing properties it was even possible to eliminate some of the paper.

Even though the paper or plastic film used for metallized capacitors was only a fraction of a thousandth of an inch thick, this was thicker than necessary to withstand the low voltages employed with transistors; and it therefore represented waste volume. But the films could not be made any thinner or they would break during the metallizing process. Another new concept was needed, and it came in the form of the thought that a supporting backing could be provided during metallizing and removed before the capacitor was wound. In Fig. 4B is shown the result of this inspiration.[2] It is a metallized unit in which the dielectric is about 0.0001 in. thick, and it occupies only 1/5 the volume of a metallized paper capacitor having an equivalent capacitance.

What about capacitors for the future? So far as general purpose capacitors are concerned, there are two developments that will bear watching. The first is improvements in the solid type electrolytics. Tantalum electrolytics using tantalum wire instead of the more conventional sintered material have been made with orders of stability and Q that already compete with paper or plastic film types. For comparison, see Fig. 4D. This shows the new volume reduction that can be expected.[3]

Another potentiality for the future lies in the application of transistor technology to capacitors. It is well known that there is energy storage in semiconductor junctions, and perhaps less well known that in a reverse biased junction this energy storage is equivalent to high capacitance per unit area with a very high Q. There are problems to be overcome before junction capacitors can compete on a general basis, but already this type of device is being considered for certain specialized applications.

Another current development of interest has to do with application of the lacquer film technique to precision capacitors. Heretofore, for applications where high quality factor and high temperature stability were important, we have depended for the most part on mica. Recently at Bell Labs, under Signal Corps' sponsorship, a capacitor has been developed whose working dielectric is a skin of polystyrene less than 0.2 mil thick. In Fig. 5 is a 25,000 μμf unit compared with the mica capacitor that it can replace.

Resistors

Resistors have always held the lead in the field of component miniaturization. Various types of precision resistors are shown in Fig. 6, ranging from the old but still useful wire-wound types to some of the smallest deposited carbon and metal film units. The smallest illustration is of a resistor in which the working body is only 0.008 diam. It consists of a glass fiber metallized with chromium and protected by a glass tube. Actually, until new schemes for terminating and packaging are devised, there is little value in carrying miniaturization to this degree. More will be said later about the problem of packaging.

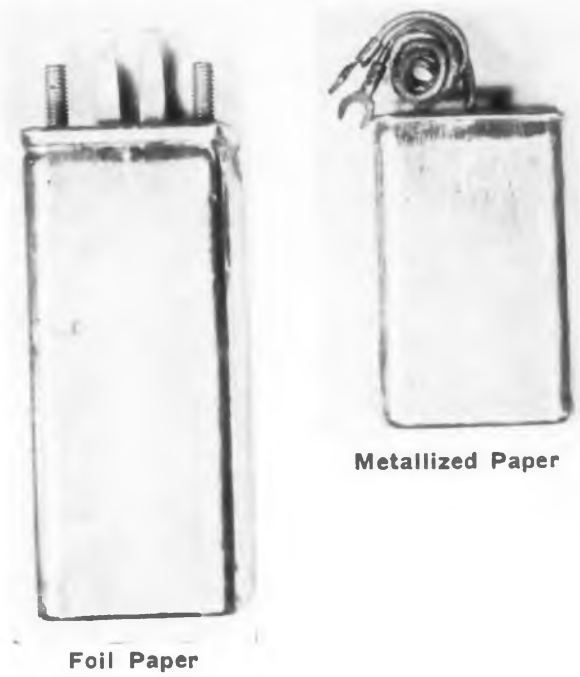
It is quite possible that in a micro-miniaturized world the resistor as an independent component will be eliminated entirely. Intensive work is being done on improving the characteristics of printed resistors, and thought is being given to metal films which instead of being on individual supports will be deposited directly on the circuit board. These will add no more volume to the equipment than do the letters on a printed page.

New Components

There are two new members of the passive components family, the diode and the switching core, both of which are inherently of an order of size

Fig. 3. Foil paper capacitors—ancient (1890) vs. modern.

Fig. 5. Evolution of precision capacitors. Both are 0.025 μf.



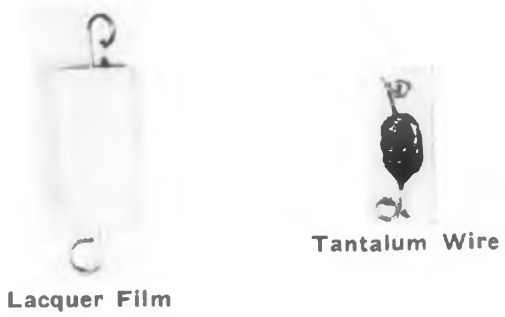
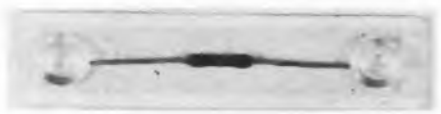


Fig. 4. Size reduction in capacitors—from foil paper to metallized paper, to lacquer film, to tantalum wire.

that puts the older components to shame. Fig. 7 is shown the working structure of a typical p-n junction diode and a common size of switching core. Both of these components are illustrative of the volumes one might associate with micro-miniaturization, and both of them present problems that will be met in micro-miniaturization. With the switching core there is the problem of handling and wiring vast numbers of these tiny elements. The assembly not only takes many times more space than the cores actually occupy, but the expense and difficulty of wiring them is a considerable item. Ingenuity has been applied to this problem; and one approach is shown in Fig. 8. Instead of using a hundred or more separate cores, a single sheet of magnetic material is perforated, and printed wiring in the desired form is applied across the sheet and through the holes.[4,5] Each perforation corresponds to a single core. The importance of this concept is that it illustrates a principle that might be applied to other components. Electronics has always been a matter of making a lot of little individual items and then laboriously putting them all together. This

Wire Wound

Deposited Carbon



Deposited Carbon

Metallic Film

Fig. 6. Evolution (top to bottom) of precision resistors.

Silicon Junction Diode

Ferrite Switching Core

Fig. 7. These components—diodes and switching cores—are basic to micro-miniaturization.

Bendix-built production test equipment calibrates precision induction rate generators and temperature compensating networks as a team.

Component Development

Micro-Miniaturization

is expensive of space as well as money. To any extent that many components can effectively be made out of one physical item, micro-miniaturization is more closely approached. Just how other multiple components will be realized remains a challenge to engineers, but Fig. 9 shows an illustration of one concept. It is an assembly of 100 tantalum wire capacitors complete with individual leads and made with exactly the same number of operations as one capacitor would have required. It can be adapted to a circuit simply by cutting away the connections that are not wanted. A unit in just this form may never find application, and it is shown only to illustrate that there can be possibilities in multiple components.

The diodes and switching cores are not the only new components that will have to be reckoned with in the future. It is certain that there will be a growing demand for many new, and some not yet invented, kinds of passive devices. Voltage sensitive capacitors, isolators, control coils and many other non-linear components are sure to contribute to systems objectives in the near future.

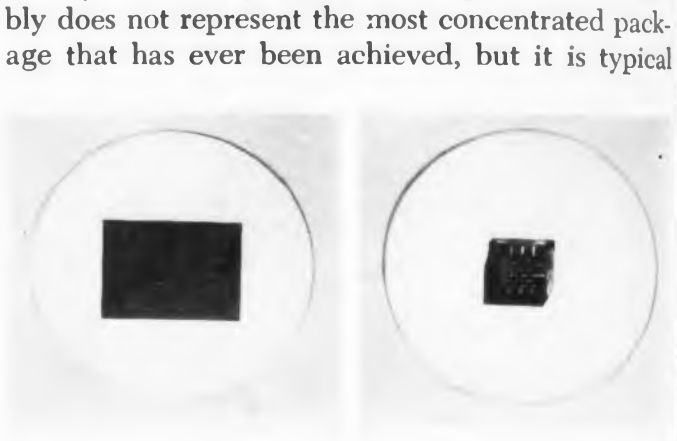
Over-all vs Working Volume

In the last analysis the progress made in microminiaturization of the many different types of components will depend on specific solutions to widely differing kinds of problems. Nevertheless, there are some observations to be made that will be applicable by and large, across the board, to the whole component picture.

One lesson that past experience in subminiaturization can teach is that factors which are trivial in large components may become of first importance when large steps in size reduction are attempted. For example, consider the over-all volume of the component and compare it with the necessary volume of the working unit. As an illustration of this point, consider again the foil paper, metallized and lacquer film capacitors. Fig. 10 shows for each of these the relationship between the volume of the actual working unit and the extra space that must be allowed for margins, terminations and housing. In the standard foil-paper capacitor, 80 per cent of the volume is actually occupied by the electrode and the dielectric. Only 20 per cent is devoted to insulators, terminations, margins, etc. In the metallized capacitor the working volume is only 33 per cent of the total; and in the lacquer film capacitor, the unit itself is down to 26 per cent of the total volume. In other words, three times as much space is devoted to incidentals as to the carefully engineered basic element. In approaching micro-miniaturization increasing attention must be devoted to the problems of terminating, protecting and housing without using up all the space that has been saved by refinements in the units themselves.

Packaging

This same line of reasoning extends to component assemblies or packages. A printed wiring assembly is shown in Fig. 11. This particular assembly does not represent the most concentrated package that has ever been achieved, but it is typical



Perforated Ferrite Plate — Printed Wire Grid

Fig. 8. New approaches to memory grids; perforated ferrite film (left), perforated film with printed wiring (right).

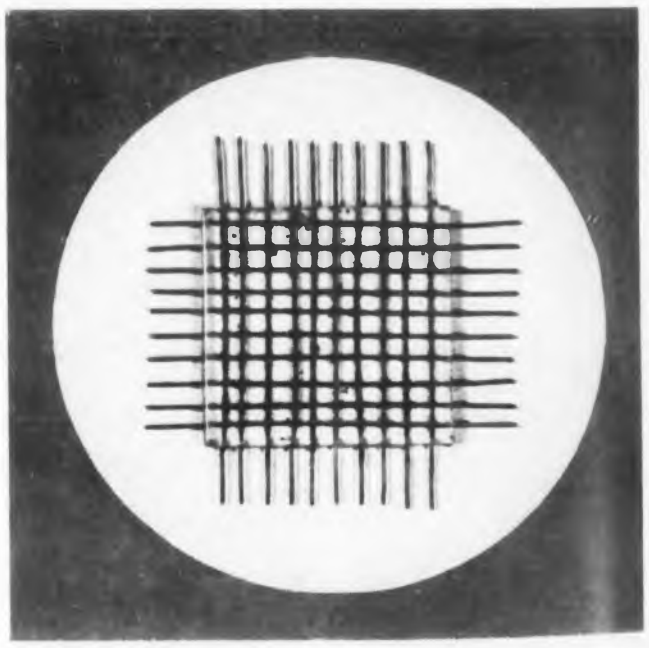


Fig. 9. Multiple tantalum-wire capacitor. A tantalum capacitor is embodied in each intersection of the wires.

of current art. It occupies a volume 7-1/4 x 7-1/4 x 3/4 in., or 39 cu in., in the equipment in which it is used; and it contains 117 components. This is an average of just about 1/3 cu. in. per component which, in comparison with chassis mounted assemblies, is most impressive. However, a rough analysis shows that the total volume occupied by the component bodies is only 1.25 cu in. This circuit has a packaging efficiency (ratio of component volume to over-all volume) of only 3.2 per cent.

It is easy to see that one reason for so much unproductive space is that the components vary widely in size and shape. Another reason is that this kind of an assembly requires an amount of headroom determined by the highest component. Obviously there is waste space when 3/4 in. headroom is allowed for a diode which may only project 1/8 in. from the board.

There are two conclusions that can be drawn here and it is easy to predict who will draw them. The equipment man will see at once that the answer is better standardization of components; and the component man will argue that if one is going to package components, the packaging scheme should be adaptable to variations in their sizes and shapes. Both will be right. There is still plenty of room for standardization in the geometry of components, but this can only be carried to a certain point. Beyond this point the essential differences in types and values of components will mean variations in dimensions, and the packaging must take such factors into account.

Materials

Just as progress in electronic systems is bounded by limitations in components available to the systems engineer, so are advances in the components themselves limited by the materials with which the component engineer has to work. Without reviewing all the interesting new developments in component materials there are a few general observations that can be made.

One is a growing recognition of the need for improved uniformity and control which has already resulted in a strong trend toward substitution of synthetic materials for natural ones. In accepting natural products we generally have to take variations in quality that we can't do anything about. For an example, the ultimate quality of capacitor paper depends not only on the kind of tree that furnishes the pulp, but even on the climatic conditions that obtain during the tree's growth. Natural materials are rapidly being supplemented by substitutes synthesized from simple compounds that are well understood and subject to control. Nylon for silk, glass for mica, synthesized oils, Mylar for paper are a few items from a rapidly growing list.

The importance of purity in materials reaches its highest level in the field of semiconductors. Germanium and silicon, for applications in transistors,

Micro-Miniaturization

are refined by ingenious new methods to the point where the impurity concentration may be less than one part in hundreds of millions. But semiconductor devices are not the only components in which a high degree of purity can be important to performance. Take, for instance, the aluminum used in electrolytic capacitors. Past practice has been to use aluminum of about 99.7 per cent purity for the foils. This is already somewhat purer than Ivory soap, but recent studies indicate that important improvements result from the use of even further purified aluminum. Some work has been done on aluminum of 99.99 per cent purity and indications are that its use in electrolytic capacitors will lead to improved shelf life, lower leakage, and fewer open circuits due to corrosion.

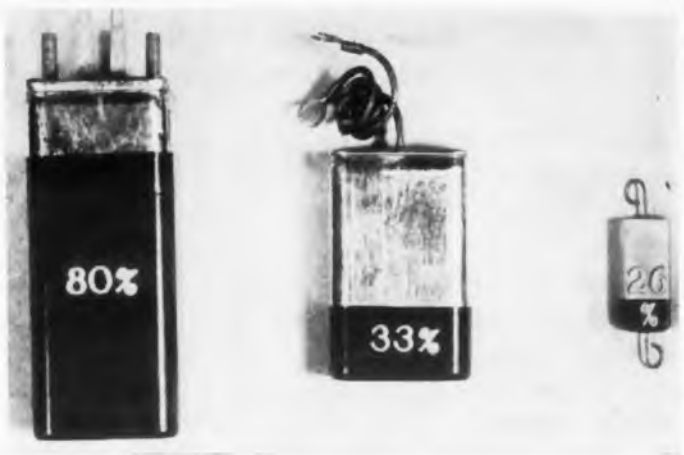
Similarly in experience with tantalum there is ample evidence to show that extreme purity in the material results directly in improved capacitor performance.

Another and highly important trend which can be observed today is the growing emphasis on fundamental understanding of materials and their behaviour. The rapid development of transistor art has resulted from basic research into the electronic nature of semiconductors. And while this important body of knowledge has been created primarily for transistors, there can be no doubt that it has an important contribution to offer for passive components of the future. To be sure, there are semiconductor passive components now, the carbon film resistor and the tantalum solid capacitor being two examples. But there will be more direct applications of transistor technology such as, for example, the junction capacitor referred to previously.

But even in the more traditional lines of component development the empirical approach has reached the point of diminishing returns. More stress than ever before is being laid on understanding of the basic physical and chemical mechanisms of conductivity, breakdown, magnetism and so forth, and this kind of knowledge cannot help but lead to better and more reliable components.

Reliability

It would be a mistake to look on micro-miniaturization only as size reduction of existing components. In addition to being smaller, the new components for future systems must meet new requirements on performance and environment. And foremost among these is the requirement of fantastic orders of reliability. Failure rates in today's passive components run from 1 in 10,000 to 1 in 100,000 per year, depending on the component and its use. These failure rates, which are already low, will still have to be decreased by orders of magnitude. This is true



Foil Paper Metalized Paper Lacquer Film

Fig. 10. How working volumetric efficiency has decreased as capacitors became smaller. Here is an area for design consideration.

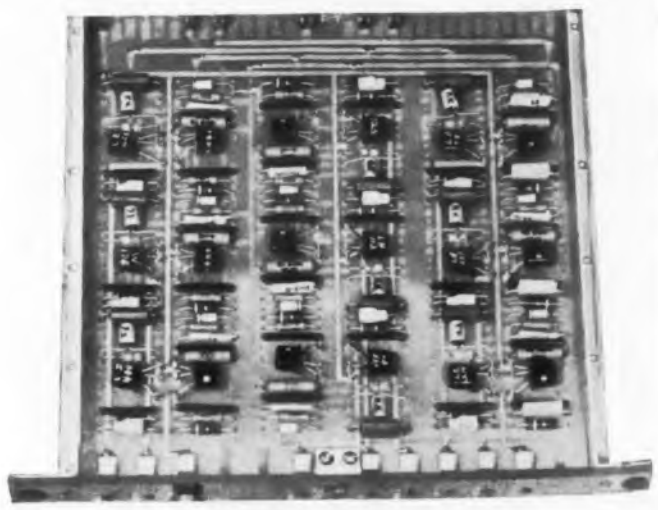


Fig. 11. Typical printed wiring assembly. Volumetric efficiency is only 3.2%.

not only for military equipment in which the urgency of dependability is obvious, but it is also true for non-military systems. This is because in everything from television to telephones the numbers of components being used, and on which satisfactory performance depends, are beginning to reach staggering proportions.

Unfortunately we are getting way beyond the point where we can evaluate component reliability by statistical methods in reasonable lengths of time. As an example of this, the components for the recently installed transatlantic cable must have an effective average annual failure rate of less than one in a million to meet the objectives for system reliability. If for every component made for the system a duplicate had been made for life testing, some 600 samples would need to be on test for 400 years before one could have demonstrated a one-in-a-million failure rate.

In the face of these facts the only possible philosophy was to build the most reliable components that could be made under the most careful control possible, so that whether or not they met the objective, they would be known to be the best that could be made.

Characterization of reliability is important, but even more important is producing reliability, and for this a higher order of control in manufacture is an unavoidable necessity. This includes control of uniformity in materials, control of cleanliness in manufacture, and control of processes by automation. It also implies a high incidence of process testing. The day has long since gone by when endpoint requirements were sufficient to guarantee a component. It will be necessary that future specifications for high quality components concern themselves with requirements covering every stage of manufacture.

Components of the future will not only have to meet more stringent reliability objectives but they will have to meet them under more severe environmental conditions. No crystal ball is needed to predict that military components will be subjected to higher orders of shock and vibration than ever before, or that resistance to radiation and to extremely high temperature, and to other environmental factors, will become prime considerations.

Microminiaturization is certainly coming, but its realization will depend on a new order of discipline in materials preparation and component design. It will require all the help that the basic sciences can give it, and it will call for a philosophy of perfection in every detail of design and manufacture.

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Micro-Miniaturization Requires New Thinking

Dr. Cledo Brunetti, Dr. Otmar Stuetzer, John W. Buffington and L. K. Lee

General Mills, Inc.

THE DEMANDS to make electronic equipment smaller, lighter, more efficient, and more reliable are getting louder, and the effort spent in these directions is greatly increased. We have a long way to go before achieving the ultimate in miniaturization. Yet, as technology opens new approaches, we see means for eventually achieving our desired goals. In guided missiles fired by intercepters, guidance systems employing well over one hundred tubes are condensed into a space less than one-half a cubic foot. The small 200 lb automatic pilots used in aircraft during World War II are now obsolete. New Models weigh much less than half this amount and perform many times the number of functions

Definition

We may define micro-miniaturization as the design of electronic equipment using solid state and other nonthermionic devices to obtain a higher order of magnitude reduction in size and weight than possible heretofore.

Why Micro-Miniaturization?

Why micro-miniaturization? It would appear that we still have to exploit all the advantages and solve all the problems attendant to subminiature size equipment. This is quite true. But we see a serious need for smaller equipment. As the use and complexity of electronic equipment becomes greater, it becomes essential that the size of the equipment be reduced. Otherwise we will be building enormous plants not just to fabricate the equipment, but also to house it. And the increasing plant size would not be a straight-line growth. The graph, Fig. 1, illustrates the increasing complexity of military electronic weapon systems measured by tubes in use. In 1937, a destroyer used 60 tubes; a 1955 destroyer uses well over 5,000 tubes. Similarly, the number of tubes in bomber aircraft has been multiplied by over 150 times since 1937. Mechanically micro-miniaturization is important, too. Switches, dials, relays, motors, gear trains and other mechanical components must also be made smaller if we are to realize to the fullest the possible impact of micro-miniaturization.

The basic need for micro-miniaturization is due primarily to increasing applications of electronic equipment, increasing complexity of electronic equipment and an increasing need for more rugged and reliable equipment.

Ruggedness is, of course, necessarily a by-word of modern equipment. We must investigate the design of equipment to operate under conditions of high shock and vibration. Here micro-miniaturization will have its impact. Let us take the specific example of a supporting member or column. For a given material, axial strength is proportional to area of d^2. For a given acceleration stress is proportional to weight ($F = ma$) or volume d^3. Thus the strength to stress ratio is $\frac{kd^2}{d^3}$ or $\frac{k}{d}$. As the size decreases, the strength to stress ratio becomes larger, and resistance to shock and vibration increases.

Micro-miniaturization is also necessary as another step towards absolute reliability. As we make things smaller and simpler by the elimination or reduction in number of connectors, for example, we remove many sources of unreliability. By the development of new design and of new techniques to produce micro-miniaturized equipment, we may be able to

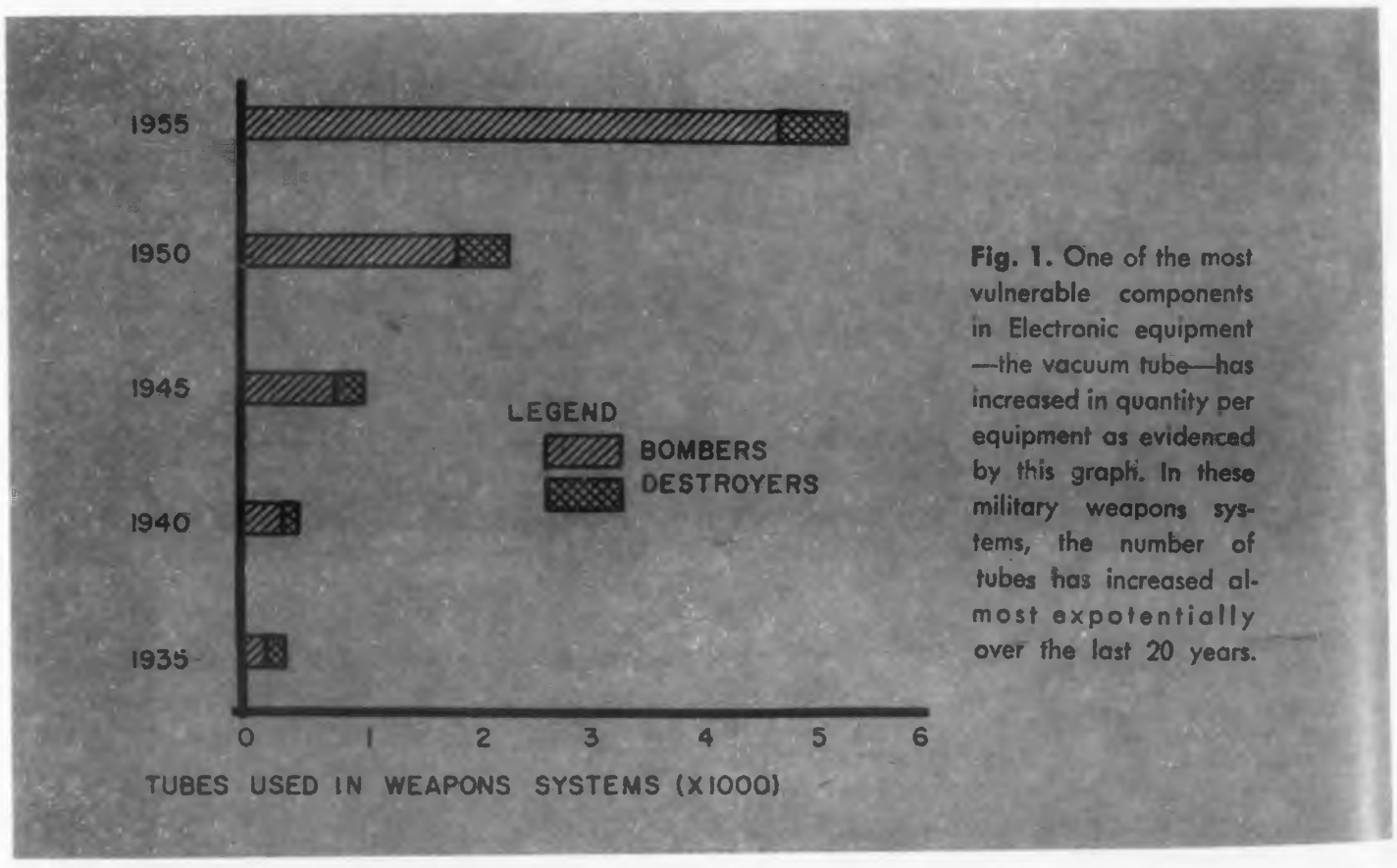


Fig. 1. One of the most vulnerable components in Electronic equipment —the vacuum tube—has increased in quantity per equipment as evidenced by this graph. In these military weapons systems, the number of tubes has increased almost expotentially over the last 20 years.

gain additional reliability which is sorely needed in all electronics equipment.

As in most technical fields, the development and acceptance of micro-miniaturization will no doubt be an evolutionary process. We see the beginnings now in equipments that use solid state devices and tubes, and in many cases still contain conventional passive components. Even in these pioneering stages, a hint is available of the advantages that micro-miniaturization will bring. New components are being developed compatible with the lessened requirements of transistor circuitry. Reliability, simplicity and ruggedness are being improved, and power requirements significantly reduced. The situation calls for focusing our sights way down the road rather than just before us.

Designer Holds The Key

How can we assure that adequate effort is applied to the development of micro-miniaturization? First, we must make our needs known to materials processors such as the chemists and physicists who must explore and pioneer the development of the materials and discover phenomena which may become applicable. At today's stage in this picture, the achievements of micro-miniaturization will be dependent even more on the chemist and physicist than on the electronics engineer.

Next comes the problem of telling or educating the consumer, the military agencies, industry and the public who will eventually use, manufacture and develop the micro-miniaturized equipment, of the advantages to be gained, the work necessary and the financial support required.

One very good method of finding ideas for micro-miniaturization is a brainstorming session on the subject: "How can it be micro-miniaturized?" Part from the conventional, or even reality, and dream up as many ideas as possible. Then judiciously examine these ideas—not during the brainstorming session, but afterwards. We did this at General Mills several months ago and were amazed at the number of promising ideas which were proposed.

Achieving the Advantages

In trying to achieve the advantages that micro-miniaturization promises, there are four steps by which we can make major gains: *1.* We must do a striptease act on our present equipment and components; 2. We must investigate new materials and their application to electronic components; 3. We must develop new fabrication techniques; and *4.* We must discover and then apply new physical phenomena.

Eliminating the Unessentials. To reduce our present equipment to its bare essentials, we must study each component and piece of hardware used and ask if each is really needed or if it is there simply because we've always used it and never taken the time to consider how to do without it. Tailor all equipment designs for specific jobs. Eliminate unnecessary components. Use components in dual capacities or functions whenever possible.

Examine the components themselves. For example, take a resistor. It is a mixture of carbon and binder that restricts the flow of current in a circuit. How is it made? First a phenolic jacket. This has no part in the resistor action, so let's strip that part off. Second, the end tabs are only a means of getting at the resistor and do not control the flow of current, so off they go, and so on.

Today, the active material of a normal electronic component or circuit accounts for only a small portion of the total volume it takes up. The rest is insulating material and empty space. Even in a tiny transistor the ratio of the volume of the element to the volume of the case is extremely small. The volumetric efficiency of a transistor is less than a thousandth of one per cent. Can we create circuits out of only the active materials first and then pot the entire circuit in a single block of insulating material?

Consider New Materials. As an example of the development and application of new materials, one company has announced an information storage unit which can reduce the size of a memory unit capable of storing a million bits of information to approximately half a cubic foot in volume. It is simpler to produce, simpler to operate and to maintain. This device consists of thin printed plates of a special ferromagnetic material which is molded into small perforated squares 0.83 in. in size. Each square is perforated by 256 apertures, each of which stores a bit, a binary digit.

Future electronic equipment will become more intricate and compact as the functional requirements become more complex and more precise. Components may be quite different in size configuration and use of materials. The resistive, capacitive and inductive components as we recognize them today, may be completely changed, any may possibly be even more different than the printed rectangular resistive element is from the conventional resistor. New circuit concepts and analysis techniques will most probably be used to take advantage of the development of new active devices in a network. Shielding and intermodulation problems will be quite different, and less bulky materials and techniques must be developed for their solution. Most important of all is the growing requirement for developing more and completely new transducers. Unless this work is accelerated, these end organs or input and output devices can rapidly become the bottleneck for complete micro-miniaturization of a system. This includes microphones, photocells, relays, transformers and others.

But many of our most significant developments today were considered possible but highly impractical twenty years ago. Through research, principally in the physics and chemistry laboratories, has come the development of materials which make the ideas and applications of twenty-five years ago more than practical today. The best example we have is the Cinderella rags-to-riches experience which semi-conductors have made in their transition from the galena crystal with its cat's whisker of 35 years ago to become the high quality transistors of today.

The transistor is a significant achievement in micro-miniaturization. This device with an average life of almost 800,000 hours is indicative of the performance of solid state devices. Its ruggedness is attested by the fact that transistors have survived exposures to shock of over 1000 g's. Compare this with the thermionic tube in which the average life is about 5,000 hours and lucky to withstand a few hundred g's. And the transistor is basically a simpler and much smaller structure than a thermionic tube.

Now we have the cryotron, a sliver of wire with another wire coiled around it. This cryotron duplicates many of the functions of both transistors and vacuum tubes. It is small enough that fifty will fit into one of the lenses of eyeglasses. It requires a cooling system which might occupy considerable space, but we can still see substantial space savings. It is conceivable by the use of this type component and others to be developed that our computers which now occupy dozens of cubic feet can one day be put into one or two cubic feet of space or, might we hope, into a brief case.

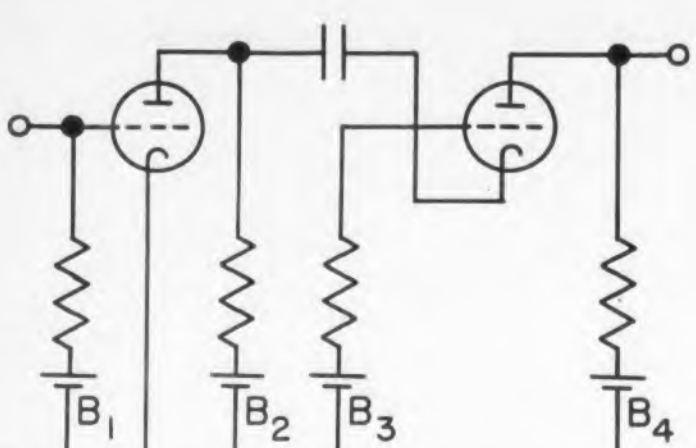
We should not laugh at such seemingly fantastic ideas as this. Remember the three-dimensional printed circuits we were experimenting with ten years ago. Today we are approaching a state of the art and knowledge of materials where these circuits should be possible and highly efficient in the not-too-distant future.

In solid-state physics we are only beginning to become acquainted with the possibilities for micro-miniaturization. We can begin to look forward to what we might call "Solid State Circuits." Solid State Circuits would be three-dimensional combinations of metallic, inter-metallic and insulating materials which transmit and control currents in the same manner as combinations of ordinary electronic components.

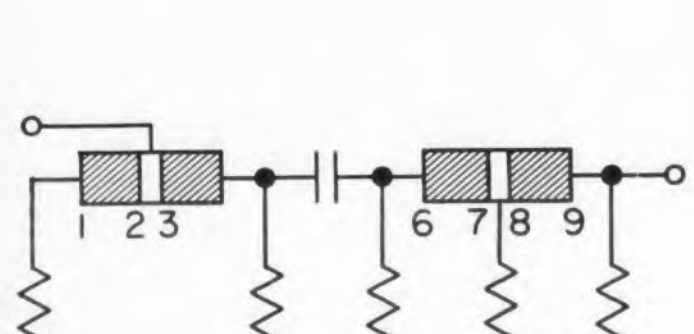
The present need to introduce terminals, connections and connectors between individual electronic components in a circuit adds parts that make no contribution to the electrical performance of the circuit, and in addition introduce a source of unreliability which the military and industry have long sought to overcome.

New Fabrication Techniques

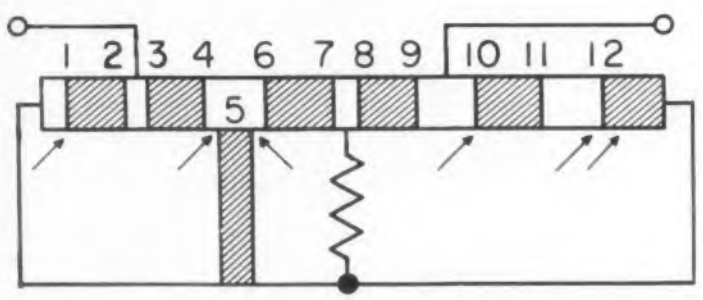
By laying down combinations of materials in three dimensional patterns, it is possible to achieve circuits of at best only fair efficiency today. Through continued research in the improvement of the types of materials used and the techniques for depositing



a. Preamplifier and cathode-coupled amplifier stage.



b. Transistorized circuit. The P-type semiconductor is shown shaded; N-type, unshaded.



c. Proposed solid-state circuit to replace **b.** Shaded area is P-type semiconductor; unshaded area is N-type.

Fig. 2. Evolution of electronic amplifier circuit—from the conventional tube amplifier at a to its transistorized version b and proposed solid-state replacement at c. Functions of the elements in the solid-state circuit are: 1. Illuminated, low penetration, low impedance, replacing R_1 and B_1; 2. emitter; 3. collector; 4. ohmic; 5. illuminated, deep penetration, high impedance, replacing R_2 and B_2; 6. illuminated, low penetration, low impedance, replacing R_3 and B_3; 7. emitter; 8. collector; 9. ohmic; 10 and 12. illuminated, deep penetration, high impedance, replacing R_4 and B_4; 11. ohmic.

New Thinking

Micro-Miniaturization

them, we should be able to effect at least an order of magnitude size reduction and a corresponding increase in reliability.

It must be borne in mind, however, that no matter how ideal an equipment is in design, it must be producible under practical production conditions. As the devices become smaller, human engineering problems will become pressing. Human hands will become too cumbersome for fabrication tasks, and automatic techniques will have to be developed. Micro-miniature equipment will be produced by completely automatic manufacturing methods. The key to micro-miniature design is perhaps the production technique.

Printed electronic circuits in the form of couplates or Bulplates or Erie Packs suggest what we can do at present using capacitors, resistors, and conductors. But what about all the other component types used in electronics today? If we are to achieve solid state circuits, we must develop substitutes for inductors, transducers and many others.

A solid state circuit containing active devices might look like that shown in "c" of Fig. 2. This is the solid state equivalent of the conventional combination of a preamplifier and cathode coupled amplifier stage shown in "a," first converted to the transistor circuitry as shown in "b." The solid state circuit consists entirely of P N junctions, such as can be rather easily produced by rate of growing techniques. Junctions 1, 5, 6, 10 and 12 are used as power supply batteries by shining a suitable amount of light on them. By using this system of power supply, the number of connections is minimized and blocking condensers are eliminated, and minimum dimensions are prescribed by the diffusion lengths of the carriers in the respective junctions.

The absence of standard types of connectors and terminals is an obvious advantage of this type of construction. There are many methods by which conducting and insulating materials can be selectively removed or added through such processes as electro-deposition, spraying, evaporation, elective etching and many other techniques or produce Solid State Circuits of size limited principally by the types of electrodes or depositing tools employed in laying down or removing the material.

Carrying one's imagination a step further, we can visualize combinations of germanium, silicon, ferroelectric, ferromagnetic and other types of organic and inorganic materials deposited automatically in volumes of a thousandth the space now occupied by electronics produced by ordinary methods.

To achieve satisfactory circuits by these means, we will have to engage in a great deal of research and development work delving into the physics and chemistry of conducting, semi-conducting, insulating, dielectric, magnetic, ferroelectric and many other types of materials. Studies will have to be conducted to either eliminate or compensate for properties of such layer built materials which can limit their performance. This includes variation in capacity with frequency and temperature, aging of the materials, high power losses and other undesirable characteristics.

Ferromagnetic ferrites for example have made it possible to reduce microwave components very materially in size. In order to extend these benefits to the lower frequencies, considerable studies will have to be made in the regions below X Band in order to improve the efficiency of phase shifters, amplitude modulators, isolators, duplexers, and switches. The ability of ferromagnetic materials to act as switches by rotating the plane of polarization of microwaves transmitted through them should be harnessed for other uses simulating the performance of resistors, capacitors, attenuators, and so forth.

New Physical Phenomena

While we can look for substantial reduction in size and weight of present types of electronic components through the use of better and more efficient materials and improved packaging techniques, our real breakthrough in micro-miniaturization will probably come from some totally new approach and the continued exploitation of the newer concepts of electronic materials.

Let us rethink our circuits through in terms of what each component or group of components is supposed to do to the current or voltage. See if we can't find a simpler way. Can we go from the input to the desired output directly? R, L, and C are mathematical concepts and may disappear as we go to the ultimate. We can treat a circuit as a short transmission line with distributed constants. Can we also use interrelated force fields (electro-static, magnetic, and others) to control the flow of current?

Walter Hausz has another interesting idea. "Fundamental to the many ways of making electronic equipment smaller is the realization that many of the things we want to do are at the information handling rather than the power handling level.

Power levels of components can be in micro-micro watts before they approach inherent noise levels that jeopardize their operation." Indeed, some sensory devices, such as the eye, already approach the ultimate and require very few quanta of input to produce a detectable signal output.

Expanding applications in all phases of industry are requiring more electronic instrumentation for greater speed, precision, control; to supply more information or to perform more difficult functions. Take, for example, the electronic computer. Although it can perform many types of operations at great speeds, the intelligence or judgment of a computer is equal to only about one-hundredth that of a moron. Rooms full of equipment are required to perform the limited computer operations. Thousands of tubes may be used, each acting as an excellent heat source. Just to cool the large computer systems requires several kilowatts of power for blowers. Although it is possible to store a wealth of information in an electronic computer, there is no simple and quick way of getting to this information. The access problem is one major bottleneck.

When we compare electronic computers with the human brain, we see how much work is needed just to catch up with Mother Nature. Some of her designs are not vastly different from our own, but the difference in size is astounding. Compare the micro-miniaturized human eye and nerve system to its electronic counterpart. Nature has contained in just several cubic inches the optical transducer and generating, modulating and control system to convert a visual picture into a parallel series of constant amplitude modulated signals to the brain. The details of this are not essential, but such a system, using sub-miniature techniques, would require something of the order of 120 cu. ft of space, and would be approximately 60,000 times larger than the human optical system.

Would we not be wise to look more closely at the performance of organic materials in our efforts to micro-miniaturize? First, we would bring together the electron scientists and the organic or physiological scientists in an effort to bring them on common ground with common objectives. Then perhaps an effort should be made to create workable organic components and systems as well as to understand those produced in nature. Both organic components and systems should be analyzed. Nature has a marvelous system of connectors. Perhaps these should be studied even more than the organic components.

In the human brain, not only can a wealth of information be stored in a very small space, but we have access to much of this information at a moment's notice. The random access problem has been solved and all the storage mechanisms needed are contained in a volume of several cubic inches, and during our most concentrated thinking, we are dissipating less than a tenth of a watt of power. Compare this to a room full of gadgets generating enough heat to require a 50 ton air-conditioning system just to keep the components cool enough so that they will work. What we need to develop is a system of low calorie circuits—circuits composed of components with low power dissipating. Thus we could minimize their acting as a source of internal heat. Unless we do materially reduce our power requirements, we will discover that as we build our circuits smaller and smaller the heat generated per unit volume will increase, and more heat per volume will have to be dissipated. Should we not examine the basic functions of components and try to eliminate all effects which are there in piggy-back style? For example, the heat generated in a resistor is an undesirable hitch-hiker. Could we use the idea described earlier of a P-N junction of a transistor to afford a voltage drop?

Great gains can also be accomplished if we can find better ways of transferring heat away from components. Again, the resistor. Instead of protecting a resistor by embedding it in plastic material, could we surround it first by a thin coat of insulating material such as beryllium oxide, and then a peltier junction? Recalling the peltier effect, what other new ideas can we come up with in solid state thermal converters to dissipate heat by converting it into another form of energy?

Our goal is to be able to build electronic equipment of a size belonging more to the insect world than to our own, and of 100 per cent reliability under all conditions of pressure, temperature, shock and vibration.

Mother Nature did a marvelously expert job of creating the human brain. Its capacity is astounding, and its size a true achievement of micro-miniaturization. But the human brain exists in delicate balance with its environment, and it is temperamental. Temperature and atmospheric changes can snuff out its life, and its efficiency is greatly affected by the lack of rest and food. Through electronic micro-miniaturization we hope to be able to build a brain —a computer—which will be able to do much the same as the human brain but which will be impervious to damage from temperature, shock, vibration or any other antagonistic condition and which will still achieve the optimum in space efficiency. Reliability must not be compromised. The achievement of this goal is a long and difficult task. We have taken some first steps, but many new and novel concepts will have to be created.

Micro-miniaturization–A

WE THINK of the term miniaturization as somewhat of a paradox—and we feel that if you don't see the paradox you really miss the most important point of miniaturization.

Of course, miniaturization, as it is commonly used, does mean smaller hearing aids, less bulky electronic computers, lighter aircraft. But these reductions in size and weight really are valid only to the extent that they provide more function, more service, more convenience to the user.

For this reason we equate miniaturization with more from less. It's a workable concept that broadens the definition and hence the field for miniaturization.

For now we can truly miniaturize a product without necessarily reducing its size or weight. We can keep the same size—and pack 50 per cent more power, twice the versatility, three times the usefulness into the same space and weight. Or, for that matter, we can build products that are twice as big, yet give four times the output of their predecessors. All are examples of miniaturization . . . or more and more from less and less.

Miniaturization has many guises other than mere reduction in size. It might better be defined as a planned increase in service or function per unit volume or per unit weight of product.

Geometry of Miniaturization

Let's consider the "Vanishing Cube" as a clue to a basic approach to miniaturization.

It's really a simple matter of solid geometry. The volume of a cube equals, and hence varies as the product of, its three dimensions. This simple geometrical gambit is probably known, if not always appreciated by all. Trouble is that most of us think in terms of addition and subtraction, while most physical phenomena increase or decrease at the more rapid rate of multiplication or division.

Cut a line or a length of pipe in three equal parts as in the diagram—and each segment is one-third the original size. Now divide a square or a sheet of metal into a tic-tac-toe pattern—three squares to a side—and each small square will contain one-ninth the area of the whole.

But slice a cube or a block of metal—each of whose sides has been divided in three—and you find that the resulting tiny cube contains exactly one-twenty-seventh of the weight and volume of the large cube.

In general this principle of the Vanishing Cube applies to solids of all shapes. It applies to the weight as well as to the size of these solids.

Thanks to the Vanishing Cube, seemingly minor reductions in all the dimensions of a product can produce dramatic savings in weight and volume. A cut in dimensions of only 10 per cent reduces volume by 27 per cent; a dimensional reduction of just 25 per cent can shrink weight and size by 58 per cent. You can work out other reductions as we did by using the chart at right.

There's a challenge here for the metallurgist and the product designer to make less and less of material do more and more—and thus capitalize on the potential savings of 27 to 1, or even more.

Miniaturization is Contagious

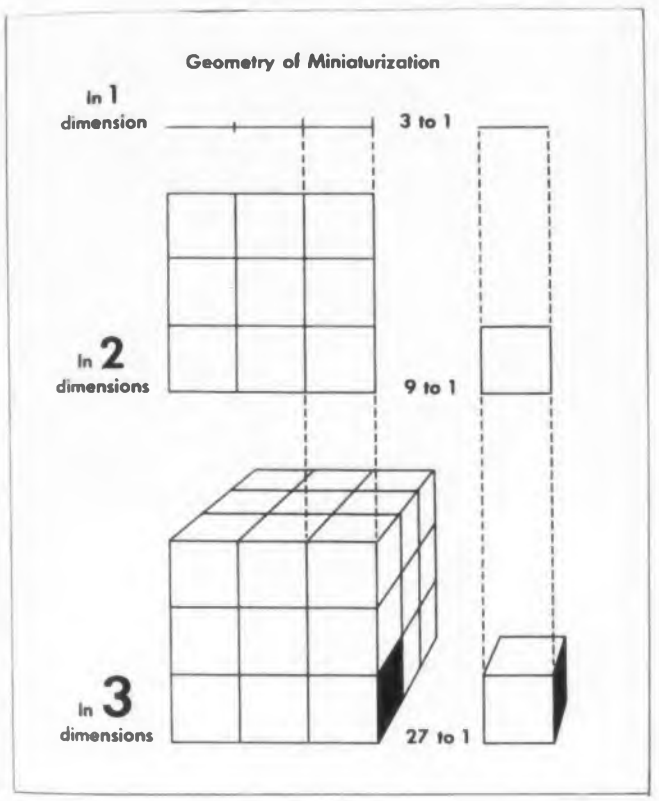
A product is only as small or as light as the sum of all its parts—and all the parts don't shrink in size or weight overnight. In practice, first one, then another of the component parts is miniaturized before the smaller end-product, once only a gleam in a designer's eye, becomes a reality.

As a result, there's steady pressure on most suppliers to keep in step. For when his best customer has reduced all other components in a product by a 27 to 1 ratio, pity the poor supplier who can't provide a part similarly scaled down.

The advent of a transistor, 100 times smaller than a vacuum tube, does not signal the immediate reduction of all electronic gear from 100 to 1. First there is need for the shrinking of a hundred and one auxiliary components to connect, contain, complement and power the tiny wonder elements. Only then can the full fruits of miniaturization be achieved.

This article expresses the views of Standard Pressed Steel Co. of Jenkintown, Pa., on "making it smaller." The thought is expressed that by miniaturization techniques, more functions and more reliability can be provided in a given-sized package.

A Paradox?



The pressure of miniaturization daily brings forth such products as mighty midget motors that can fit in a hand's palm; tiny ball bearings for shafts as thin as 0.025 in.; delicate, high speed blowers little more than an inch in diameter; lighter, more powerful fasteners, etc.

The contagion affects the makers of raw materials—those who produce the basic substances that will do more with less. New synthetics have and will be developed. New metals, like titanium, are being hurried into manhood. Old standbys, like steel and aluminum, are being more cleverly wrought and fabricated. Both are part of the continuing effort to produce stronger, lighter fasteners and other structural products.

There's no fixed goal, no smallest possible weight or size. It is a steady, continuing effort that calls upon the ingenuity of the materials engineer, the

A Paradox?

Micro-

metallurgist, the product designer and many others, to build ever more service into less and less space and weight.

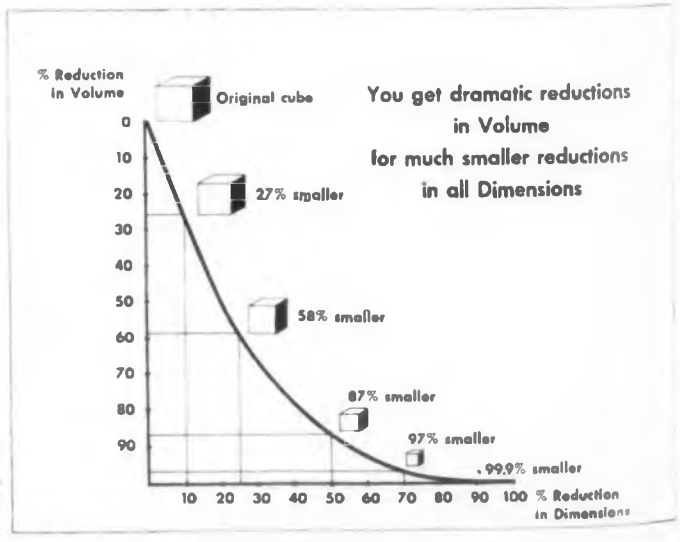
Designing for Miniaturization

Miniaturization need not wait on the discovery of wonder components, on the development of superstrength alloys. There is so much room for size and weight reduction in most products today that miniaturization really is more a designer's frame of mind than it is a manipulation of new devices and wonder metals.

Many major product reductions can be made through a study of basic function, a review and redesign of allowable stresses and necessary clearances and the use of available parts and components that already have been miniaturized.

There are many such miniaturized components available to help the designer. Some are just begging for ingenious application. One manufacturer reports that he can draw precision tubing as fine as 0.0014 in. in diam. It's so fine that no one has found use for it yet . . . but chances are it will be put to work soon.

In the realm of precision fasteners, too, there are many components that either in basic design or inherent strength are man-made tools for miniaturization. Knowledge of loads and of the ability of



Miniaturization

structural parts to sustain these loads will play an increasing role in future miniaturization.

Current lack of knowledge of this kind forces designers to rely on excessively high factors of safety to insure product durability. As a result, many structures are built too large and too heavy—much larger than an intimate knowledge of loads and materials would warrant.

Materials for Miniaturization

The basic materials, old and new, are playing a critical role in the miniaturization of a wide range of products.

New synthetics, with unusually high electric and thermal insulating properties, make it possible to pack more electric motor, more transformer and more electronic equipment into smaller spaces. Weight is being saved without loss of function by the use of nylon as a gear material, by the substitution of lightweight plastics for steel and aluminum in noncritical applications.

The metals, however, are still our most important structural materials. The future course of miniaturization depends heavily on the development of stronger, lighter metals—and on the fabrication of ever stronger parts from existing alloys.

Steel, titanium and aluminum offer the most promise for continued space and weight reduction. For this role, they are being assessed against several criterions.

One criterion is the inherent strength of the metal. The stronger it is, the less of it you have to use.

A more subtle standard—yet one of even greater significance to the aviation industry—is the strength-to-weight ratio of a metal. This is a measure of the load carrying ability per pound of metal. Though aluminum is nowhere near as strong as steel, it weighs only about one-third as much. In many applications, its strength-to-weight ratio, therefore, is greater than that of steel—and as a result you can use less aluminum than steel to do the job.

The main advantage of miniaturization lies not always in a smaller, lighter end product, but often in the ability to put more product, more service into a given space.

Micro-

FOR YEARS the watch industry has dealt with things miniature, a factor which has set a pattern for making, gaging, inspecting and handling micro-miniature, sometimes microscopically small parts and assemblies with considerable skill. Basically then, we are on firm ground from the point of heritage alone when speaking about miniaturization, especially as concerns its application to day-to-day mass production.

An example of the type of problem the average manufacturer can have with miniaturization was brought to our attention not more than a month after we entered the commercial miniaturization field at Elgin just a year ago.

We were called upon by an established manufacturer of special control devices for help in producing a miniaturized version of a sensor. It is important to note that they had already designed a smaller version of the device, but realized they had no machinery or know-how to produce it. One of their chief problems was dimension tolerance. They had no idea what strength or stresses each pinion, pivot fly-ball arrangement or plate should have, nor what materials to use to achieve these factors. Elgin was permitted to re-design any part or major assembly in the device. We successfully delivered prototype models, which are currently under test for use in jet aircraft.

Watchmaker's Technique

First of all, our design engineers worked with the customer to obtain necessary data to permit intelligent redesign of the unit. It had already been established that manufacture would be directed by the size of Elgin's machines which were capable of producing a micro-miniature version of the sensor. We actually reduced the volume by a ratio of 300 to 1. We applied what is called the parts density theory to the job. It works this way:

Miniature Techniques

W. W. Hamilton
Elgin National Watch Company
Micronics Division

One of the smallest precision mechanisms made at our plant is the movement for a ladies' wrist watch which consists of nearly 125 parts in an area the size of three dimes stacked together. On a cubic inch basis this works out to about 104 parts per 3/4 cu in. of space and determines a size base to which our machines and personnel are normally geared, and which would not necessitate new overall tooling. We determine the number of parts needed in the sensor and projected the reduction of these parts in size on a per cubic inch basis to learn whether or not the redesigned item would be in the particular size range for this project.

This method also permits a close look at the device when it is broken down into its component parts and often permits simplification of several sections of the device as well as the employment of different principles than in its larger counterpart.

Elgin engineers designed the fly-ball arrangement in the sensor by using a new spring made of watch alloys; and it was this fly-ball that was the size determinant for our miniaturization project.

Problem is Basically Mechanical

The hue and cry from the electronic industries today is not, "can we make it?" It's "how do we make it?"

Recently a design engineer for a leading aircraft company, whose job is procurement of electronic components for planes, described electronic miniaturization as a mechanical problem. As this aircraft design engineer said, the problem is one of mechanical abilities . . . the ability to design and build special machines, tools, gages, jigs and fixtures, that will produce the almost microscopically small parts that are needed for lightweight, tiny electronic components. The problem is increased by the lack of personnel equipped to handle these small parts, much less make the necessary machines.

Micro-Miniaturization

This is one of the chief areas where the watch industry can help because it has long experience in skills that are not learned in a hurry.

Special Skills Needed

The men who make our tool and dies have at least 10 years experience. Those assigned to build a shaped punch with a diameter of 0.004 in. (something they cannot see with the naked eye) usually have more than 14 years experience.

Many dies in the watch industry are of the compound, sub-press category (invented at Elgin) and are capable of stamping precision-located pivot holes in a plate not bigger than a grain of wheat. A miniature relay plate, armature assembly, or potentiometer plate requires the same machining know-how. This work is accomplished on special machines, many of them made at Elgin, and which are inherent to the watch industry. It is only recently that they have been turned loose on commercial devices foreign to the horological field.

Today's requirements in the electronic industries make it necessary for electronic designers to familiarize themselves with the capabilities of these type machines to enable them to design within their size ranges.

A Typical Design

One Elgin product is the Neomite relay, a tiny switching unit no bigger than a pencil eraser, which has an interesting history. It is important to note that it was actually designed by an electronic engineer outside the watch industry. His design was good, based on the best relay theory then known: but the item proved to small for his firm's machinery or personnel to produce. His first prototype models were assembled by, and from parts made by a local watchmaker working at his repair bench.

Elgin Watch purchased this firm nearly two years ago and was fascinated by the Neomite which then had been placed on the shelf as unproducible. It was turned over to watch engineers who began a year's study to work out, according to watch techniques, methods that would allow it to be produced by mass production techniques.

More than 10 basic designs were laid out including a new type of armature assembly and the use of tiny threaded screws for precision adjustments of the contacts in the relay. These screws are so small it takes more than 8,000 of them to fill a thimble. Because they were made of silver it was decided to use the screw itself as the contact in one application.

The armature was designed to function similarly to the pallet or balance control arm in a wristwatch, which permitted accurate and continuous operation without having the armature jumping out of action.

A tiny coil for the relay was made on a special coil winding machine designed and built at Elgin nearly five years before, during development work on an electronic wrist watch. The Neomite coil is no bigger than the head of a paper match.

Mass production of the relay was accomplished by a team of operators with an average of 5-1/2 years of experience working with tiny watch parts and assemblies, and capable of using vacuum screwdrivers, watch tapping machines and other special tools.

Machining tricks that made mass production possible included knowledge of special alloys used for contact springs, precision die-stamping for the coil frame, and watch gaging methods to govern quality control on parts so tiny that each must be assembled into the final unit with the aid of magnifying lenses.

Frame-of-Mind Important

Part of the miniaturization approach must be considered as a frame of mind—actually the ability to think small—both from the standpoint of the design engineer, the tool maker, and the production engineer. It is this frame of mind that has become a part of the watch craftsman's true mirco-miniaturization skill—his ability to approach a miniaturization problem with confidence because he considers it to be in "his neighborhood".

Design Flexibility Required

When entering the field of micro-miniaturization design engineers should have a free rein to toy with new designs of old established devices. They must enter the "dream world" of smallness. Successful miniaturization usually entails some untried method or principle, and always requires redesign.

New emphasis must be put on tool and die facilities and personnel. You can expect to make more in-plant machines since there are few outside the field who will even attempt to make what you need. The use of new materials will necessitate broader knowledge, longer learning time, and new equipment expense, especially as concerns plastics, metals, ceramics, and resins.

Smaller parts mean finer gaging, increased inspection and quality control, as well as the use of special optical projection equipment scaled up as high as 100 to 1 just to see what you are doing.

Miniaturization demands on-your-toes research and development to keep pace with what's available to help you, often in fields far removed from that in which one is familiar.

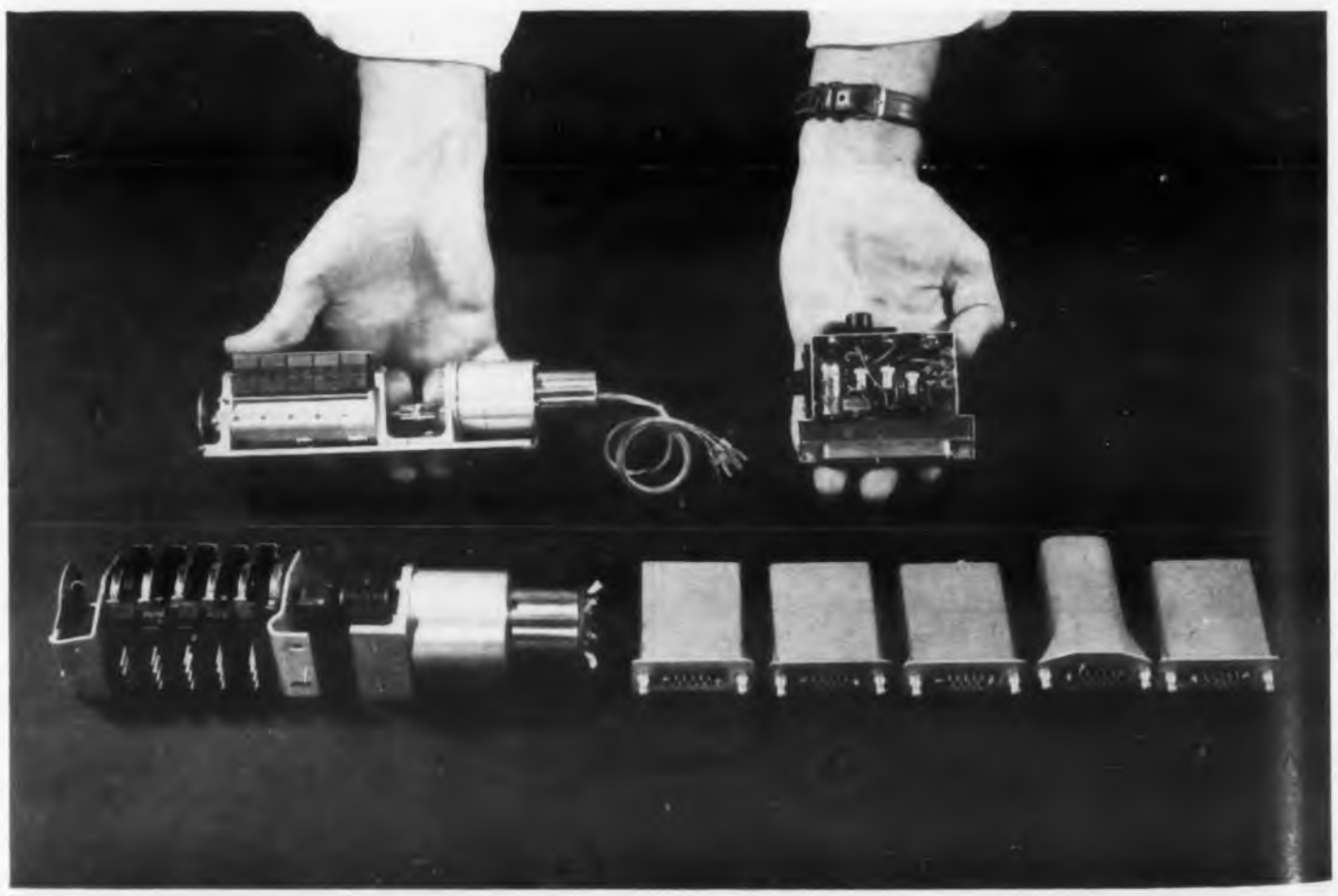
And finally, it demands that new frame of mind —that ability to think small. You will know you have achieved it when the impossible of today becomes the commonplace of tomorrow.

THINGS ARE GETTING SMALLER . . .

Watch battery with year long life. Developed by National Carbon Co. for Hamilton Watch Co.'s electric wrist watch, this is believed to be the smallest mass-produced battery of its type. Made exclusively of non-magnetic materials, it occupies only 0.31 cu mc, has a nominal rating of 1.5 v, and provides 60 ma-hr until 1.3 v cutoff.

Eveready low current battery, 95 v per in, no leakage, almost unlimited shelf life.

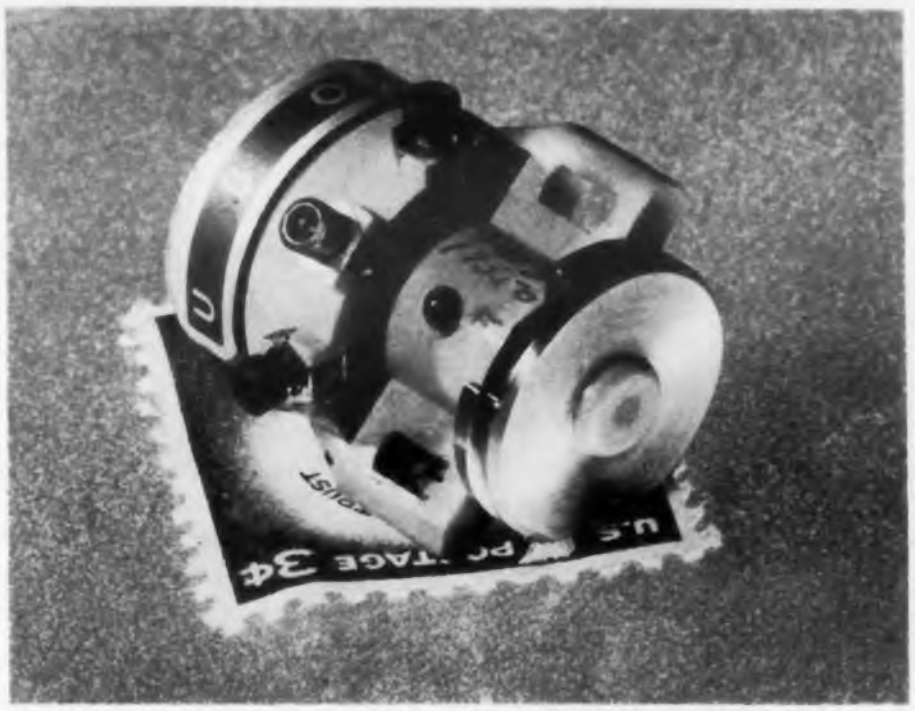
Centralab's "ultra-kap" and a conventional disc capacitor of the same rating.



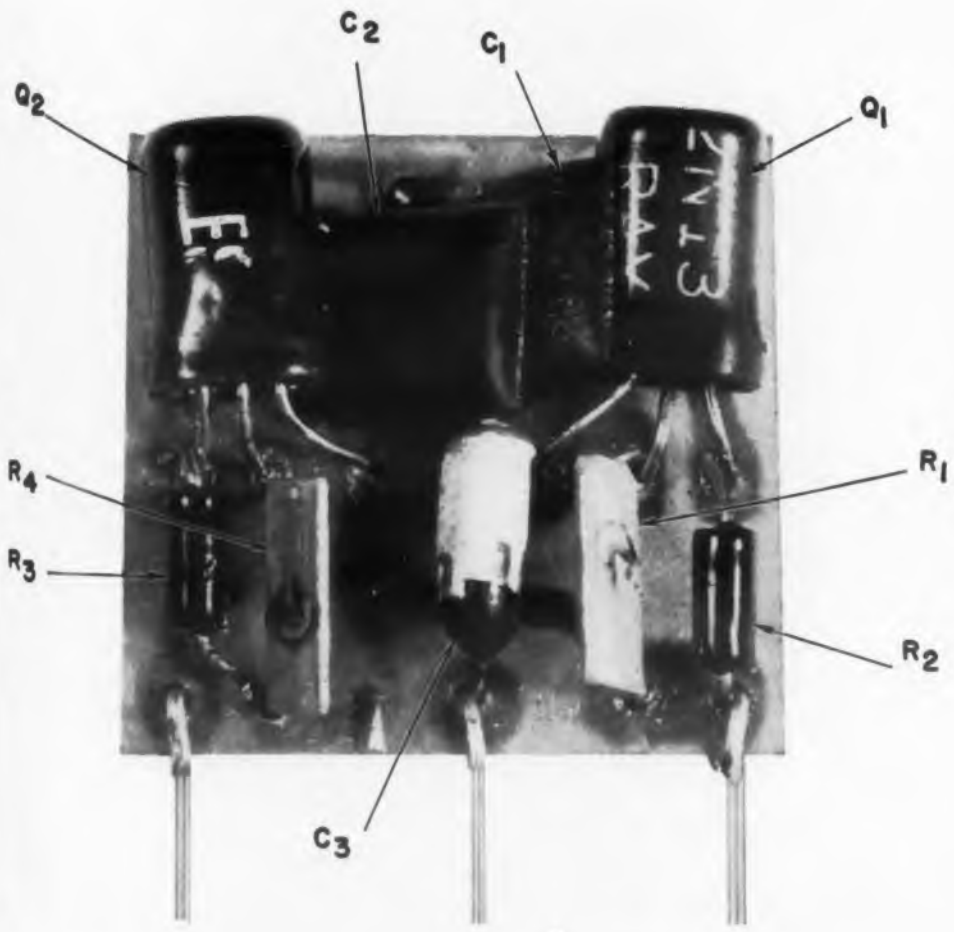
Miniaturization program at Westinghouse Air Arm Division in Baltimore has resulted in one transistorized servo amplifier (being held at right) replacing the five molded units using vacuum tubes (below). Total weight was reduced about 10 fold and power consumption 40 fold.

Aerovox's new "Cera-fil" ceramic capacitors. Shown here are 1000 μμf, 100 v dc units, claimed to be smallest ever made.

Thumb-sized potentiometer (below) for Falcon missile. It is less than 1/2 in. in diam. Developed by Fairchild Camera and Instrument Corp., the control is employed as sensors and attitude instruments in missile guidance systems.



Mechanical differential (above), developed by the Pitometer Log Corp., is believed to be the smallest in existance. Overall diam. is 1/8 in. Weight is approximately 10 grams including typical end gears. Breakaway torque: 0.01 oz-in. (08. gm-cm). Unit employs sub-miniature ball bearings.



Size, weight, and power requirements were reduced when the magnetic amplifier auto pilot (above) replaced an electronic vacuum tube system in the USAF TM-61 Martin Matador. The new unit also increases the reliability. (Courtesy, The Martin Co.)

This 400 cycle multivibrator is one of a line of miniaturized circuit assemblies which will fit in less than one fifth of a cubic. M F Electronics Co., N. Y. features stability and reliability over a temperature range from —25 to +50 C. The circuits are encapsulated in epoxy resin in a drawn nickel-silver can. In the photo, **Q1** and **Q2** are Raytheon PNP transistors; **R1, R4, C1,** and **C2** are Glenco products, R2 and R3 are Allen-Bradley resistors and C3 is made by Ohmite.

Micro-Miniaturization in Missiles

John R. Moore
General Manager,
Autonetics Division,
North American Aviation, Inc.

THE GUIDED MISSILE industry has been principally responsible for the trend toward miniaturization, then sub-miniaturization, and now to micro-miniaturization. Because a missile requires robot pilots, navigators, and bombardiers, more electronic and electromechanical equipment must be employed in the guidance and control systems than would be needed with a human crew at the controls. This equipment, together with the missile's destructive payload and required operating characteristics, now normally constitutes the basis for airframe design and power plant selection. As a result, the guided missile has reversed a former trend of airframe design which saw the power plant as the starting point followed by the requirements of the aerodynamicist, with electronic and control equipment often added almost as an afterthought and certainly without optimum system integration.

Micro-miniaturization, properly integrated into the missile system, increases the weapon effectiveness of all types of missiles. This increased effectiveness takes a number of forms and springs not only from the reduction in size and weight, but also from increased reliability, flexibility, maintainability and transportability.

Improved Missile Reliability

Micro-miniaturization guidance and control equipment makes it possible to combine relatively large numbers of circuit elements on single etched or printed cards. Experience indicates that today's printed circuits with their modern soldering methods are considerably more reliable than connectors. The micro-miniaturization which makes feasible large printed circuits also eliminates the use of many pin connectors and, consequently, increases the reliability of electronic equipment. This reverses a trend which is now prevalent in some applications and which was almost universally accepted in the aircraft industry two years ago that the best designs from the standpoint of reliability and field maintenance should employ multiple plug-in amplifiers. In addition, micro-miniaturization minimizes the need for wiring harnesses, intermodular cabling, and junction boxes, any one of which can be the weak link in a missile's overall reliability.

Also, because micro-miniaturization permits the design of equipment with minimum power requirements it is possible to maximize the reliability of prime movers, special power supplies, and cooling equipment, either by the use of unusually rugged construction or redundancy.

What To Micro-miniaturize

A missile's guidance and control system normally uses electronics as a means of getting from a measured input to a desired output. These may be the positions and velocities of a target as detected by tracking equipment, angular velocities and accelerations of the missile's airframe, and components of its velocity over the ground. Primarily, outputs may take the form of control signals to the missile's propulsion system or to its aerodynamic surfaces and signals to the missile's warhead. It is important to micro-miniaturization such input equipment as trackers, gyros, accelerometers, and air data detectors, as well as electric, hydraulic or pneumatic actuators and their position, velocity, acceleration and pressure transducers. Whereas the printed circuit and the semi-conductor have made the most dramatic breakthrough in micro-miniaturization, less spectacular but equally important work

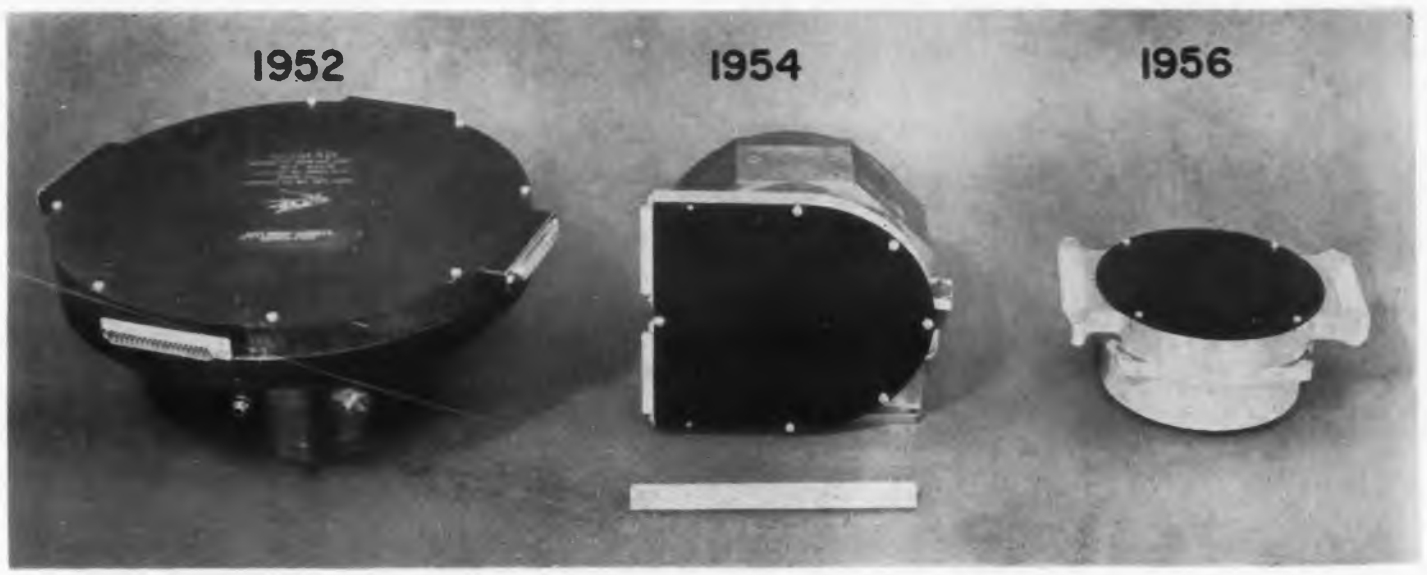


Fig. 1. Twenty thousand bits of storage information for an Autonetics' autonavigator digital computer are provided by each of these autolubricated, air-bearing magnetic-disc memory units. This graphically illustrates reduction in size and weight without loss of capacity.

as been going on in improving detectors and ransducers. In Fig. 1 is an example of the evaluation of magnetic memory units which have been tting progressively smaller.

Integrated Design Important

Major size, weight, and power reductions should be achieved by an integrated system design. Very definite progress is being made in this direction in both aircraft and guided missiles but the principal credit for starting this trend probably belongs to the missile. Consider, for example, a systems engineering approach to an air-to-air guided rocket. The autopilot and guidance equipment for such a missile requires the establishment of angles and angular rates relative to inertial space. There would be a normal tendency for the guidance equipment engineers to supply their angular reference and angular rate gyros, whereas the automatic pilot engineers would prescribe a separate set of equipment for the missile flight control system. Savings in size, weight, and cost both in the missile and in its auxiliary equipment can be achieved if a suitably designed three-axis angular reference system is provided for use throughout the missile. It must be emphasized, however, that unconsidered attempts to force the guidance and autopilot engineers into the use of the same equipment may actually lead to more difficulty than improvement. This is particularly true if the common angular reference is a source of unreliability and if it requires more auxiliary computing equipment to use its output throughout the missile than the additional gyro equipment it replaces.

Another example of the advantages of the integrated system design is found in the concept of the central computer. Such a computer combines all of the computing functions aboard the missile into a single center. Normally, these computing functions are handled separately in the autopilot, the guidance equipment, the programming elements, and the communication system. Only with the development of practical, high-performance, micro-miniaturized digital computers can such a computing center be considered feasible. However, such computers must be properly designed to withstand the environmental vibration, acceleration, temperature, and pressure characteristics of a missile. Futhermore, their reliability must be substantially greater than that of their analog counterparts. When these conditions are met such micro-miniaturized missile computing centers can result in minimized size, weight, and power along with decreasing cost and increasing flexibility.

Dangers in Electronic Micro-miniaturization

In micro-miniaturization as in every other new science, care must be exercised to avoid going overboard and generating a fiasco. An example, where present manufacturing and service facilities make micro-miniaturization impractical, is shown in Fig. 2. There are many instances on record where whole programs were based upon elements which worked satisfactorily when built in model shop quantities and tested in the laboratory, but which were complete failures in the field. The transistor itself has a history of production difficulties when used in guided missile environments which had not been predicted on the basis of engineering models or small sample pilot runs. Thus, the first requirement of micro-miniaturization is a realistic appraisal of the micro-miniaturized components in production quantities under field conditions. Other difficulties arise in a failure to take actual operating conditions into account in the initial design.

Other problems have been encountered because electronic engineers in designing their circuits neglected the effects of humidity on parallel impedances or the effects of electromagnetic pickup. There are undoubtedly many instances where it was felt that a very high impedance circuit could be used in a humid environment because the circuit was potted and its container was hermetically sealed. One example was that of a major change in system philosophy that had to be effected in a missile guidance system because signals detecting initial settings of flight path parameters obtained from the launch point countdown equipment had to go through an umbilical connector. In this particular case, despite the fact that the guidance equipment was hermetically sealed and the high impedance circuits potted, it was found that under humid conditions leakage resistance between two pins in the umbilical connector would render the missile performance totally unacceptable.

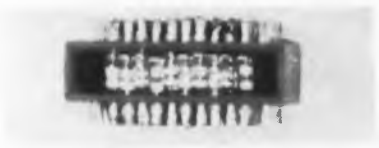
In micro-miniaturization, the engineer must be careful to properly include all of the auxiliary mechanical factors which often are more important for a successful operation of electronic equipment than the electronic design. Such mechanical factors vary from proper mounting of components to withstand vibration, through shock mounting and temperature controls of complete packages, to the effects of switching from prelaunch power supplies to missile power supplies.

Other factors which are basic to a successful micro-miniaturized design are the proper location of cold spots so that condensate does not wet electrical components and connections; the location of batteries containing acid so that the effects of an acid leak are minimized, or the placement of circuits of secondary importance (such as temperature controls) so that a short in such a circuit will not damage adjacent primary equipment. Of equal importance is to design the equipment so that test points are accessible and to package it in modules which can be removed for maintenance. Other dangers which may be encountered in the attempt to reduce size and weight are in designs which are so cramped or require so much skill in assembly that they are totally incapable of being produced in quantity.

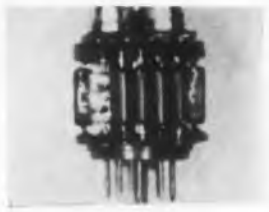
Common areas of difficulty in estimating actual weight of newly conceived guidance and control equipment include such items which appear inconsequential in schematic diagrams—cables, junction boxes, shock mounts, brackets, hear exchangers, cooling systems, switching equipment, and primary power supplies.

Material presented in the above article was selected from Mr. Moore's remarks at the IRE National Convention, Mar. 19, 1957.

Overminiaturization?



Diode Matrix



Flip Flop Plug-In

Flip Flop

Fig. 2. Indicative of possible overminiaturization, these laboratory-built units are nevertheless workable, usable devices. Each has a drastic drawback, including excessive assembly skill, difficult package utilization, and poor thermal characteristics. The diode matrix has 100 diodes together with logical interconnections in 1-1/4 x 1-1/4 x 3/4 in. The flip-flop plug-in is a complete tour-transistor unit in less than one cu in. with proven, high quality components. The flip-flop is also a complete four-transistor unit less than 0.8 cu in. in size, but minimum-size components have been used together with completely etched circuitry.

Watchmaking Techniques— Key To Micro-Miniaturization

W. A. Sterling, Operations Manager
Hamilton Watch Company
Allied Products Div.

MINIATURE is a term about which considerable confusion exists. It is often applied to a part or assembly which is just small. Even though small, it is not miniature if standard-size components are used and space utilization is not better than average. Actually, items of relatively large size can be genuine miniatures.

The concepts of miniaturization—the reduction to scale of size, weight, and cubic volume, while performance is held at the same or a higher level—is one with which the watch manufacturer has long lived. Within a generation, the size of watches made on a mass-production basis has been reduced with a scale factor of about fifty. The key term here, of course, is "mass-production." The miniaturized part or assembly must, if it is to be of use to industry, be susceptible of fast, highly accurate reproduction by the hundreds of thousands.

Generally speaking, miniaturizations are of three types. There is miniaturization to a set, limited degree, which is governed by functional factors. There is pure miniaturization or micro-miniaturization in which assembly is reduced to the smallest possible size and bulk consonant with practical operation. Finally, there is the partial micro-miniaturization, in which some dimensions of an assembly are reduced without necessarily making the whole unit smaller.

Three examples, one of each type, which have actually been produced by the Hamilton Watch Company's Allied Products Division, will serve to illustrate.

Design engineers should find, in the base plate system described, many valuable ideas on machining techniques, tooling arrangements, and inspection methods, helpful in solving their own micro-miniaturization and mass-production problems.

Selective Micro-Miniaturization

Excellent as an example of the principle of limited or selective micro-miniaturization is the Raydist Position Indicator, whose computer element was micro-miniaturized.

The old computer was 12 in. wide, 8 in. high, and 6 in. deep, with two dials with a 2-3/4 in. track diameter. It was actuated by a collection of gears which required a fair amount of power. Specifications required a computer-indicator with two input shafts operating two dials which would continuously give distances from the two known-position transmitting stations. Only one input shaft indicates the exact distance to shore station. The other shaft indicates the *difference* in the distance of the receiver from two shore stations. Hence, a differential was required to add algebraically the revolutions of the two input shafts so that the second counter would register the actual distance to its respective shore station.

A further requirement was for an improved method of resetting the dials. The values on the dials change rapidly when the Raydist Position Indicator is in use, and with the old indicator a motor-driven and time-consuming winding-through process was necessary in resetting the dials.

The new indicator, as designed by Hamilton, uses simple counters whose digital drums can be reset individually. This type of counter also offers the best torque characteristics.

Human Factors Limit Size. The actual size of the computer-indicator, and the degree of miniaturization, were limited by the dials. Since these had to be readily readable, the smallest dial size consistent with normal aircraft instrumentation policies—with a track diameter of 1-5/8 in.—was selected and the instrument built around them.

The final instrument cased measures 6-1/2 in. wide, 3-1/4 in. high, and 2 in. deep. Fig. 1 shows the old and new computers. Fig. 2 shows the high-precision gear train arrangement (backlash is less than one degree) in the new computer.

The combined computer, and the electronic com-

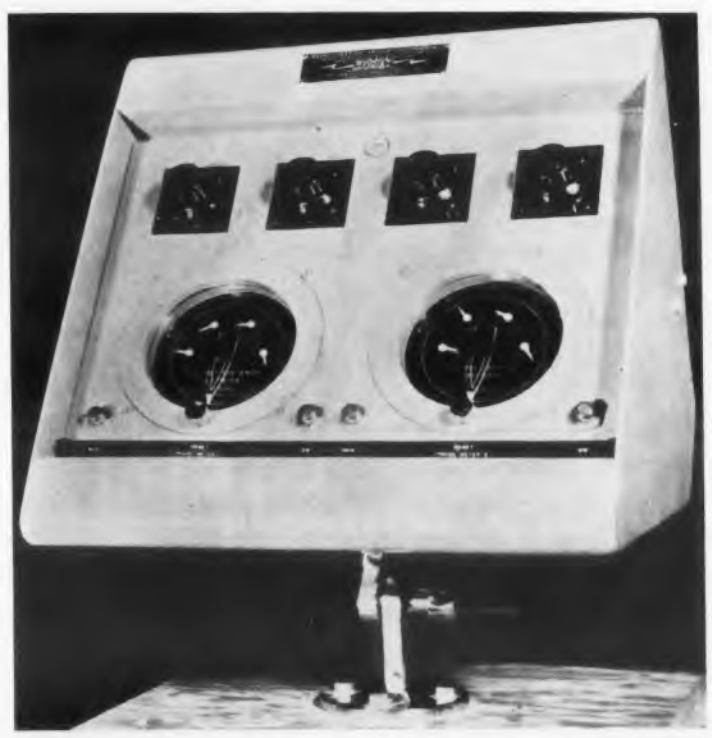


Fig. 1. Reduction in size of the Raydist Position Indicator is made possible primarily by use of watch-making techniques. Old Indicator is shown for comparison. Detailed requirements of micro-miniaturized computer-indicator are given in the text.

ponents in the redesigned micro-miniaturized Raydist Position Indicator have been reduced in weight by more than one-half, and there has been a 75 per cent reduction in space requirements. In addition, power torque requirements have diminished the size and weight of the power source by 90 per cent. These considerable reductions have been accompanied by greater range, less lag, and a three-times improvement in accuracy over the old unit.

When there are no limiting factors—such as the dial size in the Raydist Position Indicator—such micro-miniaturization can be carried down to *microscopic* dimensions. The mass-production of extremely minute, high-precision gear train assemblies at Hamilton is essentially routine. Such assemblies, consisting of wheels and pinions mounted on base plates, are universally used in watch construction and in recent years their remarkable adaptability to other tiny mechanisms has been recognized, particularly for special control instrumentation in the electronic, electrical and electromechanical fields.

The manufacture of miniaturized gear trains by this system is a two-part, interrelated process—base plates on one hand and wheels-and-pinions on the other.

Base Plate—Key Element. Base plates are the accurately-made structural elements which mount the precise moving parts in a miniature gear train. In the base plate system, all rotating or moving parts are mounted on a single, precisely-made master plate and smaller sub-plates, themselves secured to the master plate, keep moving parts in accurate alignment.

Production begins with the die-stamping of a base plate blanked out of sheet stock, which is then machined to produce accurately parallel faces. After this, the blank is successively punched with carbide "shaving" dies which first trim the blank to the precise profile required and subsequently enlarge holes in the plate to exact diameters.

All carbide dies are of standard form, using carbide inserts pressed into a steel ring (Fig. 3). The use of carbide dies prevents dimensional distortion occurring when steel dies are heat-treated for hardening. Also, die-shaving permits the simultaneous production of many holes, all accurate in size and precisely located. Holes as small as 0.019 in. are produced by this die-shaving process. A striking proof of the precision in hole-size accuracy achieved by this die shaving technique is the fact that Hamilton can push-fit jewel bearings directly into the mounting plates. No hand-fitting of the bearing is necessary, and no special mountings are needed to secure the jewel bearing in the plate.

Two other highlights of the production process, largely responsible for the high precision of the base plates produced, are the method used for dimensioning and locating, and the inspection procedure used for quality control.

The conventions of coordinate dimensioning are simple and flexible. They consist of rules and forms adapting classical Cartesian coordinates to practical requirements of engineering drawings. On drawings the coordinate field is restricted to the first quadrant (Fig. 4) to eliminate negative values. However, by adapting this principle, all dimensions are given from a single reference point in terms of distances along two (x and y) rectangular coordinated axes to locate holes on a small part. This eliminates the pile-up of machining errors due to an accumulation of tolerances.

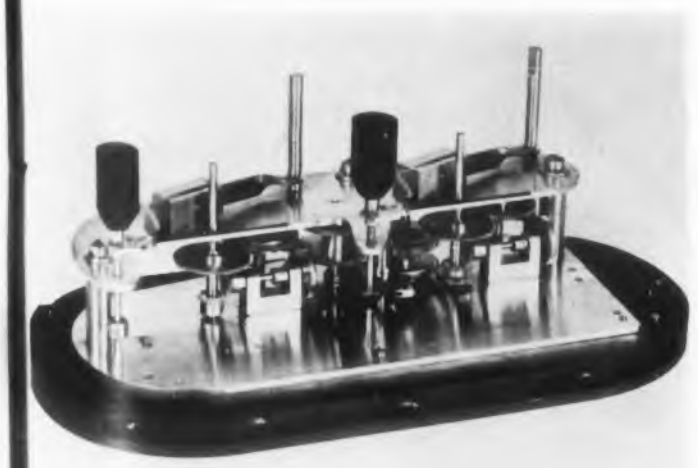


Fig. 2. Precision gear train arrangement in new computer. Gears are produced to watch-making precision. Backlash in this arrangement is held to less than one degree.

Fig. 3. Dies use carbide inserts pressed into a steel ring as shown. High accuracy results.

Micro-Miniaturization

Another important factor in eliminating errors in machining is the practice of making the base plate blank with attached tabs, also called lugs or ears. Accurate holes in these tabs permit precision positioning of the work in machining operations. Machining completed, the tabs are removed. A unique feature of the tabs is that they are outside the base plate itself. Hence, if any inaccuracy is present in the locating tabs, the error produced inside the plate is smaller. This principle helps substantially in holding machining operations to extremely close tolerances.

Microscopic Inspections. Practically every machining operation is immediately followed by an inspection operation to insure that tolerance limits are being kept. Many inspections are done either by optical projection to check profiles and locations of slots, recesses and holes, or by the use of a coordinate locator consisting of a high-powered microscope through which the work can be viewed while it is moved along either of two coordinated axes by high-precision calibrated screws, Fig. 5.

The bulk of the inspections, however, are performed by checking holes with specially designed "go and no-go" plug gages. These gages, made of long-wearing but hard-to-machine carbide, are designed with the correct gage diameter over their entire length instead of tapering at the open end as conventional plug gages do. The untapered end permits accurate gaging of holes in thin plates, for which tapered-end gages are unreliable, Fig. 6.

Final Operations. The final operations are the removal of bumps and ridges with an automatic facing machine, shaving a layer of metal 0.003 in. thick from the faces of the plate; the insertion of jewel bearings in the proper holes in the plate; and rhodium plating to prevent a corrosion. The jewel bearings are inserted before plating, because the plating process causes tiny overhangs at the edges of the holes which would break the jewels if the plating were done first.

Wheels and Pinions. Correlative to plate manufacture in the base plate system is the wheels-and-pinions operation. The mass-production manufacture of wheels and pinions—the moving parts supported by the base plate—has been refined to the point where a great deal of it, in spite of the minuscule parts and of tolerances expressed in ten-thousandths of an inch, is automatic, on machines designed and built at Hamilton.

Standard parts in wheels-and-pinions manufacture may vary enormously in size. The center pinion of a marine chronometer, for instance is 1-3/4 in. in length by 0.250 in. in diameter. Parts of comparable size are used in the Raydist Position Indicator. A center pinion for a lady's 21-0 wristwatch is 3/16 in. by 0.050 in.

Actual fabrication in either case is essentially the same and equally precise. In the first step, a section of high-carbon drill rod is set in an automatic turning lathe, with Hamilton-designed cams and tooling, and turned down to size and shape, with tolerances of ±0.0003 in. for length and ±0.0002 in. for diameter. The part is then cleaned, inspected, and put on a pinion tooth milling machine. When the teeth are cut, the part is again cleaned and inspected by optical projection, at an enlargement of 100:1, for tooth conformation. It is then hardened, tumbled, tempered, cleaned, and polished on a leaf polishing machine. It is cleaned again, inspected, gaged, deburred, cleaned and the pivots burnished. It is cleaned again and the pivots gaged. This is followed by a final tumbling.

While pinions are made of hard burnished steel, because of the torque demands on them, wheels are made for the most part of brass. The bearing of brass wheels upon the steel pinions burnishes the bearing surfaces of the wheels and supplies the best wear characteristics with the least friction.

A wheel to fit the center pinion of the 21-0 watch is first blanked from brass strip stock, 0.0075 in. thick by 0.310 in. wide. It is pierced, cleaned, gaged and stacked in an arbor for feeding into a milling or hobbing machine which forms teeth. Teeth and outside diameter are then inspected, the part is cleaned and tooth shape is checked by optical projection. The center hole is bored to fit the pinion and establish concentricity, and the part is

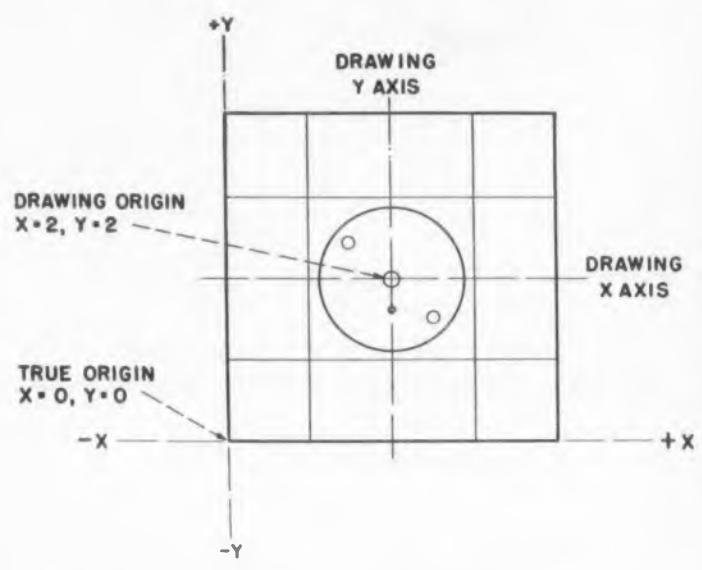


Fig. 4. On drawings, by restricting the cartesian-coordinate field to the first quadrant, all dimensions are based on a single reference point. This prevents compounding machining errors.

Fig. 5. This machine has its own built-in microscopic inspection device for close, accurate tolerances.

Fig. 6. Special "go—no-go" plug gage developed by Hamilton to assure close tolerances in holes.

Fig. 7. Typical of products possible with watchmaking techniques is this motor armature, slightly smaller than the head of a match.

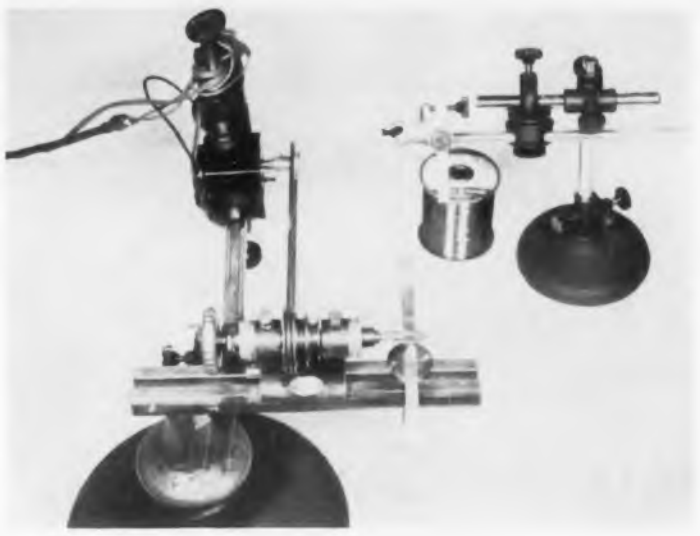


Fig. 8. Machine for winding armature shown in Fig. 7. Adapted watchmaker's lathe is employed. Wire is almost invisible to the naked eye.

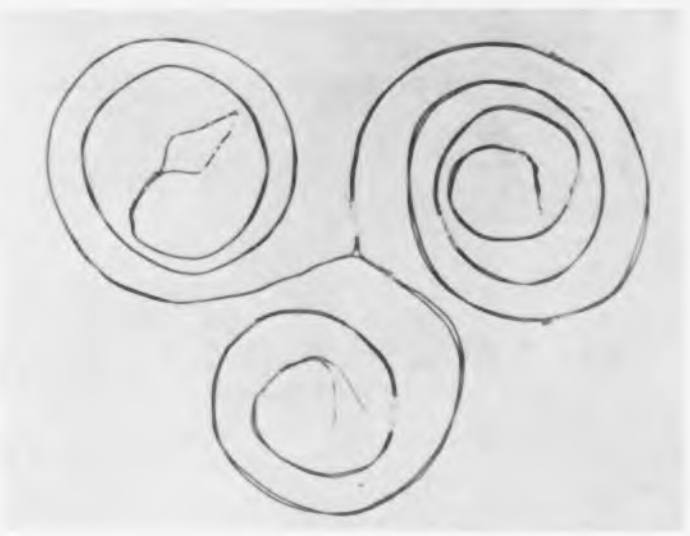


Fig. 9. Thermocouple produced by Hamilton in which the copper and constantan dissimilar elements were rolled into ribbons 0.001 in. thick in a machine designed to make watch springs.

cleaned, tumbled and cleaned. To protect it from oxidization, the wheel is plated with 24 carat gold and given a final inspection.

The next step is the assembly of pinion and wheel. The wheel is pressed on the pinion at a staking stand and then crimp-riveted to the pinion. The assembly is then cleaned and the wheel checked for concentricity and trued on an optical comparator. Final cleaning and inspection follow.

Complete Micro-Miniaturization

Here is an example of micro-miniaturization in its purest form—reducing an assembly to the absolute minimum in weight and bulk while maintaining its ability to perform its rated job without any loss whatsoever in efficiency.

The motor developed at Hamilton was originally designed for an experimental periodic-rewinding watch. It is probably the world's smallest electric motor and is certainly the tiniest practical motor which can be made on a mass-production basis—a factor which brings its unit cost below three dollars. The minuscule size of the motor is indicated by the fact that its rotor assembly is slightly smaller than the head of an ordinary paper match, Fig. 7. The entire motor will fit inside the ferrule of an ordinary lead pencil.

Development specifications on the project called for a miniature, wound-rotor, permanent magnetic field, dc electric motor to be built within the confines of a space 0.250 x 0.250 x 0.200 in. A number of possible designs were considered and many materials, for magnets, coils, bearings, brushes, commutator, etc., were tested. A first, practical unit was built in a rectangular case. Several faults were apparent, notably inability to self-start from all angular positions of the armature—owing to lack of torque—and an unsatisfactory alignment of the armature in the air-gap.

These difficulties were analyzed and eliminated by redesign, which included the substitution of a cylindrical form for the previous rectangular one. Several changes in material were made to increase wear-resistance, and a second motor was built.

This second model is practical for mass production and, given the necessary experience and know-how, easy to assemble. It has a rated output of three mph, operating on an eight ma subminiature mercury battery. It has been run for more than two hundred hours. In one instance it was run for eight hours on twice its rated voltage, with no evidence of over-heating.

The rotor assembly consists of the shaft, the commutator—to which the coil leads are soldered—and the armature. The armature is wound with six coils of 0.001 in. copper wire. This winding was done in a routine manner by using a watchmaker's lathe with a low-speed motor, Fig. 8.

Partial Micro-Miniaturization

The Problem: Illustrated here is the miniaturization of certain dimensions only, on a standard assembly—in this case a thermocouple. It resulted from a dilemma encountered by a committee of the American Society for Testing Materials, which was running tests on waxes at elevated temperatures. When specimens of these waxes were placed in a refractometer for index of refraction readings at from 100 to 154 F, there was a variable—on the same specimen and even when the tests were run by the same person.

The heat source and the thermocouple which registered the temperature were both mounted on the outside of the split prism of the refractometer. The committee members reasoned that the variable might be resulting from the fact that the temperature being registered on the outside of the prism was not the same as that at the center where the specimens were located. The solution to this, they decided, was to introduce a thermocouple between the halves of the prism in the same plant as the specimens. The question was—how?

The Approach: The thinnest thermocouple wire is 0.020 in. in diameter, and the space between the two halves of the prism was 0.0025 in. To get a thermocouple into this area posed two problems: having the wire precisely rolled to a thinness of less than 0.0025 in. and joining the two dissimilar metals without an increase in the thickness of the assembly at the joint and without burning up the metal. This, then, was the problem.

The solution: Engineers at the Allied Products Div. of Hamilton had the answer to both problems, since the fabrication required is common practice in both watchmaking and micro-miniaturization techniques. The thermocouple produced by Hamilton was standard in all respects except that its wires—copper and constantan—had been rolled into a ribbon 0.001 in. thick on a miniature rolling mill normally used to roll watch hair-springs. The hot junction was made with miniature spot welding equipment without increasing the over-all thickness. The result was an assembly of ordinary dimensions except at the point where miniaturization was required, Fig. 9.

The three examples cited are merely isolated cases used to illustrate different types of micro-miniaturization. The variety of such miniaturizations possible through the application of watchmaking techniques, equipment and experience, is almost limitless. And as critical tolerances become more and more essential in both military and industrial products, and the use of new metals raises problems in fabrication and assembly, the techniques of watchmaking become increasingly important in producing mechanical parts and assemblies whose degree of miniaturization corresponds to that of electronic components.

Miniaturization in Precision Switching

Precision Switches

Along with greater demands, especially by the military, for increased ruggedness and reliability of precision switches, is the cry to "make them smaller." We have seen work in this direction by a number of manufacturers. How far they can go in "micro-miniaturizing" them cannot yet be answered. However, the accompanying article is an example of how such a manufacturer is meeting requirements put to it. The switch described was developed by Haydon Switch Inc., to meet a specific military requirement. It undoubtedly is not the ultimate in smallness, and it may not be "micro-miniature," but it further illustrates the trend toward "thinking small."

INCREASING demands for positive switch operation under environmental extremes continually present new design problems. Complicated, electrical and electronic equipment compressed by modern scientific requirements into tighter and smaller enclosures continually taxes design and development engineers. The functional requirements of this equipment increase along with the need for making it smaller. How far can this progression to miniaturization with increased product dependability and function go?

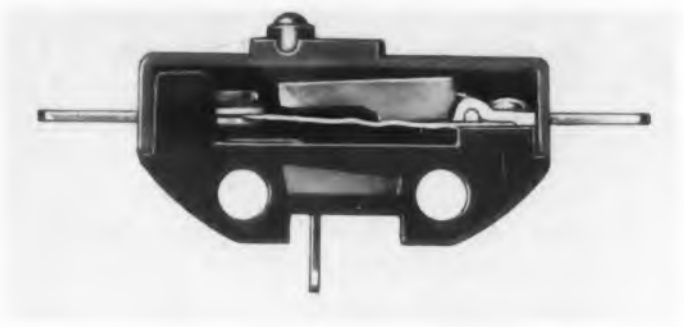
Specifications recently proposed required two precision snap switches to be enclosed in a 1 in. diam. can with a waffle finger activator between the switches. The switches had to be designed so that they could be ganged to fit into a 1 in. tube containing two or up to two hundred units complete with three contacts and necessary space for wiring.

Other specifications were: minimum contact gap 0.015 in.; operating force 20 oz max; resistive 28 v dc, 5 am load: 400 cps, 110 v ac, 5 amp load; life at rated load to be 100,000 activations; ambient temperature range −65 to +300 F.

The case selected for this switch was of glass-alkyd. This gave maximum dimensional stability, least trouble under environmental extremes, and produced the smallest precision snap switch which would meet all the required specifications.

Switch blades are one piece, and of heavy duty, Beryllium copper. Silver contacts are welded in position on the blades to give a true snap make-and-break with 20 per cent higher contact pressures at any point of activation than similar prototype switches.

A number of advantages and uses for this new switch came to light in the process of its development. One distinct advantage of the attempt toward greater miniaturization was the elimination of all non essentials, while at the same time resulting in a more functional product.



Cut-away of Haydon Miniaturized (5304) switch.

Two precision switches in a 1 in. diam case.

Micro-Miniature Inductors

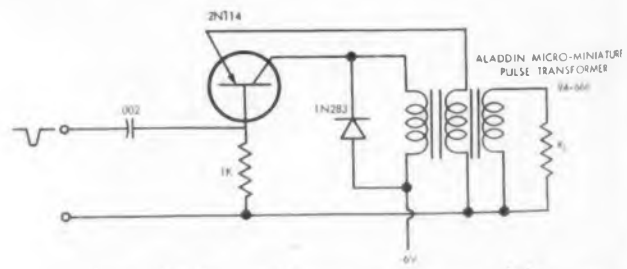
Transformers

In circuits employing transistors, transformer size reduction is often limited by techniques for winding and handling the coils and leads in production. The watch industry has apparently been most successful to date in winding microscopically small wire into micro-miniature coils. However, here is an example of a truly small pulse transformer developed by a non-watchmaker. Other manufacturers may be "geared" to make equally small and precise equipment; but, this demonstrates that practical micro-miniaturization is probably not far off.

A LINE of pulse transformers, little larger than the eraser on a pencil, is manufactured by Aladdin Industries of Nashville, Tenn. They are also in production on micro-miniature ferrite cored inductors.

Although the units were designed to a smaller size with usage in transistorized circuits such as that shown, as a primary objective, it is of interest to note that the reduction in size has benefitted several parameters. Both the leakage inductance and the distributed capacitance have decreased due to the smaller size; this in turn has led to faster rise times in the pulse transformers. Rise times as fast as 0.015 μsec can be attained and pulse width durations of 50 μsec are available. In the inductor line it has been possible to obtain as much as 1 H from one of the micro-miniature units.

Many interesting production problems have been encountered in manufacturing these miniature components. With wire sizes running as small as 48 AWG it can be a problem merely to locate the lead wires. Many of the operations have been performed under the magnifying glass, and in several instances special lighting has been used to assist in locating the leads. Closer control of the manufacturing processes has become essential due primarily to the smaller size of the components.



Typical circuit application for micro-miniature pulse transformer—a triggered transistor blocking oscillator. This unit will produce an output pulse of 10 μsec duration. Other transformers are already available that will produce pulse widths of from 0.5 to 50 μsec

Courtesy, Amphenol

Connectors

AMPHENOL'S concern with the necessary trend toward micro-miniaturization is well expressed in these words by Ray E. King, product manager of their Specialty Connector Division, in a recent issue of *Amphenol Engineering News*. "Miniaturization of electronic equipment has not only taxed the ingenuity of design engineers but has also posed a challenge to electronic component manufacturers. Before the equipment design engineers can achieve miniaturization, smaller components must be built. In the field of connector manufacturing the design engineer is confronted with such problems as maintaining an adequate current rating in the face of a reduction in the cross-sectional area of the contact. He also has the problem of a reduction in voltage rating as he tries to move contacts closer together. The plastic mold engineer also has his problems and is confronted with the necessity of working out new molding techniques caused by the smaller and more intricate plastic insert blanks." He also points out that it is necessary to achieve "miniaturization with reliability."

Cadmium bronze is making its debut as a contact material in new miniature connectors. This material provides a greater conductivity than any contact material previously used and will allow a working current up to 5 amp. Gold over silver plating is used for easier soldering and increased shelf life.

Transmission Lines

AS TRANSMISSION lines get smaller and smaller, not only is their uniform manufacture more difficult, but installation problems mount, in spite of demands for improvement. Reliability, is likely to decrease exponentially as size decreases. Reliability also depends upon installation as well as cable fabrication. Cable fasteners must avoid pinching the cable; connectors must be compatible; automatic cable-to-connector assembly techniques will be required to avoid damage on assembly. There will be other problems.

Courtesy, Amphenol

Thin Leaf Design Improves

Micro-Miniature Relay Contacts

Relays

Akin to work on coils and transformers is work on small relays. Again, the watchmaking industry has pioneered the way to producing a microscopically small device for micro-miniature equipment applications. The MV relay of the Elgin National Watch Co. is one such device. Described here is one aspect of the design problems encountered in developing this component.

THE physical design and material from which relay contacts are made, in the final analysis, determine just how well they're going to do the job of carrying current and voltage at rated loads under extreme specifications of vibration, shock, temperature, etc., as well as how well they minimize the effects of wear and electrical erosion.

In the new Elgin MV relay, which is the size of a postage stamp and about as thick as a cigarette, engineers have utilized a unique spring leaf design of the contacts to attain high vibration performance in this micro-miniature component.

Silver-Magnesium-Nickel, which has excellent spring properties, as well as high thermal and electrical conductivity, constitutes the entire spring material used. This aids in maintaining a desirable contact pressure and produces a significant wiping or relative motion between the co-acting parts.

With this combination of pressure and wipe a successful absorption of the impact energy is obtained when contacts are engaged as well as good dampening of any relative motion between contacts, thus eliminating bounce and failure during vibration and shock.

The wiping action also provides self-cleaning necessary in keeping contact resistance low and stable, especially when they are used in dry circuit applications.

The inherent spring qualities of the new material permits the elimination of heavy, bulky contact buttons, thus improving vibration qualities, as well as mechanical wear. At the same time, the thin spring design provides excellent heat dissipation necessary for minimizing electrical erosion.

The *normally closed* contacts are self-loaded and require no actuating means to maintain the contact pressure. The relay armature is entirely removed from intimate contact with the moveable blade in the normally closed position, thus improving vibration resistance.

Contact gap is kept greater than that needed to effectively quench the electrical arc when high currents are carried.

Recent tests show gold contacts improve the relay's performance in dry circuit work, yet do not destroy any of the performance characteristics in standard and military applications.

Precision alignment of the tiny fixed contacts in Elgin's new MV series relays is obtained by using an optional comparator with reticle, an apparatus used by the watch firm in the mounting of hairsprings—the delicate heart of a watch balance system.

Inside the comparator, the reticle—a scale drawing on glass—consists of an elongated square with cross lines bisecting it vertically and horizontally. The operator inserts the relay's header in a special fixture which positions it under the comparator and mounts the fixed contact blades to header posts. By aligning the contacts on each side of the reticle, they are placed in precisely the correct position when soldering.

Soldering is accomplished using resistance welding techniques, which prohibit scoring of the thin spring leaf contact blades made of silver, magnesium, and nickel.

Air Magic: The tiny contact screw with 180 threads to the inch (it takes about 8,000 of them to fill a thimble) is placed in the bushing through use of a watch industry vacuum screwdriver which holds the screw by suction permitting operator to set the screw without damaging threads. A mistake in this operation costs a nearly completed unit.

Resistance Soldering. Tiny wire leads from coil in Elgin's MV series relay are soldered in this special fixture using resistance welding technique. Operator touches foot pedal to activate current which is conducted through carbon soldering iron. Heat is set up at exact point of soldering which prevents damage to coil insulation or fine wire. Fixture revolves so that both leads can be soldered.

Watchmaking precision. Delicate watchmaking dexterity is required in the assembly of the relay armature to the relay body. Tweezers point to threaded adjusting nut (slightly larger than a pinhead) which holds contact blade and shunt to the armature only 3/8 in. long. In immediate foreground is minute spring and adjusting screw which is anchored to the top frame and permanently bonded after proper tension is acquired. The adjusting nut is tightened onto banking pin (term carried over from the watch industry) which runs through the armature and serves as a brake to prevent contact blade from jumping out of action.

Fig. 1. A single stage transistor amplifier no larger than a pencil eraser.

Tiny Transistor-Amplifier

TWENTY-ONE db of voltage gain at 1 kc has been squeezed by Centralab into a transistor amplifier package with a volume of less than .013 cu. in. This ultra-miniature, high-gain audio amplifier stage is about the size of the eraser on the end of a common lead pencil. It is intended for use in hearing aids, pocket-size radios or recorders, preamplifiers, and wherever the space factor is an important consideration.

By completely new processes developed by Centralab, 900 E. Keefe Ave., Milwaukee, Wisconsin, transistors are combined with resistors, capacitors and wiring in a single package. The amplifier illustrated here draws only 0.5 ma from a 1.3 v mercury cell and has a frequency response from 250 to 20,000 cps. Noise output is held to less than 1/2 mv.

The amplifier, which may be modified at the factory for special applications has a nominal input impedance of 1000 ohms and will drive a load from 500 to 1500 ohms.

In addition to the space saving feature, there is an economy feature. Savings in costly wiring labor, effected by reducing soldering connections from 11 to 4, are accomplished by use of these amplifier stages in place of conventional ones.

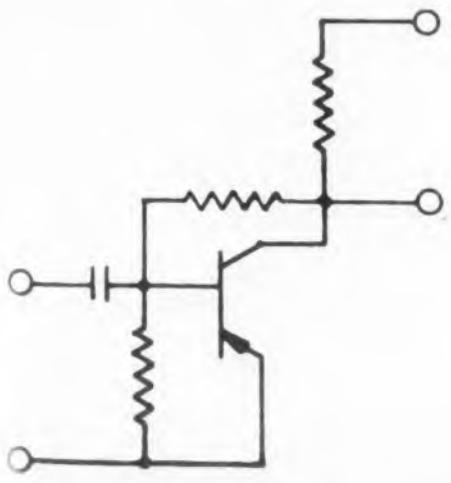


Fig. 2. Circuit of the transistor amplifier.

The Vanishing He

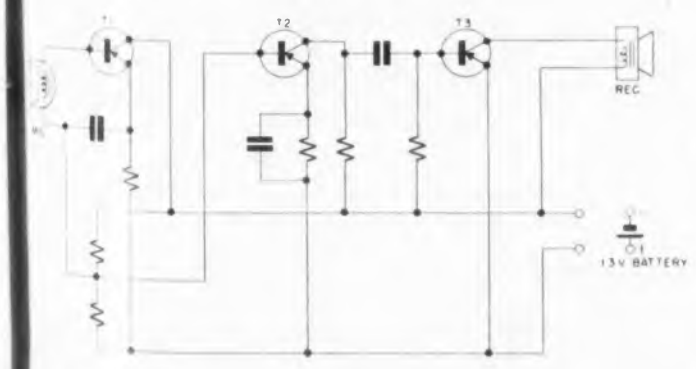
ONE of the major electronic industries, to which credit must go for hastening micro-miniaturization is the hearing aid industry. Urged on by resistance on the part of the user to unsightly gadgets, heavy batteries, tangled "hook-ups," etc., the hearing aid engineers have pushed on toward the development of a "sightless," "weightless," low cost aid to the hard of hearing. Other designers can use the components and techniques they have developed to satisfy the military requirements for gear many times smaller than "standard."

Here is an example of how things got smaller, yet more reliable, for the hard of hearing.

In-the-ear hearing aid. (Top) components mounted on chassis, including three transistors; (Center) for comparison, a nickel; (Lower) chassis without components. *Courtesy, Sonotone Corp., Elmsford, N.Y.*

ng Hearing Aid

Note the difference between a new Sonotone hearing aid worn entirely in the ear—and a hearing aid of only 12 years ago. The 1945 model (right) weighed 20 oz as worn. The large transmitter was worn on the body, and a thick cord led to a receiver in the ear. External batteries were strapped to the body or legs and connected to the transmitter by another cord. The new aid (left) is 40 times lighter. It weighs only half an ounce with battery.



Fit this circuit into your ear! You can, you know.

PRODUCTION T

Dust Free Environment

Future Assembly Line? New manufacturing techniques to hold phenomenal accuracy limits, required of gyro "platforms," brings extreme degree of factory control at Sperry Gyroscope. "Space man" flavor of rocket flight and atomic navigation begins with isolated assembly groups like this, where skilled technicians are specially gowned and work in conditions more tightly controlled than in a modern hospital.

Special laboratory equipment and accurate instrumentation are used by a National Carbon Company technician engaged in studies of the fabrication of extremely small components.

Special Equipment and Tools

Bellows-operated tweezers are used in micro-miniaturization work by a National Carbon Co. technician.

N TECHNIQUES

Ultra Precision

Mechanical precision far surpassing the watchmaker's art is achieved in the "Gnat" miniature rate gyro, developed by the Missile Systems Division of Raytheon Mfg. Co. Rotating at a speed of 30,000 rpm on bearings accurate to ± 0.00001 in. this tiny unit stabilizes the control system of advanced missiles. The "Gnat" is so sensitive it could measure the speed of the earth's rotation.

How Far Can We Go?

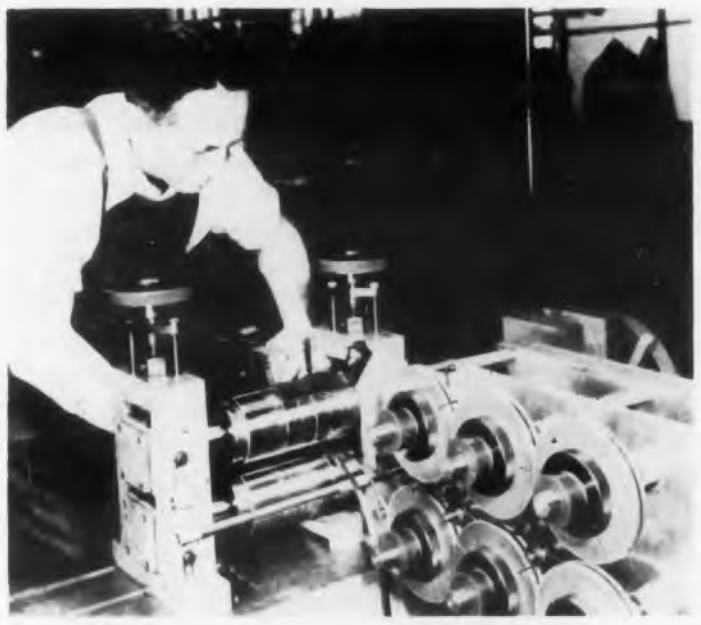
At Hamilton Watch Co., micro-thin sheet can be produced to precise tolerances. Some of the details are told here.

The Allied Products Division of Hamilton Watch Co. can furnish metal strip in widths up to 4 in. and in thicknesses from 0.010 in. down to 0.00012 in., with thickness guaranteed uniform to a tolerance of 0.00005 in. In addition, a high degree of uniformity in thickness (freedom from camber) across the width of the strip is insured. This cold rolled, ultra-thin, precision gage strip is available in a wide range of metals, from the very hard high-temperature resistant alloys down to the very soft light metals.

This strip is produced in Hamilton's "miniature integrated steel mill," a facility equipped to melt almost any alloy, or to produce almost any desired metal processing. The ultra-thin strip can be slit to widths as narrow as 0.04 in. with widths held to a tolerance of ±0.001 in. This slitting is done on special machines of Hamilton's own design which not only permit slitting in such narrow widths to such close tolerances, but which also insure clean-cut edges that are free of ripple.

This strip is especially applicable: *1.* Where exact thicknesses and precise metallurgical properties of thin metal discs (diaphragms) are required to insure accurate calibration and freedom from hysteresis in instruments or control devices; 2. in high speed production processes using thin metal strip raw materials, where the strip's close-tolerance dimensions and as specified metallurgical properties insure easy stamping and a low-percentage of rejects; and 3. in manufacture of tape-wound magnetic cores or sheaths, where precise thickness and metallurgical properties of the tape are required to produce desired electrical or magnetic performance characteristics. Examples are computer memory cores, magnetic delay lines, and distributed-constant electrical components.

Rolling extra-thin, precision gage metal strip on specially designed Sendzimir mills at Hamilton Watch Company's Allied Products Division. Elaborate electronic and hydraulic controls on these mills permit continuous adjustment of strip tension and rolling pressure, thus making it possible to roll strip as fine as 0.00012 in. with thickness held to a tolerance of 0.00005 in.



With slitting equipment shown, Hamilton can slit extra-thin metal strip in ribbons as narrow as 0.040 in. with edges that are clean cut and without ripple, and with width held to a tolerance of ± 0.001 in.

Thickness of ultra-thin precision-thickness metal strip being measured on dial gage which reads ten-thousandths of an inch.

Editors Note: Use of conductance curves[1] for designing electronic circuits has been the subject of many articles by Mr. Pullen. In this article he points out some interesting conduction ratios which can be used in the design of oscillators. Part I investigates vacuum tube oscillators. Part II which will appear in the July 15th issue, extends the techniques to a variety of transistors oscillators. In an appendix to Part I Mr. Pullen discusses oscillators from a "Necessary for Operation" point of view. **For a free reprint of this article, turn to the Reader Service Card and circle 400.**

Design of Oscillators—I

Keats A. Pullen, Jr.
Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

WHEN conductance values are used to analyze an oscillator, the loading effect of resistors, capacitors and inductors in the circuit can be easily determined. Excellent treatments of the basic oscillator circuits are available but there does not appear to be an adequate analysis of the principles in terms of practical problems of design. By using conductance curves, the active device (tube, transistor or similar device) is coordinated with the balance of the circuit. Techniques presented for the design of oscillators are approached from a small-signal point of view with emphasis on sinusoidal oscillators.

Amplifier-Type Oscillators

A major share of the oscillators producing sinusoidal outputs fall into the general category of amplifier-type oscillators. These oscillators have a circuit to feed back some of the output energy into the input of the active device to create the required negative resistance. A study of these oscillators could be based on the equivalent negative immittance characteristic, but practical design has indicated that they can be better analyzed as amplifiers.

The three most important conditions which must exist in an amplifier-type oscillator are *first*, an amplifier capable of providing sufficient loop gain to overcome losses in the coupled circuits, *second*, a coupled circuit providing a feedback path to the input of the amplifier which will pass only the desired frequency band and at the same time have the required phase characteristics to permit oscillation, and *third*, provision for automatically adjusting overall amplification as a function of amplitude of oscillation to provide a stable output. Normally, the first and the third conditions are provided by the amplifier. The second condition is dependant primarily on the passive or coupled circuit.

An amplifier for use with the oscillator must be designed to perform two functions: amplification, and regulation. The non-linearity inherent in amplifiers fortunately makes them naturally suited for the regulation function. For an oscillator to start oscillating, it is necessary that the initial amplification be more than enough to maintain oscillation. Overall loop gain must be greater than unity for such a condition to exist. If the amplifier can be designed so that loop gain decreases as the amplitude increases, the condition for stable oscillation can, but does not have to, exist in the amplifier.

What is the loop gain of an oscillator? To determine loop gain, it is necessary to open the feedback circuit and determine the ratio of output to input voltage at the division point (Fig. 2). All operating conditions must be exactly the same as with the circuit closed.

Reduction of amplification because of an increase in the amplitude of oscillation is usually accomplished in one of two ways (with transistor oscillators it is frequently a combination of the two). The first way is by shifting the static operating conditions of the amplifier. This method of control is used with most vacuum tube oscillators. Rectification of the input signal is used to change the fixed bias. The second method makes use of the variation of transconductance with bias for a fixed static operating condition. For a reduction of average amplification with amplitude to develop, the effective transconductance for positive signals must rise more slowly than it decreases for negative signals. When the operating frequency is low enough, cathode degeneration can be used to limit maximum amplification and thereby improve amplitude limiting. The average amplification of a circuit is determined from the equation:

$$K_a = (K_p + 2\,K_s + K_n)/4 \qquad (1)$$

If loss in the feedback circuit is constant, Eq. 1 can be used for estimating the average forward amplification and loop gain of the active element. When the loss is not constant, each of the amplifications, K_a, K_p, K_s, and K_n must be replaced with the corresponding product $(KK_f)_a$, etc. to obtain the average loop amplification. (The subscripts a iden-

fies the average value, p the value at most positive grid bias, s at static bias, and n at the most negative bias.) In either case, the average loop gain $(KK_f)_a$ is unity for the final operating condition. If the oscillator is self pulsing (it squegs), then the average amplification *over the squegging cycle* is unity. If, however, the output is an unmodulated carrier, then the loop gain is unity when averaged over each individual cycle. Even with multivibrators and blocking oscillators average loop amplification over the full basic operating cycle is unity.

Load Lines

Techniques for determining the load lines have been discussed many times in the electronic literature[1]. A static load line is determined and plotted if required, and a family of dynamic load lines selected. The ratio of transformation from plate to grid is determined to help approximate the effect of grid loading. An estimate of the equivalent loading resistance at the grid is 1000 ohms. This resistance is transformed back to the plate circuit and included in the load impedance for the tube.

The ratio of transformation required in the coupling circuit, between the output and the input circuit, has a minimum value which is directly related to the maximum forward gain available in the active device. The minimum value of K_f may be found from the equation:

$$K_f = g_p/g_m \text{ (for triode tubes)}$$
$$K_f = g_{oe}/g_{fe} \text{ (for transistors)} \quad (2)$$

Where K_j is feed back gain; g_p is plate conductance $\left(\frac{1}{r_p}\right)$ and g_m is transconductance. The actual value of K_f will be some what larger than given by Eq. 2, and can be found from the equation:

$$K_a K_f = 1 = K_f\, g_{ma}\, R_{LD} \quad (3)$$

Where g_{ma} is the average effective transconductance, and R_{LD} is the load impedance.

The General Oscillator

The general oscillator has been discussed rather thoroughly in the electronics literature, particularly in its linearized form. Its equivalent circuit is shown in Fig. 3. An important fact which appears to have been neglected in these discussions is expressed in the following equations:

Triode Tubes		Transistors
$g_p R_{LD} < 1$	or	$g_{oe} R_{LD} < 1$ and
$g_c (n_c/n_p)^2 R_{LD} < 1$	or	$g_{ie} (n_i/n_o)^2 R_{LD} < 1$

(4a)

Where n_c/n_p and n_i/n_o are the impedance ratios from input to output with tube and transistor circuits respectively, and R_{LD} is the output load impedance at operating frequency. Voltage feedback may be written as $K_f = n_c/n_p$, with the result that the equations may be rewritten as:

$$g_p R_{LD} < 1 \quad \text{or} \quad g_{oe} R_{LD} < 1$$
$$g_c K_f^2 R_{LD} < 1 \quad \text{or} \quad g_{ie} K_f^2 R_{LD} < 1 \quad (4b)$$

When equations (4a) and (4b) are fulfilled, loading of the active device on the frequency controlling circuit can be neglected and stability will be as good as the circuit itself will permit. The usual equations used with the general oscillator may be generalized to include non-linear properties by replacing the μ with either the ratio g_m/g_p or g_{fe}/g_{oe} as required.

Magnetic Coupled Oscillators

Magnetic coupled oscillators, Fig. 4, can be designed in a very similar manner to that used for the general oscillator. Since at least one additional variable is available with this form of oscillator, namely, the magnetic coupling, greater flexibility is available. As long as coupling between the two coils is kept below the critical value, the ratio of the turns may be traded for coupling factor to obtain an optimum design. Normally, the input coil is adjusted to have a reactance somewhat below the grid input impedance. Coupling is then adjusted to provide oscillation.

Q—Multiplier or Clapp Oscillator

Both of these oscillators utilize a cathode follower type circuit which introduces amplitude limiting through degeneration. In the Q—multiplier oscillator, Fig. 5a, the reactance from grid to ground consists of the two capacitors in series in one branch, and an inductance in parallel with them in the second branch. In the Clapp oscillator, Fig. 5b, the inductance is replaced by a series L-C circuit. The individual reactances are large compared to the reactance required to resonate the capacitors, but the difference just equals the required reactance.

Since a cathode follower circuit is used for these oscillators, amplification of the active element lies between 0.5 and unity. In order to get the required loop gain, therefore, a voltage step-up is required between the cathode and the grid. The two capacitors C_1 and C_2 form part of a resonant transformer which gives sufficient step-up to make loop gain greater than unity. Using the feedback resistance R_f as shown in Fig. 5, the amplification required of the tube or transistor is:

$$K = g_m R_k/[1 + (g_m + g_p) R_K] \geq (1/2) + R_f/Z \quad (5)$$

Where R_f is the feedback resistance, and Z is the total impedance of the tuned circuit (L/RC). (C is by the equation $C = C_1 C_2/C_1 + C_2$).

Conditions for Maximum Frequency Stability

Frequency stability is of extreme importance in a majority of the oscillators used to generate sinusoidal waves. The discussion which follows is not all-inclusive, but is intended to point out important factors, with emphasis on points often overlooked.

The Q of a tuned circuit is of very great importance in the stability of an oscillator. Actually the Q which is important is not necessarily that of the tuned circuit by itself, but that of the tuned circuit under its operating conditions. Resistive loading to grid or plate conductance causes just as much damping on the circuit as if it were actually part

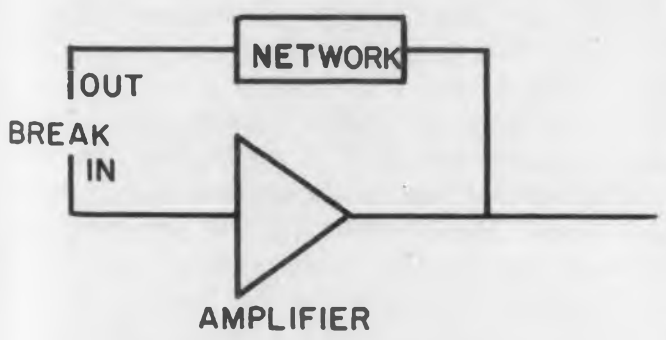


Fig. 1. Loop gain of the oscillator is equal to the ratio of output to input voltage at breakpoint.

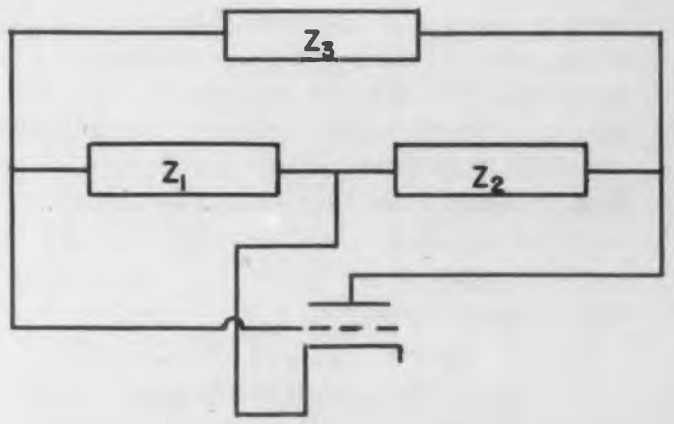


Fig. 2. Equivalent circuit for a general oscillator.

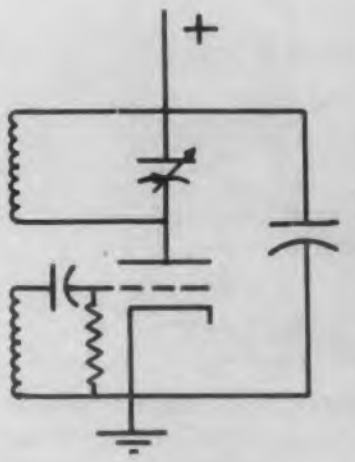


Fig. 3. *Magnetic coupled oscillator:* If coupling is kept below the critical value, the ratio of turns can be traded for coupling factor to obtain optimum design.

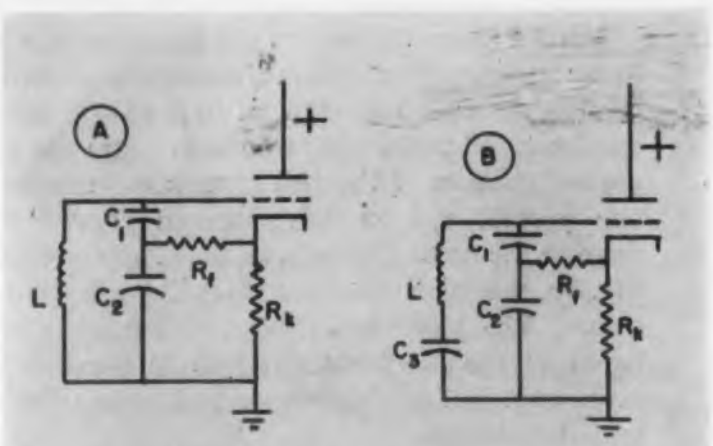


Fig. 4. Q—Multiplier Oscillator (A); CLAPP Oscillator (B).

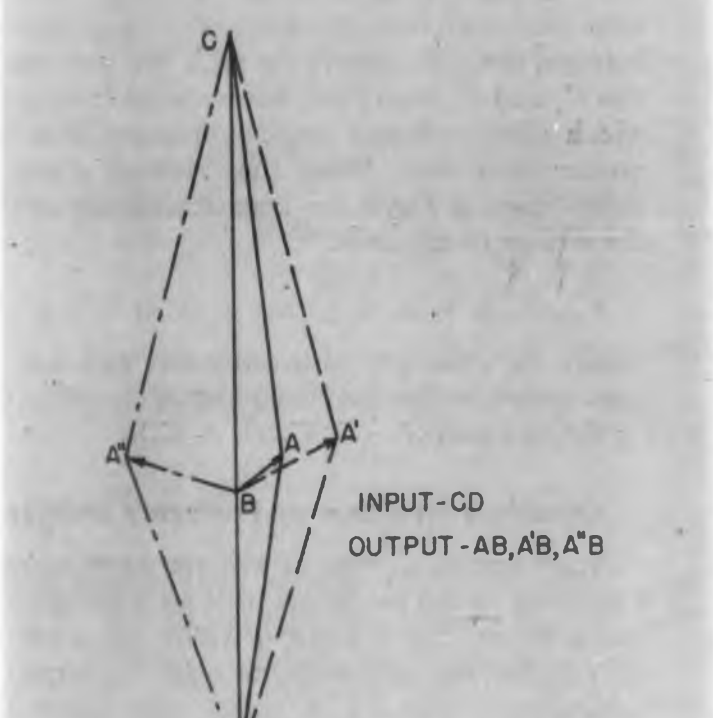


Fig. 5. *Meacham Phase Diagram:* Voltage difference between the points A and B changes much more rapidly in both amplitude and phase than the original component CA.

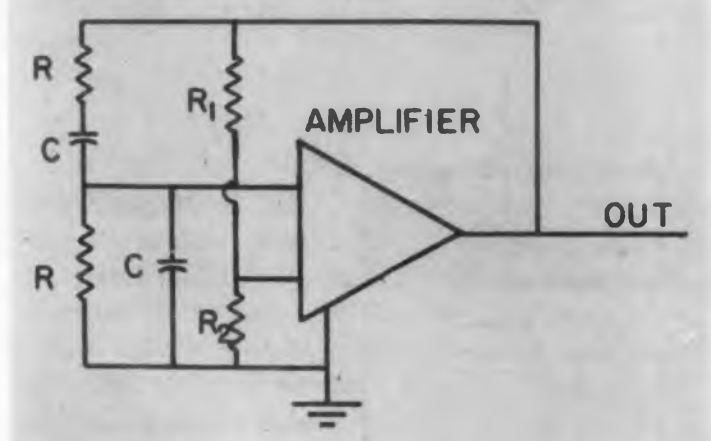


Fig. 6. *Wien Bridge Oscillator:* A two stage amplifier with zero degrees overall phase change and low output impedance is used to provide the required power to the frequency selection circuit and its association balancing circuit.

of the coil. For this reason the relations (4a) and (4b) should be fulfilled in oscillator design. As has been pointed out, loading of the active device on the frequency controlling circuit can be neglected when equations (4a) and (4b) are satisfied.

Using (4a) and (4b) to keep the impedance sufficiently low to maintain a good Q will also increase the fixed portion of the capacitance of the circuit (recall that $R_{LD} = Z = L/CR$). The result is that variations of the circuit capacitance, and particularly capacitance of the active device, are much less important than would otherwise be the case. The parasitic capacitances in tubes ranges from a fraction to approximately 20 $\mu\mu f$. In a transistor the range is from about three to many tens of thousands, depending on the individual device. Since these capacitances vary as a function of operating conditions – especially with transistors – it is important that a minimum of variation in the device actually reach the critical tuned circuit.

Rigid and well-mounted wiring will help keep variations of wire capacitance and inductance to a minimum. It should be noted that as impedance levels are lowered to keep stray capacitance effects under control, the effects of the inductance of the wiring become more important.

Use of stable and well-made parts whose characteristics change in a controlled manner with changes in environment are particularly important. Compensating capacitors used for trimming thermal drifts in tuned circuits are usually made of ceramic material. Since some of the ceramics are voltage sensitive, caution should be used, and the circuit thoroughly tested for both thermal and voltage drifts.

Oscillator circuits in which the oscillator is required to provide the ultimate in stability usually use a bridge-type circuit. A shift of phase with bridge balance is utilized to increase sensitivity of the frequency control circuit. This action is demonstrated in Fig. 6. The difference in output between the fixed arm of the bridge, identified by the letters CBD, and the variable arm CAD is required to keep the oscillator functioning. As can be seen, the voltage difference between the points A and B changes much more rapidly in amplitude and phase than does the original component CA. For this reason, a much higher order of stability can be obtained from an oscillator which uses a bridge type of control circuit rather than the more conventional feedback arrangement. The Meacham oscillator is one of the better known types using the bridge phase technique.

Phase Shift Oscillators

Phase shift oscillators depend on a time delay or advance through phase shift circuits. These oscillators usually use a combination or resistive and reactive components in the frequency control net, rather than two types of reactive components. Since the reactive component is usually a capacitor, they are often called RC oscillators.

Two types of RC oscillators are in fairly common use. The first of these – the Wien bridge type – uses an arrangement which is somewhat similar to a dual network. One member, usually the series one, consists of a capacitor and resistor in series, and the other member, which is connected in shunt, is either the load for the series combination or its source of signal. Since both resistors normally have equal resistance, and the capacitors equal capacitance, the phase angle between voltage and current through the network, for the output voltage to be in phase with the input voltage, is 45 deg. A two stage amplifier having zero deg. overall phase change and a low output impedance is used to provide the required power to the frequency selection circuit and its associated balancing circuit, Fig. 7.

At operating frequency the voltage gain in the frequency selective circuit has a maximum value of one-third. In order for oscillation to start it is necessary that the stabilizing circuit return a signal to the feedback point which is just less than one-third. The stabilizing circuit is made self-adjusting by using some type of thermistor as part of one of the two resistors. Feedback voltage then rises as the amplitude of the signal voltage rises, causing a reduction of the net amplification KK_f and limiting the output amplitude.

The second type of RC oscillator in common use takes advantage of the phase shift available in successive sections of a ladder network, Fig. 8. When the ladder sections of the network are separated by amplifiers or cathode followers, characteristics of the individual stage determine the overall operation of the oscillator. An example of such a circuit is an oscillator using three ladder sections, each with a phase shift of 60 deg. Two of the sections are coupled by an amplifier. Isolation circuits (cathode followers) are used between the two other sections. The amplifier should have an amplification between eight and twelve. The product of its gain and the gains of the two isolation amplifiers will then give an overall value of between eight and ten.

Usually the ladder sections are used without isolation amplifiers. Each section then causes an additional loss on the sections ahead of it in the chain. The equation for the operating frequency and for the loss in the network can be obtained from the numerator of the function F which is a continued fraction:

$$F = [Z_1Y_2 + \cfrac{1}{1 + \cfrac{1}{Z_1Y_2 + \cfrac{1}{1 + \cfrac{1}{Z_1Y_2 + \text{etc.}}}}}$$

The first few numerators for this expansion are:

Two ladders: $Z_1^2Y_2^2 + 3\,Z_1Y_2 + 1$

Three ladders: $Z_1^3Y_2^3 + 5\,Z_1^2Y_2^2 + 6\,Z_1Y_2 + 1$

Four ladders: $Z_1^4Y_2^4 + 7\,Z_1^3Y_2^3 + 25\,Z_1^2Y_2^2 + 10\,Z_1Y_2 + 1$

Five ladders: $Z_1^5Y_2^5 + 9\,Z_1^4Y_2^4 + 28\,Z_1^3Y_2^3 + 35\,Z_1^2Y_2^2 + 15\,Z_1Y_2 + 1$

Similar expressions can be developed for circuits having more sections. Frequency is determined from the odd order terms. The forward amplification required is obtained by substituting the frequency value into the even order terms. For example: for a three ladder net, solving the first and third power terms together gives

$$Z_1Y_2 = \sqrt{-6}$$

Substituting this in the even power terms gives a required amplification for the amplifier of 29.

As can be seen from these equations, only combinations of three and four sections give a single real frequency. Use of two sections does not give sufficient phase shift and four or more sections result in quadratics in $Z_1^2Y_2^2$, with two possible operating frequencies. Five sections give an operating frequency determined by the equation $Z_1Y_2 = \sqrt{-10/7}$, and a required forward amplification of approximately 13. The reduction in amplification results from a smaller phase shift per section and therefore a smaller loss.

When a ladder network is used with an amplifier in the described manner, its input impedance should be high compared to the output impedance of the amplifier supplying it, or its loading effect may prevent the circuit from oscillating. A reasonable gain margin—possibly twenty percent—should be provided for safe tolerances. A potentiometer can be used to readjust the gain, particularly when it is accomplished by a variation in degeneration, since principal tolerances are those of the static network.

The second part of this article will extend the techniques to a variety of transistor circuits.

Working equations for transistors oscillators will be presented. Emphasis will be on conductance values.

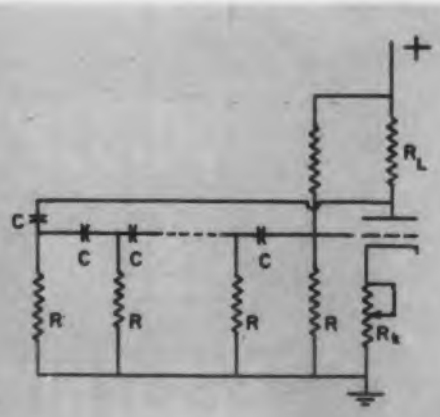


Fig. 7. *Phase Shift Oscillator:* Input impedance of the ladder should be high compared to the output impedance of the amplifier supplying it, or its loading effect may prevent the circuit oscillating.

Appendix

Necessary Conditions for Oscillation

Oscillators are energy transducers; they withdraw energy from a source capable of providing a steady flow of current (for example, a battery) and convert it into a pulsating form. Some oscillators generate sinusoidal waveforms, and others generate irregular waveforms such as square, triangular and sawtooth waves. All of these oscillators require the presence of an active element in the circuit. This active element may be a transistor, a vacuum tube or other similar device.

Sinusoidal oscillations can be generated by active elements used as negative resistance devices or they may be generated by active elements used as amplifiers in feedback circuits. Either phase shift or tuned circuits may be used for frequency selection.

Strictly, negative resistance devices should be called negative immittance devices, since immitance by definition includes both admittance and impedance. Both types of negative immitance (admittance and impedance) can be obtained with tubes or transistors. The most practical device, however, is the negative conductance type. It can be identified by the fact that its contour[1], when plotted in terms of output voltage and output current, is single valued with respect to voltage, but multiple valued with respect to current, see Fig. 8A. In a similar manner, a negative resistance device is single valued with respect to current, but multiple valued with respect to voltage, Fig. 8B. Oscillation occurs in a negative conductance element when, for the proper supply voltage, the impedance of the coupled circuit is high enough to cause the load line to intersect the negative region *A-A* in more than one, usually three, places. Likewise, with a negative resistance device, an impedance less than a specified value is required to provide oscillation. The negative conductance device is used with an antiresonant or shunt tuned circuit, and the negative resistance with a resonant or series tuned circuit.

Tuned circuits consist of elements capable of storing potential energy (capacitors) in conjunction with other elements (inductors) capable of storing kinetic energy. The former store energy by building up a pressure or voltage, the latter by building up a flow of current. With one of the elements, a change of voltage occurs in conjunction with a flow of current, with the other, a change of current develops a voltage. The two types of elements are said to be duals of one-another. Except for the interchange of voltage and current, the behavior of both elements is similar. Any network which can be obtained from another network by the substitution of L for C and vice versa is the dual of the other.

A tuned circuit cannot be built without such dual elements since both energy storage and immittance—either proportional or inversely proportional to frequency—are required. If the reactance of one element is proportional to frequency, the susceptance of the other is also proportional to frequency; if one varies inversely with frequency, so does the other. Only under these conditions is it possible to find a frequency at which cancellation of either the reactance or the susceptance can be obtained to provide the required resonant or anti-resonant condition.

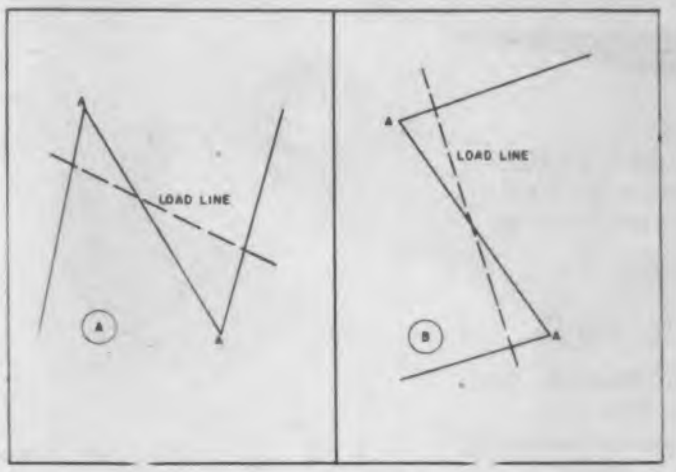


Fig. 8. A plot of output voltage vs output current shows that a negative conductance device (A) is single valued with respect to voltage and multiple valued with respect to current. A negative resistance device (B) is single valued with respect to current and multiple valued with respect to voltage.

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Oscillator Design Techniques Using Conductance Curves, K. A. Pullen, Jr., ELECTRONIC DESIGN, May 15, 1957, pp 34-37.

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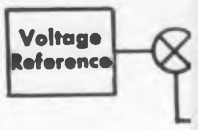

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CIRCLE 36 ON READER-SERVICE CARD FOR MORE INFORMATION

Simplified block diagram of the regulated low voltage dc power supply using a modulated ultrasonic carrier system.

Ultrasonically Regulated Po

UTILIZING an ultrasonic carrier system to achieve optimum performance, this low voltage dc power supply can deliver 0 to 7.0 v at up to 1.5 amps. In many applications, this compact unit is far superior to batteries. It may be used for strain gages, dc filaments, transistors, bias and precision electroplating. Even under load it may be used as a precision laboratory reference.

The manufacturer, Optimized Devices, Inc., Box 38, Gedney Station, White Plains, N.Y., has incorporated feedback loops and corrective networks to keep the output voltage virtually independent of line and load fluctuations. Regulation is complete even down to zero volts.

Negative voltage feedback contributes to the low drift, low noise and low output impedance, while adjustable current feedback reduces the output impedance to 0.005 ohm. This adjustment can provide negative resistance characteristics to compensate for lead length.

The output is continuously variable without switching. Two 3-1/2 in. plastic-cased meters monitor the output voltage and current with 1 per cent accuracy. High resolution is obtained using coarse and fine controls.

Regulation is excellent. The output voltage change from no load to full load does not exceed 10 mv and the output change is less than 1 mv per volt of ac line change. Drift is kept to less than 10 mv per hour.

A response time of less than 20 msec and a noise output of less than 1 mv are other features of this power supply. A floating output enables one to ground either positive or negative terminal.

Power is taken from a 60 cps line providing 105

ed Power Supply

to 125 v. At full output, the power supply draws only 70 w. It is light, compact and portable, weighing only 23 lbs. Its measurements are 10 in. h. x 8-1/4 in. w. x 13-1/2 in. l.

For further information on this power supply turn to the Reader's Service card and circle 37.

This unusual low voltage power supply uses ultrasonics and feedback to maintain excellent regulation and extremely low output impedance.

High Power Silicon Rectifier

DESIGNED to carry 140 average amp, 170 dc amp, or 1,500 one cycle surge peak amp per cell at a 40 C ambient, this silicon cell assembly is available in voltage levels from 50 to 300 piv. The ability of the rectifier to operate at high ambients—up to 200 C junction temperature—makes it useful in supplying filament power for industrial and transmitting tubes, power supplies for computers and radars, and airborne transformer rectifiers.

Believed by the General Electric Company, West Lynn, Massachusetts to have an infinitely long theoretical life, the cell is expected to be reliable. The cost of silicon makes it competitive with other rectifier materials, when it can be used up to its full rating. Silicon cells are generally smaller and more efficient than selenium or germanium for a given power rating. While the G. E. cell must be current-derated at elevated junction temperatures—down to 0 at 200 C—it will supply about 75 amp at 125 C; a triad of cells operating in a three phase circuit could supply 215 amp.

All cells are furnished in matched sets so that parallel operation is practical. Load equalizing reactors are in this way dispensed with. The cells can

Fig. 2. Hermetically sealed c
ramic-and-stainless-steel cell pac
age. Cutaway view shows Fer
steel cup and flange, ceramic w
and lower copper contact-b
tom. Steel is brazed to the c
ramic and all seams are welde

Fig. 1. This silicon rectifier cell is capable of carrying 140 average amp in a 40 C ambient, with 1,000 linear ft per min cooling air and mounted on a 6 x 6 x 1/4 in. copper plate. Standard stud mounting insures tight fit to cooling plate, using conventional nut. Power take-off is heavy braid for low resistance path.

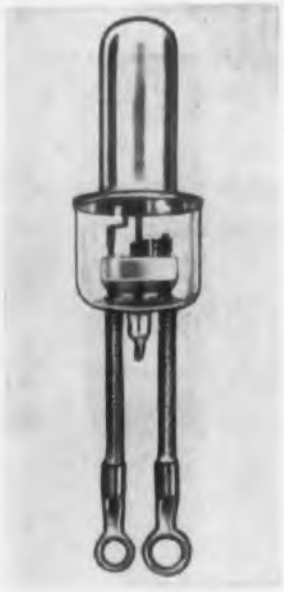
be connected in series by using shunting resistors across each.

The cell mounting device, shown in Fig. 1, is a standard stud rather than a tapered stud. This means that the rectifier can be bolted to a plate with a conventional nut and pulled up tight. A tight fit between the cooling plate and the body of the rectifier is needed for good heat transfer; this is difficult of accomplishment with tapered pipe thread. The G.E. design provides a hex-head so that the cell assembly can be held with an open-end wrench. Any strain in mounting is on the stud, not the cell. A heavy braided power take-off lead insures a reasonably low resistance path and at the same time contributes substantially to the cooling of the cell.

Enclosed is a hermetically sealed package of ceramic and stainless steel, the construction of which is shown in Fig. 2. The silicon wafer is adequately protected for field environments. This construction has been used very successfully over a long period of time with germanium rectifiers.

For further information on this silicon rectifier, turn to the Reader's Service Card and circle 40.

New Products



External Anode Tube
Power Diode

This thermionic power diode is designed for air or liquid immersed operation. As a rectifier, the 545 provides an average plate current of 50 ma dc and is rated for EPX 5 kv. Weighing less than 0.7 oz, the tube is 2 in. long, 7/8 in. wide and has a shock rating of 300 g. Maximum bulb temperature is 265 C.

United Electronics Co., Dept. ED, 42 Spring St., Newark, N.J.

CIRCLE 42 ON READER-SERVICE CARD FOR MORE INFORMATION

Instant Reset Delay
No Wait to Recycle

Type BR time delay relay resets instantly when its energizing circuit is interrupted, either during the timing cycle or after its completion. The unit contains thermal and magnetic elements mounted in a single case. The total delay interval comprises a brief heating period followed by a longer cooling period, and the output contacts operate when this total cycle has run to completion. The thermal elements at this point are cool and ready for another timing cycle. Short energizing pulses may be repeated indefinitely without causing contact operation.

Type BR units are available for standard delay intervals of 2, 5, 15, 20, 30, 60, 120, 180 and 300 sec. Energizing voltage is 28 v dc. Time delay tolerance is ±10 per cent. Output contacts are either normally open or normally closed spst. Contacts are rated at 2 amp up to 230 v ac and 1 amp up to 32 v dc. Energizing power averages 6 w during the timing cycle. Ambient temperature range is −65 to +125 C and the device will withstand shock of 30 and 10 g vibration over the 5 to 500 cps range.

G-V Controls Inc., Dept. ED, Hollywood Plaza, East Orange, N.J.

CIRCLE 43 ON READER-SERVICE CARD FOR MORE INFORMATION

Diffused Junction Transistor
Dissipates 15 W at 100 C

This gaseous diffused-junction silicon transistor has a rated power dissipation of 37.5 w at 25 C and 15 w at 100 C, making possible high power transistorized servo and audio output systems for use in high temperatures. With a 2 amp collector current, the 2N389 features a maximum saturation resistance of 6 ohms. When used in aircraft applications, a 60 v collector-to-emitter rating allows power to be taken directly from the 28 v power supply.

This is the first commercially available transistor produced by a diffusion process similar in basic principles to the process announced by Bell Telephone Labs., Inc. in January, 1956. Operating temperature range is from −65 to +150 C. The transistor is projection welded in a metal case designed to meet the requirements of MIL-T-19500. All diffused-junction 2N389 high power units are stored at an ambient temperature of 185 C for 16 hrs and then temperature cycled before being electrically tested.

Texas Instruments, Inc., Dept. ED, 6000 Lemmon Ave., Dallas 9, Tex.

CIRCLE 44 ON READER-SERVICE CARD FOR MORE INFORMATION

Current Transformer
Weighs 13 Oz

Used for metering and relaying on airborne systems, the unit has a 250:2 amp current ratio and operates on 115 v, 3 phase, 4 wire, 400 cps systems. The transformer is molded from a new lightweight high-temperature insulating resin, and has a smooth, metallic finish and rounded edges. It will operate in ambient temperatures from −55 to +170 C. It will withstand vibration, shock, and extreme humidity normally encountered in aircraft systems and conforms to requirements of specification MIL-T-7210 for Type D-2 current transformers. The unit has a maximum height and width of 3.25 in., a hole diameter of 1.12 in. min, and weighs less than 13 oz.

Westinghouse Electric Corp., Dept. ED, P.O. Box 2099, Pittsburgh 30, Pa.

CIRCLE 45 ON READER-SERVICE CARD FOR MORE INFORMATION

Coaxial Attenuators
1000 to 10,000 Mc

These Broadband coaxial attenuators have type C connectors and cover the frequency range of 1000 to 10,000 mc. Units in these series are available in 1 db steps from 1 to 10 db. Model 520, 521, and 522 have various combinations of male and female connections.

Typical Properties of 3 db Unit, Model 520-3 are: 5 w Average, 10 kw peak power input; accuracy at 4 kmc of 3 ±0.1 db, and maximum frequency sensitivity, from 1000 to 10,000 mc, of 0.4 db.

Weinschel Engineering, Dept. ED, 10503 Metropolitan Ave., Kensington, Md.

CIRCLE 46 ON READER-SERVICE CARD FOR MORE INFORMATION

Switch Actuator

Requires 40 Grams

The ATM-1 actuator requires 40 g maximum to operate the snap action of a USM switch. When used with this basic switch, pre-travel is 1/8″ and over-travel is 1/32″ approximately. The actuator mechanism, furnished separately from the switch, may be used with all USM Series switches. These switches are manufactured for use up to 275 F and will satisfy MIL-S-6743.

Division of The Maxson Corp., Dept ED, Ives Road, Wallingford, Conn.

CIRCLE 47 ON READER-SERVICE CARD FOR MORE INFORMATION

Scintillation Well Counter

Radioactive Measurement

Model DS5-5 contains features not previously available in radiation detectors of this type. These include: a scaler-spectrometer circuit which permits use of the detector with any scaler, ratemeter, or gamma-ray spectrometer system; more than 2 in. of lead shielding surrounding the sodium iodide well crystal to reduce cosmic ray and other background to a minimum; a position lock at the side of the lead shield to enable the operator to move the detector to any height; and a detector which can be removed from the lead shielding to permit substitution of alpha, beta, or solid gamma sensitive crystals for the well crystal.

The instrument permits accurate measurement of gamma sources with activities as low as 10^{-5} microcuries. Overall sensitivity is approximately 50 per cent. Background counting rate when used with a scaler or ratemeter is approximately 300 counts-per-minute and is reduced to 20-30 counts-per-minute when used with a gamma-ray spectrometer system. Count rate is independent of sample volume up to 5 milliliters.

Nuclear-Chicago Corp., Dept. ED, 229 West Erie St., Chicago 10, Ill.

CIRCLE 48 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Voltage Check Panel
Null Type Calibrator

A specialized voltage check panel, Model 7102 is for use as a null type calibrator with strain gage power supplies. Specifications are as follows: Power, self contained battery guaranteed one year in normal usage; voltage adjustment, 10 turn potentiometers; reference voltage, Model 4 type 3 standard cell; ±0.01 per cent null meter, 1.5 μamp for 5 deg deflection at null, 300 μamp continuous without damage. When used with Model 7P01 strain gage power supplies, the output voltage may be adjusted to 10 v dc, ±0.02 per cent with this instrument. This unit is rack mounted on 7 x 24 in. panel.

Western Gear Corp., Dept. ED, P.O. Box 182, Lynwood, Calif.

CIRCLE 64 ON READER-SERVICE CARD

Power Amplifier
For L and S Bands

The Series 411 power amplifier is a cavity amplifier specifically designed to utilize the 2C39B Lighthouse Triode of ceramic construction, covering the range from 1,250 mc to 2,400 mc. The cavity features a gain of 10 db to 15 db with a minimum rf output of more than 20 w. It has a resonant anode cavity with four tuning slugs, for a maximum tuning range of 100 mc. The cathode section is coaxial line, and can be adjusted by knob or screwdriver for a tuning range equal to that of the anode section. Input and output connections are 50 ohm loop couplings, with Teflon insulation on input line to minimize rf losses. External grid biasing is provided to allow accommodation for metering grid drive. All electrical surfaces are silver and rhodium plated. External surfaces are nickel-rhodium or anodized. Aluminum alloys are used wherever possible, for lightweight construction.

Amerac, Inc., Dept. ED, 116 Topsfield Rd., Wenham, Mass.

CIRCLE 65 ON READER-SERVICE CARD

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Voltage Check Panel
Null Type Calibrator

A specialized voltage check panel, Model 7102 is for use as a null type calibrator with strain gage power supplies. Specifications are as follows: Power, self contained battery guaranteed one year in normal usage; voltage adjustment, 10 turn potentiometers; reference voltage, Model 4 type 3 standard cell; ±0.01 per cent null meter, 1.5 μamp for 5 deg deflection at null, 300 μamp continuous without damage. When used with Model 7P01 strain gage power supplies, the output voltage may be adjusted to 10 v dc, ±0.02 per cent with this instrument. This unit is rack mounted on 7 x 24 in. panel.

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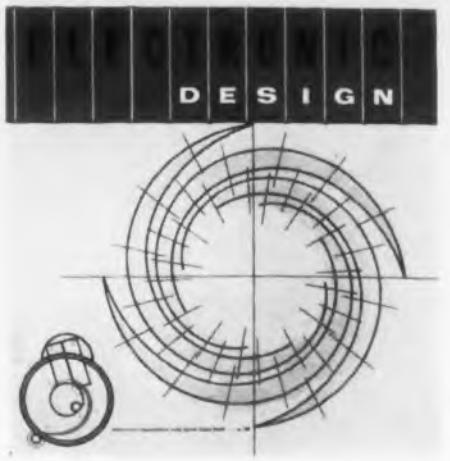

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Searching Electronic Patents, by John T. Milek (p 22) A compilation of source material on what has been patented.

Germanium Rectifier for TV (p 26) Low cost power rectifiers for improved reliability. (General Electric Co.)

Vibration Tube Testing, by Lewis B. Martin (p 28) A study of microphonics and fast, accurate vibration test methods.

Printed Circuit Heat Exchanger (p 32) A heat exchanger for efficiently cooling closely mounted printed circuit boards. (United Aircraft Products, Inc.)

Military Standardization of Dummy Loads, by Leon Field and Arthur C. Metzger (p 34) Processes and problems involved.

Automatic Interpolation with Spiral-Scale Dials, by Christian D. Berger (p 38) Operation, applicability and design equations for an automatic interpolation dial.

Ceramic Film Resistor (p 42) A new deposited metal film ceramic type precision resistor featuring high physical strength. (Weston Electrical Instrument Corp.)

Radiation Absorbers, by Donald J. Newman (p 44) Electromagnetic energy absorbers simulating free space in the vhf, uhf, and microwave regions.

RF and IF Amplifier Design with Conductance Curves, by Keats A. Pullen, Jr. (p 48) Design of tuned rf stages including variable gain amplifiers and limiters.

Ideas for Design (p 90)—No Mistake Dial; Transistor Circuits; Simplified Testing of Printed Circuit Laminates.

What the Russians Are Writing (p 102) Annotated table of contents of Avtomatika i Telemekhanika, August 1956; annotated list of new Russian books on electronics. (Russian Translation)

Russian Wire and Cable (p 106) A list of Russian wire and cable for winding and hookup with descriptions. (Russian Translation)

Printed Wiring in Three Dimensions (p 108) Application to computers and approach to cabling problems. (Abstract)

True Motion Radar (p 112) A system offering a more dynamic presentation of marine traffic. (Abstract)

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Design for Molding Small Plastic Parts, by George A. Scherry (p 22) Basic considerations in molding small parts from thermosetting plastics at low cost.

Series-String Tubes, by Robert M. Hughes (p 26) Problems in switching to series-string tubes.

Subminiature Potentiometer (p 30) High resolution, rugged wirewound quarter watt unit. (Miniature Electronic Components Co.)

Printed Circuits for Military Equipment, by J. K. Scott (p 32) Difference in requirements, techniques, materials, and packaging for military and commercial applications.

Selecting Plastic Materials, by R. R. Moyer (p 36) Many factors contributing to proper choice of plastic materials.

Oriented-Ceramic Permanent Magnet (p 38) New high energy magnets. (Indiana Steel Products Co.)

Selection and Application of Precision Film Resistors, by P. Nuyl and C. Wellard (p 40) Check-off lists and specific application hints.

Closer Crystal Oven Temperature Control, by Maynard D. McFarlane and Ramey B. Metz (p 44) Better regulation of oven temperature without moving parts using the change-of-state principle.

Binary Code Indicator (p 48) Indicators which can display, store, or transfer data in accordance with a predetermined binary code. (Union Switch & Signal Div. of Westinghouse Air Brake Co.)

Ideas for Design (p 112)—Triple Coincidence Thyratrons; Tube Pin Cleaning; Light Deflection-Yoke Cores; Rubber "Safety Glass" Interlayer; Glass-Filled Silicone; Acrylic Implosion Shields; Circuits for Low-Cost Transistors.

What the Russians Are Writing (p 132) Annotated tables of contents of Elektrosviaz', August 1956, and Radiotekhnika, August, 1956. Announcement of new Russian literature. (Russian Translation)

Amplifier With 1 Cycle Bandwidth (p 136) High-selectivity amplifier for noise spectroscopy. (German Abstract)

Heat Dissipation—Transistors Vs. Tubes (p 138) A comparison of permissible temperature and space requirements for transistors and tubes as a function of signal level. (Abstract)

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Junction Transistor Counters, by A. William Carlson (p 28) Discussion of various transistorized counters.

Centimeter Dry Calorimeter (p 32) Microwave power measurements from 18 to 26.5 kmc. (Polytechnic Research and Development Co.)

Simplified Calculations for Servo Function Generators, by Holton E. Harris and Rawley D. McCoy (p 34) Function generation by resistance loading on tapped servo potentiometers.

Compact Broadband Coaxial Hybrid Ring (p 38) Broadband operation with excellent isolation and balance. (Bogart Manufacturing Corp.)

Noble Metal Wire for Precision Potentiometers, by Adolph Cohn (p 40) The use of new alloys for low noise level potentiometers.

Conductive Rubber Resistance Cards (p 44) Uniform resistance over a wide microwave frequency range through a unique plastic laminating process using conductive rubber (U. S. Rubber Co.)

Silicon Diode Application Notes, by Arnold Bergson (p 46) Equations and criteria for designing practical circuits.

Collet Fitting Knob (p 50) Locking collet, eliminates knob slippage due to set-screw loosening. (Dale Products, Inc.)

Trends in Components (p 52) A review of some papers presented at the 1956 Electronic Components Symposium.

Integral Mold Connectors (p 56) An entire connector assembly, including contacts, leads and special inserts–by a new single-shot injection process. (Alden Products Co.)

Microwave Film Resistors, by Bernard Rosen and Robert Saul (p 58) Partial solution to requirement for resistors with properties alike at dc microwave frequencies.

Switching Transistor (p 62) A high power transistor with a maximum power gain of 30 db. (Delco Radio Div. of General Motors Corp.)

Coaxial Switching Connector (p 64) An unusual connector which may be used as an SPDT switch at rf and video frequencies. (Tru-Connector Corp.)

Ideas for Design (p 168)—Simple Transistor Test Set; Tube Cooling With Chimneys.

Russian Television Camera Tube (p 180) A new photoconductive TV pickup tube of the vidicon type. (Russian Translation)

What the Russians Are Writing (p 184) Annotated tables of contents of Radiotekhnika i Elektronika, April and May 1956. (Russian Translation)

Applications of Travelling Wave Tubes (p 188) Use of TW tubes as wobbulators, frequency multipliers, or oscillators. (German Abstract)

A DC Restorer (p 190) A circuit which minimizes effective shunt capacitance. (German Abstract)

A New UHF Diode (p 191) Features a frequency range up to 1000 mc. (German Abstract)

Audio Spectrum Analyzer (p 192) A tone frequency spectral analyzer covering dc to 20.5 kc. (German Abstract)

Versatile Holder for Dielectric Measurements (p 194) A specimen holder to be used with a bridge or resonant circuit in determining electrical properties of dielectrics over a wide temperature and frequency range. (Abstract)

British Component Developments (p 196) Interesting examples of British developments in resistors, capacitors and magnetic materials. (Abstract)

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Report on Power Transistors for Converters, by B. Reich (p 22) The present status of power transistors with respect to their mechanical and electrical reliability is outlined.

High Power Silicon Rectifier (p 24) A single 3 φ full wave bridge silicon rectifier unit replaces 6 hard tubes, reduces circuit complexity. (Bogue Electric Mfg. Co.)

Corona Discharge VR Tubes, by N. Anton and M. Youdin (p 26) Erratic starting of corona regulator tubes has been remedied by introducing a small amount of radioactive isotope. Characteristics and application notes for these tubes discussed.

Stretchable Cable (p 28) High current cable stretches to twice its relaxed length. (United Cable Div.)

Optimizing Airborne Electronic Equipment, by S. Hubelbank (p 30) Highlights of MIL-E-25647 of Sept. 1956. The primary objective of the spec is overall optimum equipment design.

Fire-and-Overheat Detectors (p 32) Using newly-developed inorganic salts, this detector exhibits a very sharp temperature-resistance response, does not "average". (Fenwal, Inc.)

Fast Digital Printer with Analog Output (p 34) Recorder prints 11-digit lines at 5 lines per sec, produces a simultaneous analog output to feed into a separate graphic recorder. (Hewlett-Packard)

Aeronautical Electronics Problems (p 36) Problems and trends in airborne electronics brought up in a recent annual meeting of the Institute of Aeronautical Sciences.

Ideas for Design (p 84) Balancing an Inclined Chassis; Hi-Voltage Insulator Bushings; Flush Mounting for Controls; Bearings Need No Lubricant.

What the Russians Are Writing (p 94) A review of technical articles that have appeared in recent Russian periodicals. (Russian Translation)

Design of Wide Band Transistor Amplifiers (p 98) Approximate formulas for the frequency response of emitter-coupled amplifiers are used in the design of amplifiers which havs a band width exceeding 20 kc. (German Abstract)

Measurement of Core Losses at High Densities (p 100) A new technique for determining ferromagnetic core losses at high flux densities, developed at the National Bureau of Standards. (Abstract)

Transistorized Telephone "Bell" (p 102) This transistor-operated tone ringer may replace the conventional telephone bell. Circuit is shown and description of operation given.

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Transistors Can be Reliable, by C. H. Zierdt, Jr. (p 22) Transistor characteristic changes and effect on theoretical reliability.

High-Strength Electrical Conductor (p 26) New cable with higher breaking strength and flex life. (Hi-Temp Wires, Inc.)

Epoxy Foams, by L. Bolstad and A. Stenerson (p 28) Properties and status of epoxy foam insulating materials is reported.

Mag-Amp Motor Control (p 32) A passive device to regulate the speed of a series-wound universal motor within ± 5 per cent over the full torque range from 0 to 100 per cent. (CGS Labs, Inc.)

Miniature Strip Transmission Line and Components—I, by E. N. Torgow and J. W. E. Griemsmann (p 34) Deals with the versatility and important characteristics of strip line and strip line components.

Tunable Stalos (p 38) Description of stable local oscillators which are tunable over a range of 10 per cent of center frequency. (Pitometer Log Corp.)

Molded Printed Circuits (p 40) Clever but simple molded printed circuit design for use in an inexpensive automatic component assembly machine. (Die-Form Circuits, Inc.)

UV-IR Photometer (p 44) The use of transistors resulted in a precision portable photometer design and manufacture. (Servo Corp of America)

A New Family of Transistor Switching Circuits (p 46) A number of outstanding advantages are gained by a new circuit using direct-coupled pnp and npn transistors, dual-range circuits. (AIEE Winter General Meeting Report)

Transistor NOR Circuit Design (p 48) Design of a transistor NOR circuit producing a single logic element. (AIEE Winter General Meeting Report)

Ideas for Design (p 72) Making Printed Circuits in the Laboratory; Transistorized Transmitter; Push-Pull Flexible Control; Visual Commutator Inspection.

Cathode Follower Nomogram (p 88) A working nomogram for computing the output impedance and bandwidth of a cathode follower. (Russian Abstract)

What the Russians Are Writing (p 90) Devoted to papers dealing with radio engineering and electronic phases of the design of high-energy proton accelerations. (Russian Translation)

Measuring Techniques for Nonlinear Networks (p 92) Method is presented for determining the even-harmonic content of a distorted signal. (German Abstract)

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Design Procedures for Semiconductor Regulated Power Supplies, by S. Sherr, P. Levy and T. Kwap (p 22) The article describes design procedures and shows several practical circuits, with calculated and measured performance data.

A Review of Modulators and Their Requirements, by M. H. Zinn (p 26) Operational factors and circuit requirements and their relationship to the modulator device are reviewed; advantages and limitations of various modulator types are discussed.

Versatile Current Stabilizer (p 30) The Current Governor can be used as a constant current source, an ammeter calibrating reference and for various voltage and component tests. (North Hills Electric Co.)

Purchase Specifications for Pulse-Forming Networks, by J. W. Trinkaus (p 32) A guide listing the salient items to be included in a purchase spec.

Miniature Strip Transmission Line and Components—II, by Eugene N. Torgow and John Griemsmann (p 36) The design of various strip line components for miniaturization.

Simplified Coincident Motion Picture Sound Using a Tape Recorder (p 40) The design of an inexpensive, technically straightforward sound track for all film sizes and speeds.

Elapsed Time Indicator (p 44) The Chronistor is an electro-chemical device that measures total number of hours of operation, fits into a 3AG fuse clip. (Bergen Laboratories)

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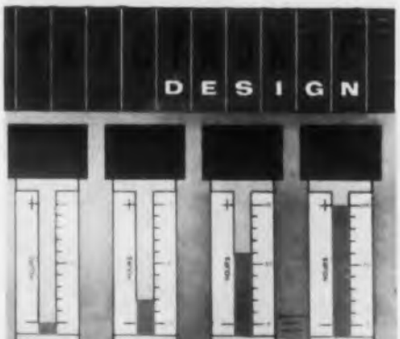

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High-Efficiency Crystal Detector Mounts (p 46) Used for frequencies between 500 and 4500 mc, provide a video gain improvement of 2 to 6.5 db. (American Electronics Laboratories)

Ideas for Design (p 120) Improved Radar Target; Spring Washer Cartridge; Edge Trim for Sheet Metal; Preferred AFC Circuit; Beryllium Spring Solves Fatigue Problem.

The Regeneration Method in the Design of Transistor Amplifier Stages, by J. George Adashko (p 134) Defines the regeneration coefficient as applied to a transistor-amplifier stage and tabulates the coefficients for different circuit types. (Russian Translation)

Electronic Test Image Generator (p 138) Adjustable video signal, easily duplicated. (German Abstract)

Transistor TV Deflection System (p 140) Transistors are used in a TV deflection system; circuit diagram is given. (Abstract)

Radio Communication in Tunnels (p 140) The problem of economical communication in tunnels is solved by using a continuous transmission line for a radiating antenna. (Abstract)

Backward-Wave Oscillators (p 144) Two bwo's for use as voltage-tunable local oscillators. (Abstract)

The Clamp-Type AC Microammeter (p 146) Capable of measuring microamperes over a side band of audio frequencies, this experimental, 7-transistor circuit is shown. (Abstract)

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Reliability in Electrical Connections, by R. George Roesch (p 20) A survey of problems involved in making electrical connections, soldering, fluxing, et al.

Adjustable Precision Resistor (p 26) Socket head screw adjustments are used to vary the resistance from 1 K to 200 M. Coarse and fine adjustments featured. (Clark Electronic Laboratories)

Jamming Figure of Merit for Radar Designers, by A. Mandell and W. G. Madison (p 28) A hand calculator for determining the cross-over point (the distance at which a radar target can be detected through jamming noise) of any radar.

Brushless Alternator (p 30) This dc-excited salient pole synchronous alternator has no brushes or slip rings; only rotating part is a smooth cylinder. (Bekey Electric Co.)

Broadband Microwave Amplifier (p 32) The Platinotron is a crossed-field vacuum tube used to generate microwave energy. (Raytheon Mfg. Co.)

500 C Insulator (p 34) Supramica 560, a moldable ceramoplastic insulating material, with stands 500 C ambient. (Mycalex Corp. of America)

Designing With Modular Enclosures (p 36) Involving no packaging development cost, modular cabinets also save time when used for prototypes to prove out a design.

Sweeping Power Supply (p 40) For general-purpose laboratory use with traveling-wave tubes, this supply delivers an exponentially increasing output with linearly increasing input. (Alfred Electronics)

Design for Service (p 42) Meeting report of the *Instrumentation and Control In the Process Industries* conference.

Transformer Design Nomograph—I, by M. Berger (p 44) An Iron Core Inductance nomograph is shown. It is intended to aid in designing small audio transformers and filter coils.

Ideas for Design (p 78) Hybrid Hi-Fi Amplifier; Convenient AC Outlets; Quick Hole Seal; Appearance Design.

What the Russians Are Writing (p 92) A review of developments published in recent Russian periodicals. (Avtomatika i Telemekhanika)

Stabilization With Temperature Compensated Thermistors (p 96) Above 10 cps a thermistor acts as a constant resistance, while below this frequency it has a zero or negative differential resistance. This sluggishness makes it suitable for stabilization purposes. (German Abstract)

Analog Correlation System (p 98) Designed to measure the degree of correspondence between two wave train wave pairs. Schematic, block diagram, and theory is given. (Abstract)

May 15

Cooling Packaged Electronic Equipment—I, by A. Hay (p 22) Basic design principles of cooling and methods of natural air connection and metallic conduction are described and presented.

Relay-Operated Voltage Divider (p 26) High accuracy and reference standard stability is provided by this unit. (Julie Research Labs)

The Cryotron—A New Computer Device—By S. Parker (p 28) This computer element is small, light, and dissipates little power. A large-scale digital computer could be packed in 1 cu ft, dissipate one-half watt.

Direct Printed Circuits (p 32) Silver inks can be printed on virtually any material; circuits produced may have excellent flexibility and conductance characteristics. (J. Frank Motson Co.)

Oscillator Design Techniques Using Conductance Curves—by K. Pullen (p 34) Some notes on oscillator theory are given and design procedures for developing regenerative detectors and oscillators, Q-multiplier oscillators, RC oscillators, and 3 phase RC oscillators. An outline of the requirements for oscillator stability is presented.

Transformer Design Nomograph—II, by M. Berger (p 38) Used for computing the reactance of known components and the capacitance needed to tune a given inductance. Frequency limits between 60 and 400 cps.

Extra High Resistivity Potentiometer Wire (p 40) Resistances up to 1100 ohms per mil foot are possible using palladium–gold iron alloys (Baker and Co. Inc.)

Modular Instruments (p 42) Rack, stack and carry instruments are designed to be mounted or stacked without sacrifice of space, efficiency or performance. !Teletronics Lab, Inc.)

Miniature One-Shot Power Supply (p 44) An output of 28 v at 700 w is produced for 2 min by this miniature silver-zinc battery. (Frank R. Cook Co.)

Broadband Ceramic Klystron (p 44)—This reflex Klystron has ceramic insulation, a continuously variable output frequency from 1500 to 6000 mc. (Polarad Electronics Corp.)

Performance and Packaging of Modulators, by M. Zina (p 46) A review of the performance and packaging factors imposing limits on the design of radar modulators.

Rigidized Flexible Waveguide (p 50) Flexible waveguide can be rigidized by application of a paste-like compound which hardens into a strong, lightweight jacket. (Technicraft Labs, Inc.)

Determining Transistor Reliability, by B. Reich and H. Wood (p 52) This article compares the results of operating and non-operating life tests in an effort to reduce the problem of component overspecification.

Ideas for Design (p 112) Transistorized Sawtooth Amplifier; Surge Limiting Device; Simplified Potting; Three Bolts Do the Work of Four.

What the Russians Are Writing (p 130) Devoted to semiconductors and their applications in engineering; annotated table of contents of Radiotekhnika i Elektronika, August 1956. (Russian Translation)

A New Photocell for Infra-Red (p 134) This photocell uses a lead sulfide semiconductor whose resistance is proportional to infra red radiation. Characteristics given. (German Abstract)

Ionization Chamber Time Delay Relay (p 136) Use of an appropriately designed ionization chamber permits time delays up to several hours with a rather small capacitance. (German Abstract)

Transistors in a Reactor Field (p 138) Transistorized electronic equipment for use in a Nuclear field should take into account transient, semipermanent and permanent designing effects. (Abstract)

Transistorized Phase Discriminator (p 139) High sensitivity and temperature stability between +125 and −55C obtained with this device. Schematic given. (Abstract)

Portable Frequency Standard (p 140) Circuit schematics and general description of a compact frequency standard requiring only periodic connection to a commercial power line is presented. (Abstract)

Interference Control Through Design (p 142) Greater reliability, improved performance, longer life and less maintenance for any equipment will result from observing the design principles outlined. (Abstract)

Microwave Noise Generation (p 144) A good quality noise source useful for radar jamming and producing signal strengths of the order of 1μw per mc over a broad band is described.

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Ferrites—1957 (p 20) The composition and material properties of ferrites are dealt with, along with an exposition of the various fields of application. Emphasis on rf-device cores, rectangular hysteresis loop toroids and broadband microwave devices.

Heater Voltage-Current Relationships, by A. Szilasi (p 24) Tube heaters act as nonlinear resistances; law governing this empirical fact is examined and discussed.

A Q-Probe for RF Monitoring, by R. Baer (p 26) A means of inspecting a transmitter modulator carrier by sampling the rf signal and displaying it on a scope is presented.

Blocking Oscillator Transformers (p 30) Miniature plug-in pulse transformers for use in NBS-"preferred" circuits have been developed. (Airpax Products Co.)

Modular Preferred Circuits (p 30) Twenty-three single tube modular circuits are provided in a kit, together with the NBS "Preferred Circuits Handbook." (Dale Boison Co.)

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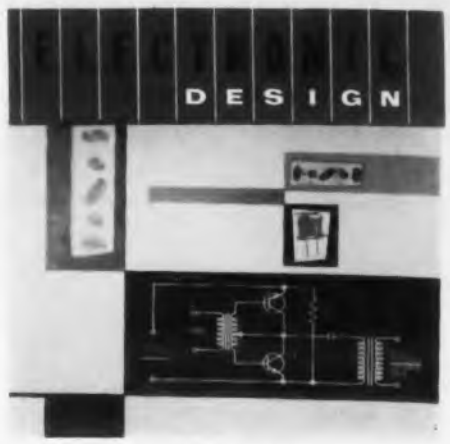

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Design of Mixers Using Conductance Curves, by K. Pullen, Jr., (p 32) Diode, triode and multigrid mixer design using transconductance characteristics is exposed. Examples given.

Transformer Design Nomograph—III, by M. Berger (p 36) Intended for use in designing small audio transformers and filter inductances. Given two parameters of dc magnetizing force, number of turns or type core, the third may be found.

A High Input Impedance Transistor Circuit, by P. Anzalone (p 38) Presents a design method for increasing the obtainable input impedance orders of magnitude beyond that observed for conventional transistor circuits.

Developments in Printed Antenna Design, by J. McDonough, R. Malech, J. Kowalsky (p 42) End-fire and broadside arrays practical for microwave frequencies, using etching techniques.

Continuously Variable Coaxial Attenuator (p 46) An insertion loss of 1 db instead of 15 to 20 db for previous piston type models is obtained. (Douglas Microwave Co.)

Cooling Packaged Electronic Equipment—II, by A. Hay (p 48) Methods of cooling are presented, together with design data to aid in selecting the right method for a given application.

Ideas for Design (p 102) Modular Design with Printed Circuit Connectors; Dielectric Fluid; Electrostrictive Relay; Polyethylene Stabilized by Electron Bombardment; Fidelity in Miniature; Tube Fitting for Flexible Tubing; Filled Nylon Thrust Washers for Vertical Shaft Motors; Adjustable Parts Bin.

What the Russians Are Writing (p 118) Contents of Radiotekhnika i Electronika No. 9, 1956; brief abstracts.

Amplifier Design with Simple HF Compensation (p 120) Pentode amplifier design, without making possibly erroneous assumptions concerning parameters. (Russian Abstract)

Classification of Crystal Oscillators (p 122) Crystal controlled oscillators as series or parallel resonant. (German Abstract)

Wobbulator with Large Frequency Deviation (p 124) For the visual examination of amplitude characteristics of two terminal pairs. Large-frequency-swing wobbulator development is described. (German Abstract)

June 15

Selecting Plastic Laminates, by Norman A. Skow (p 22) Aids to initial selection of plastic laminates with cost related to dissipation factor, dielectric strength, and water absorption.

Direct Coupled Transistor Logic Complementing Flip-Flop Circuits—I, by E. G. Clark (p 24) An investigation into building-block circuits utilizing direct-coupled transistor logic.

Vacuum Coaxial Relay (p 28) A high power coaxial transmission line switching relay which permits switching under full power up to 1100 mc. (Jennings Radio Mfg. Corp.)

Electronically Modulated Transistorized DC Amplifier (p 30) Modulated entirely by electronic means, this all-transistor dc amplifier uses no mechanical chopper. (Texas Instruments, Inc.)

Resistor Performance Levels, by Ralph Osche (p 32) Performance characteristics of general purpose composition resistors, deposited carbon film resistors, and the new pyrolitic film resistors.

3-D Printed Circuit Laminate (p 36) The first commercially available three dimensional molded and laminated printed circuit board. (Rogers Corp)

Basic Standards for Science and Industry—I, by R. Huntoon (p 38) A fundamental approach to basic standards.

High Power Silicon Transistor (p 42) A diffused-junction silicon transistor applicable to transistorized servo and audio output systems. (Texas Instruments, Inc.)

Transformer Design Nomograph—IV, by M. Berger (p 44) A nomograph useful for calculations of wire size and mean turn lengths.

Ideas for Design (p 106) Transistorized Amplifier Design; Low Speed Indicator; 10-Minute Etching and Anodizing Process; Felt Lubrication Seals.

What the Russians Are Writing (p 126) Annotated tables of contents of Radiotekhnika, Sept. 1956, and the October 1956 issues of Radiotekhnika i Elektronika, Avtomatika i Telemekhanika, and Elektrosviaz'. (Russian Translation)

Status of Special Purpose Tubes (p 134) A brief review of the major trends in special purpose tubes. (Abstract)

Temperature Limited Diode

RMS Detector

Type 1236C diode is designed for service as a rms detector for differential voltmeters; as a rms detector for ac voltage and current stabilizers, or as a detector for dc voltage and current stabilizers. It has a T9 bulb with a Bakelite base of the 8 pin locking-in type D8-1. Its average operating characteristics are a cathode voltage of 1.9 v ac or dc, 440 ma and a plate voltage of 600 dc, 0.7 ma dc.

The Superior Electric Co., Dept. ED, 83 Laurel St., Bristol, Conn.

CIRCLE 66 ON READER-SERVICE CARD

Pressure Lubricant

Bonds to Metal

Molykote, Type GX, is a molybdenum disulfide lubricant with a strong affinity for bonding to metal without building excessive accumulation on the surface. In Type GX the maximum effectiveness of MoS_2 as an extreme pressure lubricant in a grease is achieved by increasing the total surface area of the molybdenum disulfide through a reduction of particle size. This permits a sharp reduction of the MoS_2 content.

The decrease in particle size brings more molybdenum disulfide in contact with the metal while the reduction in solid content minimizes excessive surface accumulation.

The Alpha Molykote Corp., Dept. ED, 65 Harvard Ave., Stamford, Conn.

CIRCLE 67 ON READER-SERVICE CARD

Magnetic Tape

No Print Through

Layer-to-layer magnetic print-through has been reduced in order to cause no harmful effects during long storage. The reduction in print-through, amounting to 8 db as compared with present standard thickness tape, has been achieved without any change in the other characteristics, such as frequency range, signal-to-noise ratio, etc. Thus the tape is completely interchangeable on recording machines with standard tape.

Audio Devices, Inc., Dept. ED, 444 Madison Ave., New York, N.Y.

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CIRCLE 69 ON READER-SERVICE CARD ➤

APPLICATIONS

Electrical and Acoustical Measurements
Electrical Communication Systems (Selective Calling)
Remote Operation and Supervisory Control of Machinery and Apparatus
Electrical Computers and Telemetering Systems
Electro-Mechanical Bandpass Filters

Frahm Oscillator Controls, Type ROC, make possible the design and construction of inexpensive, precision tone generators that are small and light weight. These generators will have accurate output frequency and output voltage with very nearly sinusoidal wave shape.

They can be made with any one nominal control frequency between 20 and 1100 cps. They will control the output frequency of circuits, under specified conditions, constant within $\pm 0.15\%$ of the nominal control frequency.

We particularly encourage your inquiries and correspondence on special applications and problems. If you haven't explored these Frahm Oscillator Controls we'll be glad to send you complete specifications, characteristics, etc. Write for Bulletin 34-ED.

B-706

JAMES G. BIDDLE CO.
ELECTRICAL TESTING INSTRUMENTS • SPEED MEASURING INSTRUMENTS
LABORATORY & SCIENTIFIC EQUIPMENT
1316 ARCH STREET, PHILADELPHIA 7, PA.

CIRCLE 55 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Temperature Transducer

Glued to Surface

A surface-temperature transducer accurate between at least —320 and +950 F consists of a woven grid of fine platinum wire. It can be attached easily to any surface with a special dielectric cement, with the grid interstices providing good mechanical interlock. Purchasers can specify a 100 ohm change or more over an assigned temperature span of 100 to several hundred degrees. The device has a high thermal mass because of the grid design, and thus can follow rapid temperature transients closely. To go with the transducer, a lead tape composed of strands of fine silver woven into porous glass has been developed. It can be attached to surfaces with the same cement used for the transducer itself. The tape is available with either two or three conductors.

Charles Engelhard, Inc., Dept. ED, 850 Passaic Ave., East Newark, N.J.

CIRCLE 56 ON READER-SERVICE CARD FOR MORE INFORMATION

Variable Transformer

Isolated Secondary

Variable transformer type LW136 is a double wound assembly with an isolated secondary on a single core. The absence of an electrical linkage between the windings permits connections for its use as a source of adjustable low voltage output, a limited range line corrector or a limited range buck-boost variable transformer. The primary consists of two windings arranged for either parallel or series connection.

Any single phase unit can be connected for either 120 or 240 v, 50 to 60 cps input and can be used as a source of 0 to 30 v isolated output, as either a 120 or 240 v line corrector, or as a 120 or 240 v limited range buck-boost variable transformer.

The Superior Electric Co., Dept. ED, 83 Laurel St., Bristol, Conn.

CIRCLE 57 ON READER-SERVICE CARD FOR MORE INFORMATION

Coaxial Line Filters
VSWR of 1.06

These filters offer the following features: They have a vswr averaging less than 1.06 over the band, with maximum insertion loss on reject band (over 40 db) and minimum insertion loss in the band pass frequencies. To preserve contact integrity and longevity of corrosion resistance, precious metal plating is employed.

General Bronze Corp., Dept. ED, Stewart Avenue, Garden City, N.Y.

CIRCLE 59 ON READER-SERVICE CARD

Diode Mount
High Voltage

Type CS-84 diode mount, is designed for reliable operation at high voltages and altitudes. It is available in four internal thread sizes ranging from 6-32 to 1/4-28 to accommodate various makes of stud-type silicon diodes, rectifiers, and power transistors. Other thread sizes are available on order.

The mount consists of a copper-alloy body, terminal lug, and insulating sleeve brazed into one piece. The entire chassis serves as the heat sink, resulting in an overall thermal drop of approximately 1 C per w. Voltage rating is 1500 v at sea level.

Raytheon Manufacturing Co., Dept. ED, Ceramic Sales, Waltham 54, Mass.

CIRCLE 60 ON READER-SERVICE CARD

Finish Remover
For Epoxy Resin

Epoxystrip is an all-purpose finish-stripper. Tests prove it will remove paint, lacquer, enamel, and many other finishes from various metal surfaces, and is especially formulated to work on epoxy-resin finishes. After 20 sec following application, the treated epoxy-resin swells and pops off. It can be then flushed away with water. The metal surface is left clean and, after drying, is ready for refinishing. It does not remove or damage the bonderizing or phosphate coating.

Beck Equipment Co., Dept. ED, 3350 West 137th St., Cleveland 11, Ohio.

CIRCLE 61 ON READER-SERVICE CARD

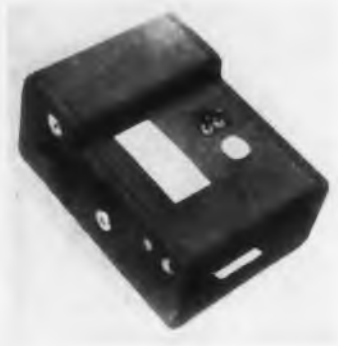
CIRCLE 62 ON READER-SERVICE CARD➤

Voltage Adjuster
Both Up and Down

The Model LVB-10 has a 250 w, 100 to 130 v 50 60 cps rating. It has a 4 position switch with 10 v boost; 10 v drop; straight through; and off positions. Finish is oven baked. The unit has a size of 3 x 3 x 3 in. in a weight of 2 lb.

Microtran Company, Inc., Dept. ED, 145 E. Mineola Ave., Valley Stream, N.Y.

CIRCLE 50 ON READER-SERVICE CARD FOR MORE INFORMATION



Gyro Drift Recorder
Drift and Random Only

The Model 2249 recorder is capable of detecting and recording with accuracy the minute increments of drift characteristic of high-precision gyros. The machine ignores Scorsby motion, dither, and other cyclic motions, while remaining highly sensitive to drift and random disturbances. The recorder provides a permanent record of the mean shaft position of any mechanical device that is subject to a gross symmetrical motion, such as Scorsby oscillation, dither, or sustained vibration. The pen motion is deliberately limited to a rate of 2 deg per min, resulting in an accurate plot of mean position, including low velocity relative motion, while ignoring cyclic motional velocities of unlimited amplitude, occurring at rates as low as 1 cy per min.

A 10 deg sector of shaft rotation is plotted across 2 in. of chart width. The chart is pulled past the pen at 12 in. per hr. The standard model is fitted with a synchro ct input device, compatible with any standard 26/11.8 volt 400 cycle synchro shaft pickoff device. The recorder can easily be adapted to work with other than synchro data pickoffs. About 2 va at 16 to 28 v, 400 cps nominal, is required for the reference input.

Lear Inc., LearCal Div., Dept. ED, 3171 South Bundy, Santa Monica, Calif.

CIRCLE 51 ON READER-SERVICE CARD FOR MORE INFORMATION

Speed Reducers

Interchangeable Parts

This in-line series of speed reducers, designated StraitLine, is available in double and triple reduction. Double reduction units are offered in 15 standard ratios from 3.39:1 to 57.3:1 with ratings up to 100 hp. Triple reduction units are available in nine ratios from 82.1:1 to 190.7:1 with ratings up to 50 hp. The reducers feature complete interchangeability of individual parts throughout frame sizes as well as packaged sub-assemblies.

Western Gear Corp., Dept ED, P. O. Box 182, Lynwood, Calif.

CIRCLE 53 ON READER-SERVICE CARD FOR MORE INFORMATION

Binary Decimal Counter

Maximum Speed 500 Kc

Model BDC-1 is a high speed transistorized counter. It utilizes a gated binary circuit reset to zero on the count of 10. The unit is packaged as a printed circuit card with input, output and reset available. Accessory cards are available for readout and preset. The counter cards may be used in multiple, each driving a succeeding stage from its output. Each printed circuit card together with its components measures 4-1/2 x 5 in. mounted on 5/8 in. centers. A 22-pin printed circuit connector is provided.

Power requirements are 12 v at 14 ma, 6 v at 1.4 ma and —12 v at 1.8 ma. Total power consumption per card is 0.2 w. Maximum speed is 500 kc. A 5 to 8 v negative pulse with a one-half μsec rise time produces a 5 v square wave at the output. The counter may be reset to zero by opening the reset lead. It may be preset electronically or manually to any number.

Ransom Research, Dept. ED, P.O. Box 382, San Pedro, Calif.

CIRCLE 54 ON READER-SERVICE CARD FOR MORE INFORMATION

Infrared Detector

Sensitive to 7 Microns

An infrared detector is available which is sensitive to seven microns and has a time constant of less than one μsec. Operating without the need for cooling or bias voltage, the detector has a noise equivalent power of about 0.001 μw.

Radiation Electronics Corp., Dept. ED, 8241 N. Kimball Ave., Skokie, Ill.

CIRCLE 72 ON READER-SERVICE CARD

Microwave Absorbing Materials

99 Per Cent Absorption

One of the two classes of these materials is wide band, while the other utilizes the interference principle. Both feature low reflectivity and high absorption at centrimetric wavelength. The absorbing materials, developed for S and X band frequencies, are fabricated of loaded rubber sheets bonded to brass gauze. AF 10 and AF 11 broadband dielectric materials are for use over the frequency range of 2500 to 50,000 mc with 99 per cent power absorption. M materials are backed with perfect reflectors and have a power absorption of 99.5 per cent.

Gulton Industries, Inc., Dept. ED, 212 Durham Ave., Metuchen, N.J.

CIRCLE 73 ON READER-SERVICE CARD

Cleaning Solvent

No Damage to Surface

SS-25 solvent has no flash at the boiling point and is a safe replacement for many inflammable petroleum solvents. It is corrosion free, leaves no residue, safe for all surfaces, and has never been found to contribute to dermatitis.

It is recommended for cleaning and degreasing electric motors, parts and components. SS-25 will not harm rubber or enamel insulation, and may be applied to any surface or part by a sprayer, either hand or air, by a brush, or by wiping with a soft saturated cloth.

National Disinfectant Co., Dept. ED, 2417 Commerce St., Dallas, Tex.

CIRCLE 74 ON READER-SERVICE CARD

◀ CIRCLE 71 ON READER-SERVICE CARD

DC to AC Power Supplies

One and Three Phase

These transistorized units produce up to 250 va from 28 v dc input, and custom units are available for up to 2 kva output. Units can be made to meet MIL specs, and can be as compact as 2/3 cu in. per va and as light as 1/2 oz per va. Typical of the series is model UAC 100 va/115-1000 which delivers 100 va (100 v ac, 1000 cps at 1 amp), weighs 3-1/2 lb and comes in a 3-29/32 x 3-11/32 x 5-7/32 in. package. Dc to 3-phase ac units are available for special applications.

Universal Transistor Products Corp., Dept. ED, 143 East 49th St., New York 17, N.Y.

CIRCLE 76 ON READER-SERVICE CARD FOR MORE INFORMATION

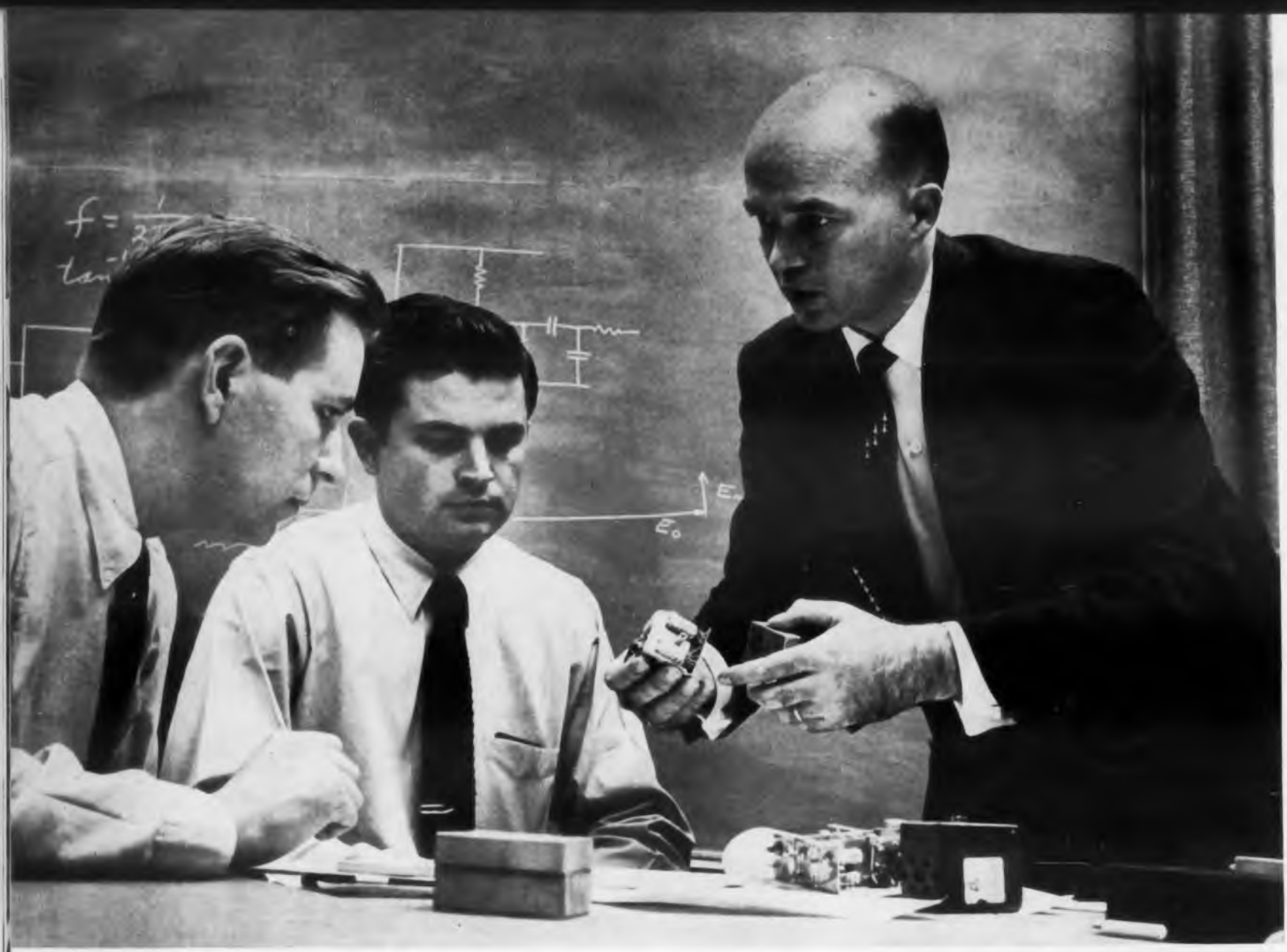
30 Oz AC Voltmeters

3 to 5 Per Cent Accuracy

These transistorized instruments measure 3-1/4 in. wide x 5-1/4 in. high and weigh 30 oz. Known as the D-21 series, the three voltmeters provide coverage, respectively, of the frequency ranges 10 cps to 1 mc, 5 cps to 500 kc, and 10 cps to 500 kc. Accuracy is better than ±3 per cent throughout most of range, and within ±5 per cent full range. Readings from 1 mv to 300 v are available full scale; readings may also be made with accuracy down to 50 uv. Battery power plus high internal impedance insures low stray pickup and freedom from noise. The D-21 series voltmeters employ high alpha cut-off transistors. They may also serve as null indicators, broadband amplifiers, or sensitive ammeters when used with appropriate shunt resistors. For multiple-instrument installation, they are available in relay rack mounts containing from two to five voltmeters mounted side-by-side.

Alto Scientific Co., Dept. ED, 855 Commercial St., Palo Alto, Calif.

CIRCLE 77 ON READER-SERVICE CARD FOR MORE INFORMATION



George L. Larse (right), Group Engineer, Instrumentation and Development, discusses development of high performance FM sub-carrier oscillators for application in advanced telemetry systems with Electronic Research Engineers Hans Becker (left) and Jay Cox.

ELECTRONIC SYSTEMS FOR GUIDED MISSILES

Continuing advances in guided missiles require electronic systems possessing ever faster, more accurate perceptions and reactions. Problems faced by missiles engineers and scientists grow constantly in magnitude and complexity.

At Lockheed Missile Systems Division, Electronic Systems and Components Engineers receive the broadest possible responsibility in fulfilling their assignments. New activities have created positions in a wide range of areas, including:

- Command guidance involving development and application of radio frequency communication, pulse circuitry and control devices.
- Data transmission and telemetry involving development and application of antennas, transducers, VHF transmitters and receivers.
- Automatic data processing equipment requiring analog-to-digital conversion, and electronic and magnetic storage devices.

Positions are open on Lockheed's Palo Alto, Sunnyvale and Van Nuys Staffs. Those possessing a high order of ability in both systems and component development are invited to write. Please address the Research and Development Staff, Palo Alto 22, California.

Lockheed

MISSILE SYSTEMS DIVISION

LOCKHEED AIRCRAFT CORPORATION

PALO ALTO • SUNNYVALE • VAN NUYS

CALIFORNIA

New Products

Record-Reproduce Heads

Wide Range Available

Originally developed for use with the company's magnetic recording systems, ET200 Magnetic Recording Heads are offered in a broad range of electrical and mechanical characteristics. Typical of the ET200 line is the Type 2A Head, with an inductance of approximately 500 mh and a resistance of 200 ohms. Gap width is 0.00025 in.; the head has a track width of 0.05 in. Type 2A Heads measure 0.656 x 0.77 x 0.125 in. The heads are available either singly or in multiple-head blocks. They can be permanently imbedded or made individually replaceable. All hears are vacuum impregnated and potted in epoxy resin. Shielding is of Mumetal.

Electrodynamic Instrument Corp., Dept. ED, 2508 Tangley Road, Houston 5, Tex.

CIRCLE 80 ON READER-SERVICE CARD

Mounted Paper

For Durable Drawings

For drawings that are subject to frequent handling or alteration over a period of years, Stabilene opaque drawing film combines a high-grade paper with a muslin backing. Tear strength, durability, flexibility, and flatness, are some of its qualities. In addition, the film is fully resistant to moisture, where paper can be made only partly water repellent at best. The film will not smudge and can be wiped clean with a moist cloth. It has a dimensional stability of 0.000006 in. per in. averaged in both directions for temperatures from 80 to 220 F. and in the range from 0 to 98 per cent relative humidity. It takes pencil and ink well without feathering, penetration, or ghosting, even after erasures have been made. Very hard degree pencils may be used.

Keuffel & Esser Co., Dept. ED. Hoboken, N.J.

CIRCLE 81 ON READER-SERVICE CARD

◀ CIRCLE 570 ON READER-SERVICE CARD

Relays

1 Mw per Contact Sensitivity

Sensitivity in this series, Types 101, 102, 103 and 104, can be adjusted to as low as 1 mw per contact and is available in combinations from spst to tpdt. The dust cover is made of impact extruded aluminum and is available either with the removable bayonet cover, pressure fit or crimped covers. Screwdriver adjustment can be made to change contact pressures, pickup and drop-out characteristics, or power requirements.

The relays are designed with a thorough wipe action on the contacts for self cleaning for good contact connections. Pickup and drop-out ratios can be made as high as 85 per cent or as low as 10 per cent. Coil resistance is standard up to 30,000 ohms, and special winding to 100,000 ohms. Contact capacity ranges from 3 to 5 amp resistive, depending on sensitivity. The relays are made for either dc or ac operation; ac relays are made with built-in rectifiers or diodes. Mounting is available in standard plug-in headers or with solder lug terminals. Tests have indicated the life of these relays to be well over 25 million operations with no evidence of fatigue or deterioration on the contacts.

General Automatic Corp., Dept. ED, 12 Carlton Ave., Mountain View, N.J.

CIRCLE 83 ON READER-SERVICE CARD

Load Isolator

8.2 to 12.4 Kmc

Model X-121, a broadband load isolator, operates within a frequency range of 8.2 to 12.4 kmc. Forward attenuation is 1.4 db max. Reverse attenuation at band edges is 20 db max. Vswr is 1.25 max. Power handling capability is 200 w average, 200 kw peak. The unit is 9-1/2 in. long over-all and weighs 5 lb. Input and output flanges are UG-39/U.

Cascade Research Corp., Dept. ED, 53 Victory Lane, Los Gatos, Calif.

CIRCLE 84 ON READER-SERVICE CARD

How to be a magnetic tape recording expert

Introducing a useful new brochure on tape in instrumentation

Tape is the stuff of which memories are made — the versatile data memories for a jet propelled age of electronic miracles. If you are one who keeps up with times and techniques, it is a field well worth knowing. This new brochure gives a wide-angle view of the whole subject.

Typical pages

What kinds of applications do you think of when magnetic tape recording is mentioned? Sound recording, of course, and telemetering, if you are in that business. But what about simulating a rough road to test truck axles, controlling a milling machine to cut an aircraft wing section out of a solid billet, monitoring for a sudden occurrence that may happen only once in a year or two, recording data that can be reduced to graphs and tabulations without ever being touched by human hands? These and many more are described.

How significant is the fact that magnetic tape recording reproduces data in the same electrical form in which it was recorded? Enormously important, when you realize all the things the reproduced data can do that couldn't be done with the original signals or with the common forms of visual recording. For example the data can be slowed down to look at fast transients. It can be speeded up for wave analysis. It can be read out in any form. A tabular comparison between original signals and taped signals gives the full story. And a step-by-step pictorial demonstration of magnetic tape recording and reproduction puts the electrical-data idea into tangible, easily visualized form.

What does the data on magnetic tape look like? You can't see it, but the brochure will give you an idea of what it would be like if you could. And incidentally this may help to clarify the differences between various magnetic-tape-recording techniques.

Do you talk in tape's language? When is a tape recorder not a recorder? What is the difference between a channel and a track? What is a servo speed control? A much needed glossary gives the consensus of our views on terms.

For whom did we write this booklet . . . the expert, or the man for whom the whole subject is new? Both. It is written and illustrated so that any engineer or technically trained person can readily grasp the concepts and gain a broad understanding of the subject. If you are one of those who has already worked extensively with tape, you will find some new twists in the way the subject is explained, and perhaps ideas on new areas you hadn't explored. And incidentally, a copy of this brochure in some handy file will give you a good start in indoctrinating that new man in the department.

For your copy, write us today on your company's letterhead. Address your request to Department ZZ-5.

INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
934 CHARTER STREET · REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

CIRCLE 85 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

DC Power Supply

28 V DC Input

The REL-202 Power Supply transforms the standard 28 v dc aircraft power supply to high voltage dc. Transistors serve as switches to obtain a square wave ac which is stepped up through a toroidal wound transformer and then rectified to provide the dc output voltage. Output voltage and current from the connector, as determined by jumper position is +350 v dc at 110 ma, +300 v dc at 130 ma, and +260 v dc at 160 ma. Output power is 40 w, and ripple is less than 1.5 per cent. Regulations for load variations is 3.0 per cent, from 10 per cent to full load. Operating temperature range (no derating) is −35 F to +165 F.

Rheem Manufacturing Co., Dept. ED, 9236 East Hall Rd., Downey, Calif.

CIRCLE 87 ON READER-SERVICE CARD

Battery Connectors

Moisture Sealed

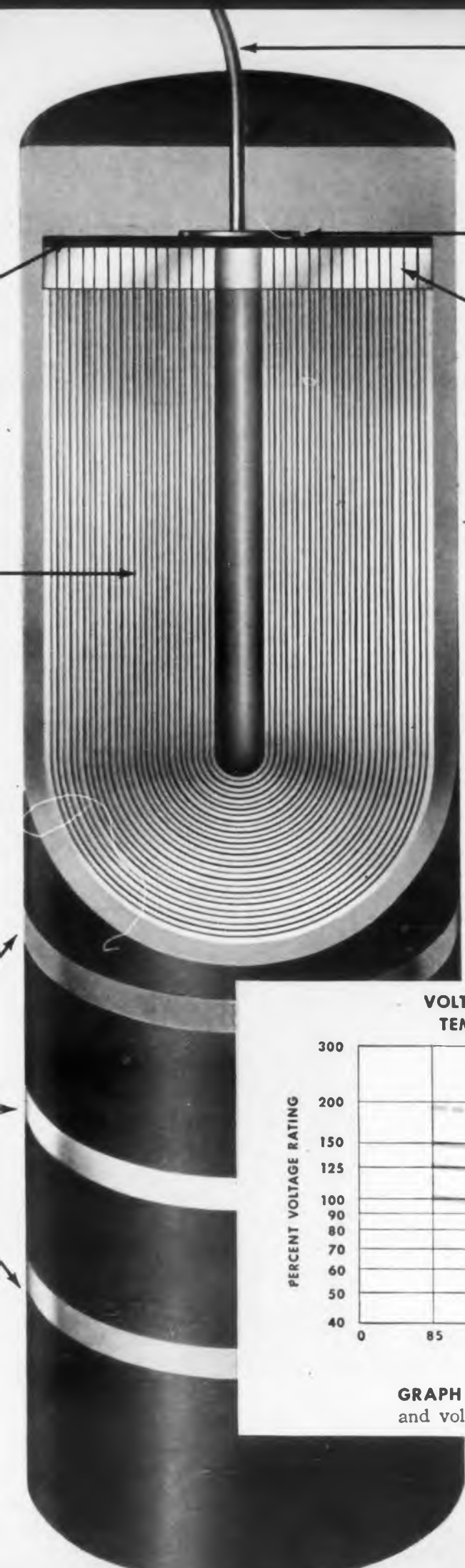
A moisture sealed, single pole battery connector has been designed for service up to 28 v dc at 300 amp. CA21986 receptacle is panel mounted and incorporates O rings for moisture seals on both sides of the panel and about the contact of the mating plug. The receptacle contains a bail latch that allows the plug to rotate 360 deg when mated and latched.

CA21985 plug incorporates a terminal lug for a no. 1/0 cable that is 90 deg to the contact. The socket terminal ends are designed for a no. 1/0 terminal lug.

Cannon Electric Co., Dept. ED, 3208 Humboldt St., Los Angeles 31, Calif.

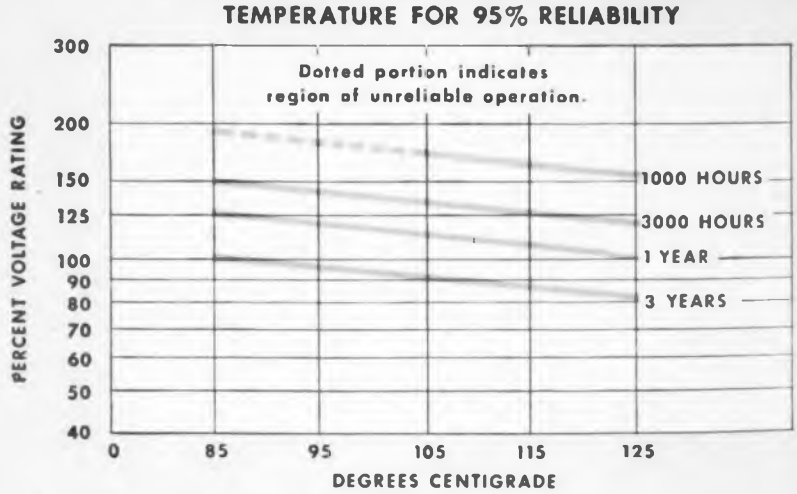
CIRCLE 88 ON READER-SERVICE CARD

CIRCLE 89 ON READER-SERVICE CARD ➤



CUTAWAY VIEW OF PVZ CAPACITOR ENLARGED 13 TIMES

VOLTAGE RATING VS LIFE AT ELEVATED TEMPERATURE FOR 95% RELIABILITY



GRAPH ABOVE shows outstanding temperature and voltage characteristics for 95% reliability.

Temperature Probe

0 to 1200 C

A miniaturized (.004 in.) high temperature resistance thermometer probe is capable of operation over a range of 0 to 1200 C. Probe allows measurement of high temperatures, by the resistance thermometer technique, in a small area. Utilizing a grid of extremely fine platinum wire welded to platinum lead wires, the probe is a flat grid temperature element wound on the end of a 1 mm tube. All temperature sensitive wires lie in one plane, giving grid resistance value of from 12 to 16 ohms at room temperature.

Arthur C. Ruge Assoc. Inc., Dept. ED, Cambridge, Mass.

CIRCLE 90 ON READER-SERVICE CARD

Fabric Reinforced Seals

Fluoro-Silicone Rubber

Fuel resistant, fabric covered and fabric reinforced seals for —65 to +400 deg F applications are being produced using LS-53, Dow Corning's fluoro-silicone rubber. The fabric covered seals provide high tear and abrasion resistance. The LS-53 fluoro-silicone rubber remains resilient, resists swelling and destruction by aviation fuel and synthetic oils at extreme temperatures. Although fluoro-silicone rubber costs considerable more than ordinary silicone rubber, fabric covered or fabric reinforced seal constructions provide the most practical and economical use of the rubber.

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

CIRCLE 91 ON READER-SERVICE CARD

◀ CIRCLE 89 ON READER-SERVICE CARD

New Products

Torque Motor
Unharmed by Stall Current

Designed for tape recorder take-up reel drive and capable of withstanding stall currents continuously, the SR-89 has a nearly linear speed-torque curve to stall. No-load speed is 2150 rpm. Double shielded, factory lubricated ball bearings are used. It weighs 5-1/4 lb.

Dalmotor Co., Dept. ED, 1375 Clay Street, Santa Clara, Calif.

CIRCLE 95 ON READER-SERVICE CARD FOR MORE INFORMATION

Pulsed Power Source
Combined L- and S-Band

Model PC-52 pulsed power source utilizes a Federal X-6825 traveling-wave tube and an Eimac X-551E klystron. Either L-band or S-band power is obtained by switching a common high voltage pulser to one tube or the other. The Federal tube produces up to 200 w of pulse power over the band from 2.7 to 2.9 kmc. The Eimac tube produces 1.5 to 3 kw pulse power over the band from 1.25 to 1.365 kmc. Pulse lengths are variable from 2 to 10 μsec at repetition rates from 200 to 450 cps.

System includes a built-in trigger generator capable of internal or external sync, a Maxson M1141 uhf power oscillator as the source of low level signal power, a Tektronix 315D oscilloscope for monitoring, a Hewlett-Packard 430C power bridge for power measurements, and both L-band and S-band directional couplers. Equipment requires about 4 kva of power from a 115-v, single-phase, 60-cps source.

Levinthal Electronic Products, Inc., Dept. ED, 758 Stanford Industrial Park, Palo Alto, Calif.

CIRCLE 96 ON READER-SERVICE CARD FOR MORE INFORMATION

Miniature DC Motors

Durable Design

Designated Series 500, these precision-built motors are designed to resist shock, heat and cold. Nylon-molded commutator hubs, lead insulators, motor brush supports and governor mounting base resist vibratory fatigue and are self-lubricating. Six series, 100 to 600, of small dc motors have torque ranges from 0.3 to 3-1/2 in. oz and speeds varying from 1800 to 18,000 rpm, for 3 to 24 v usage. The 500 and 600 series motors are available with governors for constant speed applications.

Allied Chemical & Dye Corp., Barrett Division, Dept. ED, 40 Rector St., New York 6, N.Y.

CIRCLE 97 ON READER-SERVICE CARD FOR MORE INFORMATION

One Ton Strain Gage

Total Excursion; 0.00035 In.

Measuring forces up to 2000 lb with a total excursion of 0.00035 in., these strain-gage force pickups are useful in measuring sudden forces applied to rigid physical structures such as rocket launching platforms and airframes. Either compression or tension forces may be measured, depending on how the instrument is mounted. The force pickups may also be used to test force-producing components such as solenoids. These pickups can measure initial solenoid output force as distinct from armature momentum. The pickups consist of a force probe, an unbonded strain-gage, and an electrical strain-gage connector built into a small cylinder. In operation, a pickup is mounted so that the force probe is in direct physical contact with the object under study. Linearity is within 0.5 per cent of full scale. Hysteresis is 0.25 per cent, maximum, full scale. Acceleration effects are limited to 0.005 psi per g. Temperature range is −65 to +350 F. Mounting threads are 1/2 in., no. 20. Units are constructed of stainless steel and weigh 2 oz.

Dynamic Instrument Co., Inc., Dept. ED, 28 Carleton St., Cambridge, Mass.

CIRCLE 98 ON READER-SERVICE CARD FOR MORE INFORMATION

HUGHES
SEMICONDUCTORS
First of all, for reliability

RELIABILITY

WHAT IT IS. At Hughes, reliability is the probability that a device will give satisfactory performance during a specific period of time when used in the manner intended. And at Hughes, the probability is high, approaching certainty.

HOW HUGHES ACHIEVES IT. With meticulous consideration to every detail, Hughes has accumulated extensive knowledge of the semiconductor art, extensive knowledge of all the subtle and delicate, yet critical, factors involved. To *really* know is essential. Then, and only then, reliability becomes an automatic result—built into every unit.

HOW HUGHES MAINTAINS IT. Hughes Quality Control is the "watchdog," checking and rechecking every phase of production on a carefully regulated statistical basis. This extensive effort ensures prompt discovery of any variation which might affect the ultimate quality—and the *reliability*.

HOW YOU OBTAIN IT. Specify Hughes, for the greatest possible assurance. For additional information, please write:

SEMICONDUCTOR DIVISION
HUGHES PRODUCTS
International Airport Station, Los Angeles 45, California

Creating a new world with ELECTRONICS

HUGHES PRODUCTS

HUGHES
SEMICONDUCTORS

CIRCLE 99 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Variable Delay Line

50 μSec Range

Model 103-10R provides for 50 μsec delay with 10 fully adjustable outputs. The closest pickup separation is 0.75 μsec, and the minimum pulse transmitted is 0.05 μsec. With a 1 μsec input pulse, attenuation is 45 db. The unit measures 1-3/4 x 19 x 4-1/4 in. back of panel.

Deltime, Inc., Dept. ED, 608 Fayette Ave., Mamaroneck, N.Y.

CIRCLE 101 ON READER-SERVICE CARD FOR MORE INFORMATION

Motor Generator

Miniature 400 Cps Supply

The Dalmotor MG-146 is 7-3/4 in. long over-all, 4-1/4 in. high, 4-5/8 in. wide and weighs 7 lb 5 oz. It is a two-bearing machine consisting of a dc motor and an alternator utilizing a common shaft. The unit delivers 100 va, 400 cps, at 115 v continuously. Output termination is a three phase Y with one leg grounded. Maximum harmonic distortion is less than 3 per cent. The MG-146 draws 7 amp at full rated load with input voltage at 28 v. Output voltage is maintained within ±7.5 v and remains within ±8 cps of 400 cps, with input varying between 25 and 29 v. The unit will deliver up to 200 va, twice its rating, for periods of up to 5 sec without causing output voltage to drop below 90 v even if input voltage is as low as 25 v. Both input and output circuits are equipped with rf filters. The alternator employs a permanent magnet rotor, obviating the need for slip rings. The governor-regulated, compound-wound dc motor runs at a rated speed of 8000 rpm. For special applications this unit can be provided with other input or output voltages and other output frequencies within the limits of the frame.

Dalmotor Co., Dept. ED, 1375 Clay St., Santa Clara, Calif.

CIRCLE 102 ON READER-SERVICE CARD FOR MORE INFORMATION

DC Power Supply

Three Outputs

This dc power supply has three simultaneous outputs rated at +300 v dc at 300 ma.; +150 v dc at 200 ma.; and —150 v dc at 200 ma. The unit operates on 208 v, 400 cps current and provides regulation against input and load better than 0.01 per cent. Long time stability is also rated at better than 0.01 per cent (24 hr).

The supply is designed to meet MIL-E-5400 specifications for operation from —50 C to +50 C at altitudes up to 50,000 ft. The unit weighs 68 lb and measures 10-1/2 in. high 17 in. wide and 17-1/2 in. deep.

Davenport Manufacturing Co., Dept ED, 1713 N. Ashland Ave., Chicago 22, Ill.

CIRCLE 103 ON READER-SERVICE CARD FOR MORE INFORMATION

Low-Level AC VTVM

Fits Into Standard Consoles

Designed specifically for panel-mounting, the Model 109-1 ac vtvm is suited for integration into test equipment or modular-type consoles. Its signal leads are so isolated that voltages may be measured between any two independent test points. The instrument is capable of reading as low as 50 μv. Twelve ranges from 1 mv to 300 v ac are provided with an over-all accuracy of 2 per cent of full scale. Input impedance is 10 meg and frequency response is 20 to 80,000 cps.

Having printed circuit construction, the 109-1 is simple to maintain. Two adjustments perform complete voltage and frequency calibration. Line voltage variations of 70 to 140 v do not appreciably affect readings or accuracy. Vacuum tubes may be interchanged or replaced without matching or preselection. The unit operates from a 115 v, 50 to 500 cps source. Its 5-1/4 x 9-1/2 in. panel, with standard RETMA notches and spacings, fits standard modular-type consoles.

Trio Labs., Inc., Dept. ED, 4025 Merrick Rd., Seaford, N.Y.

CIRCLE 104 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Rotary Grounding Switch

Three Positions

In such circuit applications as sensitivity controls, this switch permits easy adjustment of signal strength for local, intermediate and fringe reception. Simplified construction permits quick, low-cost assembly due to twist-tab mounting of switch to chassis or wiring board.

P. R. Mallory & Co., Inc., Dept ED, Indianapolis, Ind.

CIRCLE 107 ON READER-SERVICE CARD FOR MORE INFORMATION

Selector Switches

For Pyrometry Circuits

The switches provide versatile means of connecting sensing elements to indicators, recorders or other instruments. Two-position key switches, 4pdt, permit the optional connection of a number of sensing elements to either of two instruments. Selection or transfer is made by flicking a switch. Locking or non-locking construction.

Two-position key switches, dpst, permit rapid checking of temperatures from many points or averaging temperatures from a number of sensing elements. Non-locking construction is available for spot checking and locking construction for maintained contact.

Three-position key switches can be used to connect thermocouples or resistance bulbs to an indicator or recorder or to transfer them from one instrument to another. Moisture-proof and dust-tight cases are suitable for flush-panel or wall mounting. Case capacities range from 12 to 144 points for both thermocouples and resistance bulbs.

Thermo Electric Co., Inc., Dept. ED, Saddle Brook, N.J.

CIRCLE 108 ON READER-SERVICE CARD FOR MORE INFORMATION

Switch and Actuators

High Rating

Five actuators including leaf, frame leaf, roller leaf, plunger and toggle models, are available for use with a developed switch about 3/4 in. in length. The switch is rated 10 amp 125-250 v ac; 1/4 hp 125 v ac; and 10 amp 28 v dc. It is of double throw, double circuit design. The switch mechanism is enclosed in a durable plastic case.

Robertshaw-Fulton Controls Co., Acro Division, Dept. ED, Columbus 16, Ohio.

CIRCLE 109 ON READER-SERVICE CARD FOR MORE INFORMATION

Precision Delay Generator

1 to 10,000 μSec.

The delay generator type 6010, consists of three modular constructed units with both power and signals internally interconnected by cabling to make a self-contained piece of test equipment. The three units comprising the complete generator and their functions are as follows:

Trigger Generator Type 101—provides a standard negative pulse output from an input signal composed of slow rising sine waves or fast rise time pulses or either polarity up to 100 kc. The unit can also function as a self-contained pulse generator, producing its own repetition frequency at anyone of ten preset frequencies ranging from 50 cps to 100 kc.

Delay Generator Type 131—triggered by the standard negative pulse output from the Type 101 Trigger Generator, the unit produces five outputs; both positive and negative delayed pulses, positive and negative gating pulses, and a linear negative going ramp function.

Power Supply Type 9804—the supply maintains less than one mv rms of ripple on the output voltage. The unit provides three positive voltages and one negative voltage with regulation better than 0.5 per cent.

Burroughs Corp., Electronic Instruments Div., Dept. ED, 1209 Vine St., Philadelphia 7, Pa.

CIRCLE 110 ON READER-SERVICE CARD FOR MORE INFORMATION

PRECISE FREQUENCY CONTROL

Robertshaw-Fulton Crystal Oven

This new compact precision Crystal Oven uses fusion temperatures of crystalline materials to provide extremely constant crystal cavity temperatures.

Completely self-contained, the unit features a continuous proportional control system which eliminates contact noise, power surges, random variations of oven temperatures, and cavity temperature drift.

SPECIFICATIONS

CAVITY TEMPERATURE:
70.6°C at 24°C ambient.

TEMPERATURE CONTROL:
Within ±0.5°C from −20°C to +50°C ambient.
Approx. ±0.005°C at fixed ambient.

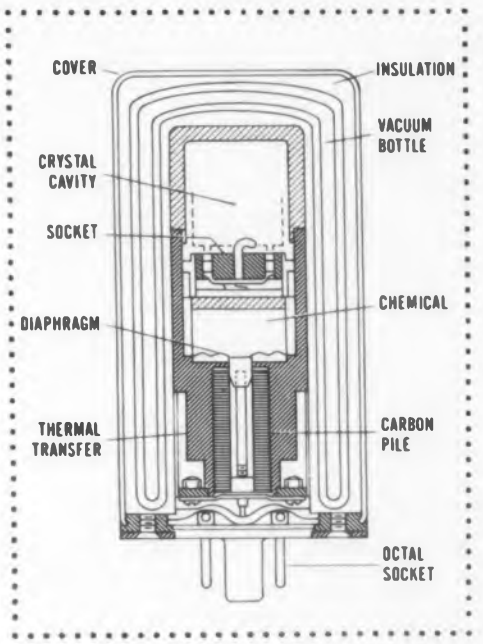
HEATER VOLTAGE:
5 v. a.c. or v. d.c. regulated ±2%.

HEAT POWER:
On warm up: approx. 5 watts
Under control: 1.6 w at TA 24°C
3.5 w at TA −20°C

DIMENSIONS:
2" O.D. x 4" Length.

WEIGHT:
Approximately 12 ounces.

CRYSTAL HOLDER:
Accommodates 1 HC-6/U holder.



APPLICATIONS

Temperature control of a crystal or crystal oscillator for secondary frequency standards.

Temperature control of sensitive components, such as resistance-capacitance networks in oscillators or computer circuits.

Temperature control of zener diodes for voltage reference units in d.c. power supplies.

Constant temperature for thermocouple reference junctions.

Reference temperature for calibrating thermistors by using ovens with different cavity temperatures.

For more information on this compact, extremely reliable Crystal Oven, send for Bulletin No. 1181-1.

PRODUCTS FOR PROGRESS
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AERONAUTICAL DIVISION
Robertshaw-Fulton
CONTROLS COMPANY
Santa Ana Freeway at Euclid Avenue • Anaheim, California

OUTSTANDING FACILITIES FOR THE RESEARCH AND DEVELOPMENT OF SPECIALIZED CONTROL DEVICES

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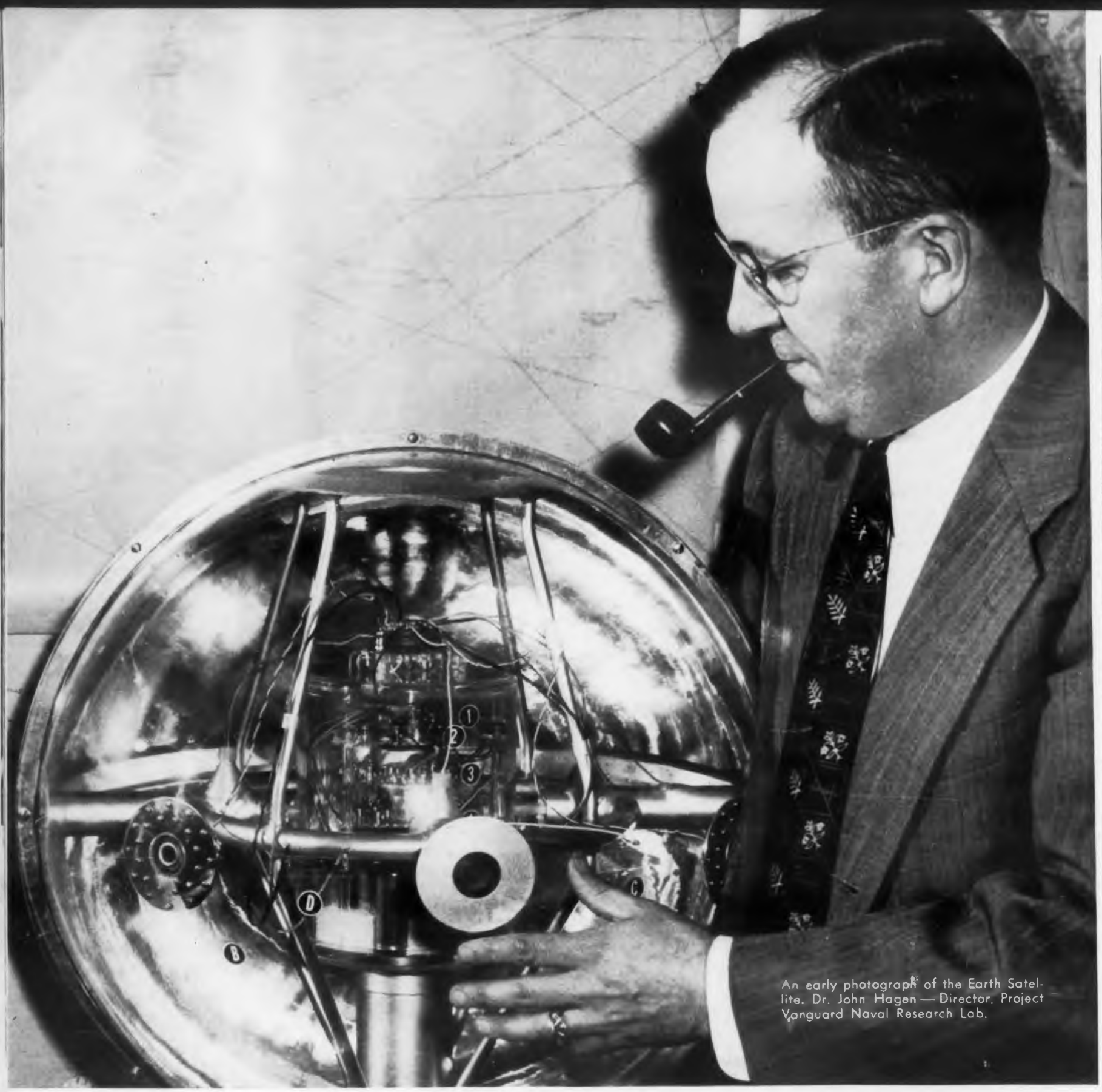

An early photograph of the Earth Satellite. Dr. John Hagen — Director, Project Vanguard Naval Research Lab.

New Products

Hysteresis Motors
8000 and 12,000 Rpm

This synchronous motor is available in a size 10 frame (1 in. OD), and comes in 8000 and 12,000 rpm models, single-phase and 3-phase, 26-v and 115-v. The motors are constructed with homogeneous rotors and stators featuring constant torque independent of rotor position. They have an inherently high starting torque, and are designed to meet the environmental requirements of MIL-5400.

Luther Manufacturing Co., Dept. ED, 7312 Varna Ave., North Hollywood, Calif.

CIRCLE 113 ON READER-SERVICE CARD

Monitor Amplifier
Low Level Input

For themocouples and strain gage pickups, Type P/P-C has an input impedance in excess of 200 k and works with spans as low as 5 mv dc. Both low and high level adjustable 5 amp. alarm contacts are provided. Input floats relative to ground. Circuit utilizes chopper and single quality vacuum tube. The input impedance permits use with loggers and servo instruments with insignificant loading error.

Indikon Co., Dept. ED, 76 Coolidge Hill Rd., Watertown, Mass.

CIRCLE 112 ON READER-SERVICE CARD

Micro-Microammeter

10^{-3} to 10^{-11} Amp

The Model 411 micro-microammeter provides high resolution for a range of measurements from 10^{-3} to 10^{-11} amp. It has no switching transients and covers eight decades with 17 ranges. Zero drift is less than 2 per cent of full scale per week from source voltages above 10 v. Response time is less than one second on the 10^{-10} range and drops to 40 μsec on the 10^{-3} range with 5000 μμf across the input. Input drop is less than five mv. Added features include a 216 v tap for polarizing ion chambers, and a 10 v output to drive either 50 mv or 5 ma recorders.

Keithley Instruments, Inc., Dept. ED, 12415 Euclid Avenue, Cleveland 6, Ohio.

CIRCLE 115 ON READER-SERVICE CARD FOR MORE INFORMATION

Galvanometer and Amplifier

Chopper Stabilized

The Model 204A is a combination dc null detector, linear deflection indicator, microvoltmeter, micromicroammeter, and low level dc amplifier. It is functionally equivalent to suspension galvanometers. The instrument is insensitive to vibration, shock, microphonics, earth's magnetic field and stray pickup. It may be mounted in any position, can withstand overloading with no offset on return to zero and has rapid response. Seven decaded ranges cover dc voltages from 10 μv to 10 v full scale or currents from 0.001 μa to 1 ma full scale. The sensitivity control functions as an attenuator and is calibrated in attenuation. Input resistance is a constant 10,000 ohms and there are no restrictions on source resistance. A high degree of isolation is provided between ac line, chassis, and the amplifier circuit. The unit has a floating input. As a current galvanometer, it has 2×10^{-11} amps-per-division sensitivity. As a voltage galvanometer, it has 10^{-14} w full scale power sensitivity.

Kin Tel (Kay Lab), Dept. ED, 5725 Kearny Villa Rd., San Diego, Calif.

CIRCLE 116 ON READER-SERVICE CARD FOR MORE INFORMATION

SERIES 341 **TEN-TURN** *PRECISION* **POTENTIOMETER**

Smaller in diameter than a fountain pen — no longer than a shriveled up Gryllidae Gryllus*, this tiny "pot" offers ultimate precision in the smallest package on the market.

Check some of the standard specifications of this precision-built, wire-wound, ten-turn potentiometer:

SIZE:	**17/32" x 1-1/64"**
WEIGHT:	**10 gms. max.**
BACKLASH:	**Essentially zero**
PHASE SHIFT:	**Less than 0.1° at 400 cps**
VIBRATION:	**20gs to 2000 cps (3 attitudes)**
POWER:	**2.5 watts at 40°C, 0 watts at 140°C**

* also known as a cricket

STANDARD MODELS AVAILABLE IN PRODUCTION QUANTITIES NOW . . . SPECIAL REQUIREMENTS CAN USUALLY BE MET. WRITE TODAY FOR COMPLETE INFORMATION CONCERNING THIS AND OTHER MINIATURE WIRE-WOUND, PRECISION POTENTIOMETERS.

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One-turn, Wire-wound, Precision Potentiometer.
LOW COST
HIGH PERFORMANCE

CIRCLE 117 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Digit-Set Counter

1 Msec to 100 Sec Time Base

Model 1040 counter is for measurement of analog quantities that can be converted into frequencies. Features include the readout and the use of magnetron beam switching tubes. It provides time base selection from 1 msec to 100 sec in 1 msec increments, non-overloading amplifiers from 5 mv to 100 v from 5 cps to 100 kc, and printed readout facility. Reliability is obtained by use of 50,000 hr magnetron beam switching tubes in the counting and dividing circuits. A self-checking feature is also included.

Systron Corp., Dept ED, 2055 Concord Boulevard Concord, Calif.

CIRCLE 118 ON READER-SERVICE CARD FOR MORE INFORMATION

Variable Transformers

Increased Ratings

The Type W50 Variac replaces the older Type 50 and is available in a complete series including 115- and 230-v models. Current ratings are increased to 50 and 25 amp for the single 115-v and 230-v models, respectively. Motor drives are available in several speeds for all W50 models.

Model W5L, shown, has been designed for those 115-v, 60-cps applications where the usual overvoltage feature is not needed. By limiting the maximum output voltage to the line voltage and frequency to 60 cps, it is possible to use larger wire and still keep other physical dimensions identical with other Type W5 Variacs. Type W5L can control loads drawing up to 11 amp at line voltage, thus giving an output power rating of over 1-1/4 kva. Up to 8.5 amp can be drawn from the unit at any voltage.

General Radio Co., Dept. ED, 275 Massachusetts Ave., Cambridge 39, Mass.

CIRCLE 119 ON READER-SERVICE CARD FOR MORE INFORMATION

ANALOG COMPUTER MODEL 3000

Simplified analog computer solves wide variety of engineering problems. Detachable problem boards and plug-in components facilitate rapid problem set-up.

Can be expanded building block fashion to larger computing system. Function generator, multiplier, chopper stabilizer, and other accessories available. Write for complete data. Model 3000, $1150, FOB Factory.

Problem board $95

PONNER SCIENTIFIC COMPANY

832 Galindo Street
Concord, California

CIRCLE 121 ON READER-SERVICE CARD

Calorimeter

Constant Flow Type

This direct reading rc calorimeter, with frequency range of dc to 4000 mc and power measuring range of 10 to 150 w, is of the constant flow type. It does not use flow meters, or thermometers and does not require any flow adjustment. The only control is the on and off switch for the constant flow system. After the radio frequency power is connected the meter needle climbs to the correct value for approximately one minute. Power is read directly on the meter. Accuracy is 5 per cent. Power supply: 105-120 v, 60 cps 60 w. Other calorimeters covering the range of dc to 12,000 mc, coaxial and waveguide, are available.

Electro Impulse Laboratory, Dept. ED, 208 River St., Red Bank, N.J.

CIRCLE 122 ON READER-SERVICE CARD FOR MORE INFORMATION

Transformer Line

Output Proportional To Input

Available in voltages up to 500 vda, these transistorized transformers have a dc output voltage directly proportional to the input as in conventional ac transformers. Characteristics include load regulation from 6 to 12 per cent, ripple of 0.01 per cent, output range from 15 to 80 w with input of 24 to 30 v dc. Another in the line is a dc voltage regulator consisting of a transistorized oscillator employing a magnetic amplifier as the regulating element. The regulators feature small size, fast response, no maintenance, tantalum capacitors, and very low ripple. Transistorized dc inverters have been designed to provide dependable power for rate gyros where frequency regulation is necessary. Supplied with a normal output of 115 v ac, other characteristics include line wave of 400 cps, harmonic distortion of less than 5 per cent, temperature range of −55 C. to +71 C, frequency stability of ±0.25 per cent and a voltage charge of ±6 v ac.

Gulton Industries, Inc., Dept. ED, Engineered Magnetics Div., Metuchen, N.J.

CIRCLE 123 ON READER-SERVICE CARD FOR MORE INFORMATION

METAL-CAL STICKS FAST THROUGH "OPERATION DEEP FREEZE"

Your product will probably never undergo the grueling treatment seen here at Operation Deep Freeze (temperature 60 below), but if it *is* subjected to weathering in *any* way, you'll be interested in new, patented Metal-Cal.

Metal-Cal's super-strength adhesive makes your product's label permanent in blistering heat or Arctic cold. Best of all, years and years of accumulated weathering leave Metal-Cal clear, sharp, and easy to read... that's because only patented Metal-Cal is made of .003" anodized and dyed, etched aluminum foil. Find out today what Metal-Cal can do for your product.

if it's important, make it permanent

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Send this coupon for free sample and brochure TODAY!
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415 East Beach Avenue
Inglewood 3, Calif., Dept. ED

Name_____

Company_____

Address_____

City_____ Zone____ State_____

U. S. Patent 2,769,265

CIRCLE 124 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Indicator Tube
Monitors Transistor Circuits

The Type 6977 filamentary indicator triode with fluorescent anode is designed specifically for visual monitoring of transistorized computers and other transistor circuits. It is approximately 1-1/8 in. long, has less than 1/4 in. diam, and gives a bright blue-green indication when its control grid is at zero potential. It is designed for 20,000 hrs life. Heater voltage is 30 ma ac or dc. The anode will draw 0.6 ma from a 50 v supply during the zero-bias on condition. A 3.5 v dc voltage is sufficient to cut off plate current and light. High input impedance and small consumption prevent it from loading transistor circuits. Since it permits the use of a series grid resistor, it does not short out the transistor circuit if it should develop a defect in operation.

Amperex Electronic Corp., Dept. ED, Computer Products Div., 230 Duffy Ave., Hicksville, N.Y.

CIRCLE 126 ON READER-SERVICE CARD FOR MORE INFORMATION

Flutter and Wow Meter
Regulated

Designated as Model F1-3D, this flutter and wow meter is designed to the requirements for measuring flutter content in recording and reproducing systems as established by the IRE, ASA and SMPTE. Full scale sensitivities of 2.0 per cent and 0.5 per cent are available with accuracies better than 10 per cent. An output terminal is included to provide a dc to 250 cps signal for graphic recording purposes. A regulated power supply insures stable operation of internal 3000 cps carrier oscillator over wide excursions of the input line voltage. The FL-3D measures 7 in. x 12 in. x 6 in. and weighs 10-1/2 lb.

D & R, Ltd., Dept ED, 402 East Gutierrez St., Santa Barbara, Calif.

CIRCLE 127 ON READER-SERVICE CARD FOR MORE INFORMATION

Pressure Transducers

Fused Silica

Single or multiple convolution bellows and twisted bourdon tubes are the two basic types of pressure cells offered made from fused silica. The bourdon tube shown is 8 mm diam by 45 mm long. Its scale factor is 0.2 deg rotation per atmosphere with a safe working pressure of 5 atmospheres. Other tubes 15 mm in diam with a 0.8 deg rotation per atmosphere have been produced. The three convolution bellows is 15 mm in diameter and has a sensitivity of 0.0001 in motion per psi, 5 atmospheres working pressure.

Emil Boblett Co., Dept ED, Box 666, Manhattan Beach, Calif.

CIRCLE 130 ON READER-SERVICE CARD FOR MORE INFORMATION

Variable Power Supply

Nonshorting, 500 μv Ripple

A continuously variable dual transistorized power supply produces 2 to 30 v at 0 to 1.0 amp. The Model 800-A power supply features a ripple voltage of less than 500 μv, less than 0.01 output voltage variation from no load to 1.0 amp, with automatic short circuit and overload protection. When the load exceeds the rated current by 50 per cent, a protection circuit opens the regulator loop and prevents the output current from flowing. At approximately 4-sec intervals the supply endeavors to reestablish the output voltage, and it will succeed when the overload or short circuit has been removed. The response to a sudden no-load to full-load change in current does not break the regulator loop. For example, a no-load to 1.0 amp current change produces an output voltage transient of less than 50 mv.

Harrison Labs., Inc., Dept. ED, Berkeley Heights, N.J.

CIRCLE 131 ON READER-SERVICE CARD FOR MORE INFORMATION

THERMAL CONDITIONING OF ROCKETS AND GUIDED MISSILES

HEATING OPTICAL, ELECTRONIC, OR HYDRAULIC AIRBORNE EQUIPMENT

WHERE CAN YOU USE G-E SPECIALTY HEATING EQUIPMENT?

Whenever your equipment requires thermal conditioning, General Electric specialty heating equipment can help.

G.E. has had extensive design and manufacturing experience in providing controlled heating for a wide variety of applications. These applications range from giant guided missile blankets to tiny one-inch-long accelerometer heaters. Problems of intricate shape, large or small size, unusual environmental conditions, and amount of heat required have all been solved.

LET US ANALYSE YOUR HEATING PROBLEM; a General Electric specialty heating expert is available and a prompt answer is assured.

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Section NN220-10A, Schenectady 5, N. Y.

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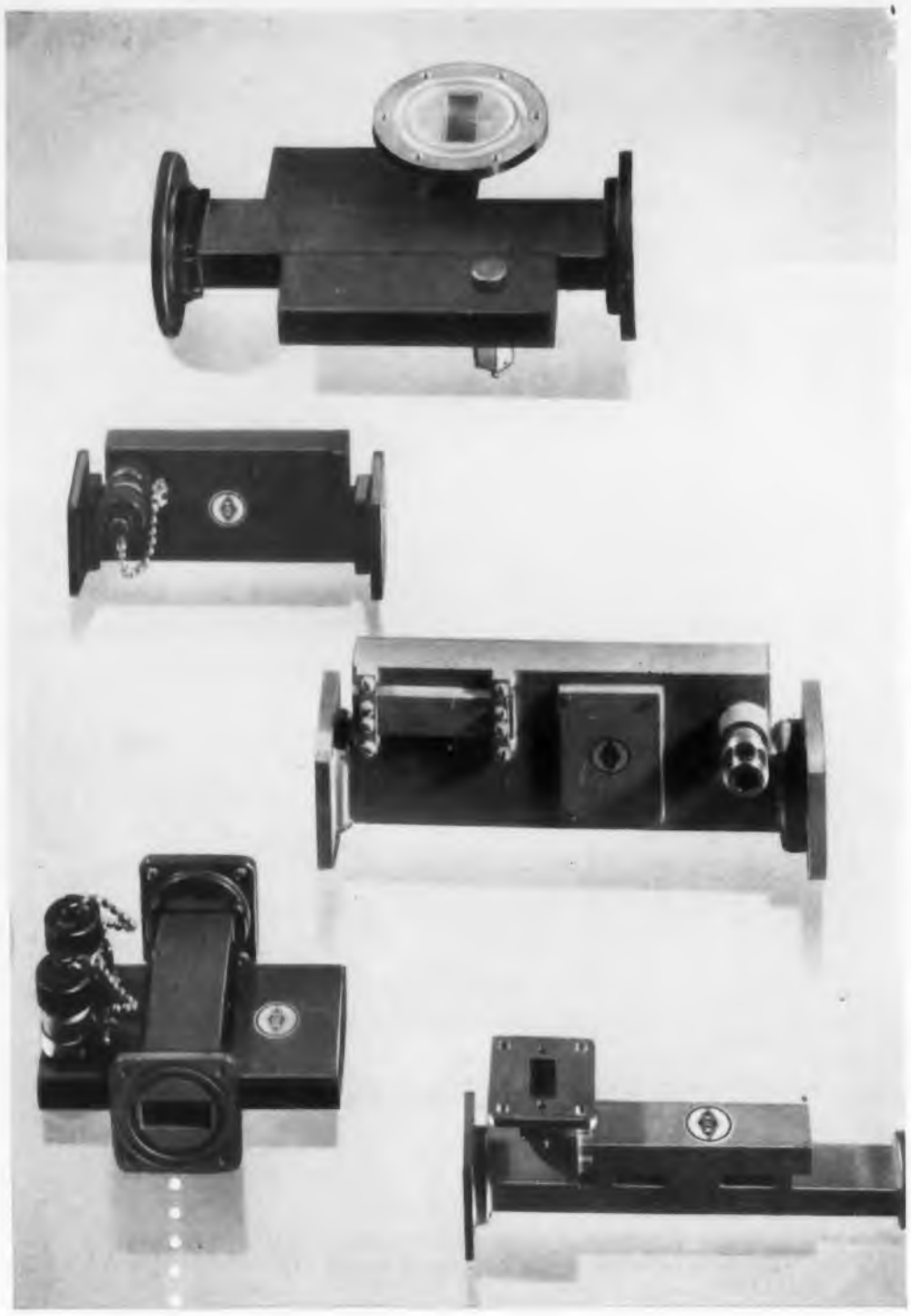
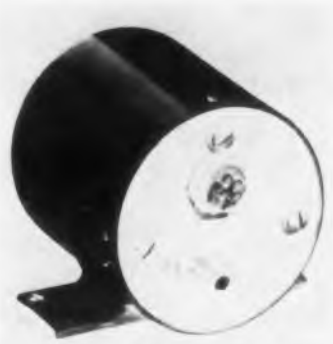


New Products



Pressure Transducers

1 Per Cent, —54 to +100 C

Models have been designed to measure pressures in extreme environments. One is linear, the other provides high resistance pick offs and non-linear functions, and both have temperature range of from —54 to +100 C. The units feature good performance in respect to resolution, repeatability, hysteresis, linearity and acceleration error. In model 22002 maximum change in output is 1 per cent except at resonance, in model 22008 maximum change in output is 1 per cent.

Physical Measurements Corp., Dept ED, 1650-19th St, Santa Monica, Calif.

CIRCLE 134 ON READER-SERVICE CARD FOR MORE INFORMATION

Function Programmer

32 Switching Functions

The function programmer is an electro-mechanical timing control device consisting of two basic parts; a supporting frame and cover equipped with a dc driving motor and operating controls, and basic linear switching elements. There are eight switching elements which can be sequenced in multiples to handle up to 32 switching functions, timed in accordance with customer requirements. Units can be provided with linear or non-linear potentiometer elements to be used in lieu of or in combination with switching elements. Six of the eight switching elements can be of the modified plug-in type providing timing changes, to be incorporated into the flight control program, before firing. The additional function of an identifying pulse at every 1/2 sec interval, can also be had without any major design change in the timer.

Hubbard Scientific Labs., Inc. Dept. ED, 1292 E. Third St., Pomona, Calif.

CIRCLE 135 ON READER-SERVICE CARD FOR MORE INFORMATION

Using Thermistors

Edited by
FENWAL ELECTRONICS

Here's more news on thermistors — the tiny, highly temperature-sensitive, semiconductors that are being used in more and more applications in all types of industry.

Let's look at just three ways thermistors are now being used . . . Time Delay, Remote Control and Switching.

A thermistor placed with a variable resistor in series with a battery and a relay (Fig. 1) makes an excellent time delay relay. The high resistance of the thermistor limits the current flow when the switch is closed. The delay time may be increased or decreased by increasing or decreasing the series resistance.

By selecting a thermistor with the same constant as the tube filament it will be in series with, you can keep the current constant during the initial warm-up and prevent an initial current surge.

Bead thermistors are available with attached heaters and mounted in a vacuum bulb. (Fig. 2) The thermistors' resistance is reduced when power is applied to the heater. When placed in the input of a vacuum tube amplifier these thermistors make smooth, noiseless remote gain controls, because there are no moving parts or controls in the grid circuit.

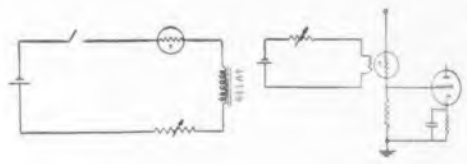


FIG. 1 FIG. 2

When several low voltage light bulbs are connected in series with a suitable thermistor connected in parallel with each unit, (Fig. 3) very little current will pass through the thermistors. Thermistors are not appreciably heated by the small voltage drop across the bulb. If one bulb burns out, the other bulbs remain lighted — the thermistor continues to carry the load of the extinguished bulb. When the bulb is replaced it takes the current from the thermistor. The thermistor then cools off and returns to its idle condition of high resistance and low current.

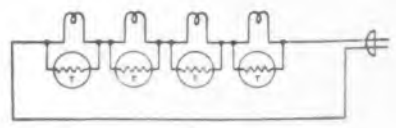


FIG. 3

Engineers: these and other thermistor applications are discussed in 12-page catalog EMC-1. Write for your copy to FENWAL ELECTRONICS, INC., 36 Mellen St., Framingham, Massachusetts.

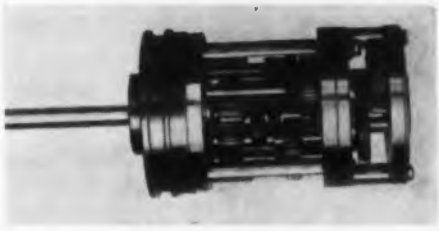
Fenwal Electronics

Makers of Precision Thermistors

CIRCLE 136 ON READER-SERVICE CARD

Gearhead Variations

For Size 11 Motor



Four precision motor gearhead adaptations in 1.062-in. diameters have been designed for use with Size 11 motors. Gearheads 1384-GH, X-295, X-507 and X-414 are essentially variations of the standard 1062-GH gearhead in order to suit custom needs for extended ratios, special sizes, off center shaft positions and other mechanical requirements. Tandem design in the X-507, shown, provides ratios up to 3 million to 1 and higher, while maintaining the low backlash of smaller units. 1384-GH is for installations requiring short length at standard ratios, but which must withstand relatively heavy duty applications. X-295 features an off center shaft and ratios up to 1000 to 1. The unit mounts to MK-14 motors by using an adapter plate. X-414 contains internal stops to limit rotation, and has a slip clutch to prevent damage to the motor gearhead. All four custom variations include general 1062-GH specifications such as an operating load torque of 25-in.-oz, and starting torque of 0.005 in.-oz.

Bowmar Instrument Corp., Dept. ED, 2419 Pennsylvania St., Fort Wayne, Ind.

CIRCLE 138 ON READER-SERVICE CARD FOR MORE INFORMATION

Traveling Wave Tube

L-Band

The HA-14 operates from 1.0 to 2.0 kmc without the necessity of any electrical or mechanical operating adjustments. The tube is a high gain, low noise broadband device suitable as the first stage of a receiver in microwave applications. Noise figure reduction is accomplished by multi-anode techniques in gun construction, with all electrode potentials less than 200 v. Noise figure of 10 db max; small signal gain of 30 db min; saturation gain of 25 db; magnetic field of 1000 gauss; capsule length of 15-1/2 in.; capsule diam of 1.0 in.; and net weight of 1 lb.

Huggins Labs. Inc., Dept. ED, 711 Hamilton Ave., Menlo Pk, Calif.

CIRCLE 139 ON READER-SERVICE CARD FOR MORE INFORMATION

ANOTHER **MANSON** MILESTONE

1-mc HARMONIC REFERENCE OSCILLATOR

A frequency standard with a stability of parts in 10^9 per day.

A high-quality, high level millimicrosecond pulse source for harmonic measurements.

Precision engineering and versatility, with a new design concept that reduces costs to a small fraction of any comparable instrument.

The instrument, ready to use, is priced at $750

These Features are included:

- ★ Output Frequency independent of all circuit parameters except the Crystal, which is shock-mounted to provide a high degree of insensitivity to vibration and is maintained ±0.01° C in an oven.
- ★ Unique Circuit for adjusting fundamental frequency ±25 cps without degrading stability.
- ★ Ultra-linear Dial, accurate to 0.01 cps, with direct-reading frequency counter giving substantially zero-error readability.
- ★ Sine-Wave Output, 3 Volts rms across 50 Ohms.
- ★ Millimicrosecond jitter-free balanced Pulse Output; 40-Volt peak across 250 Ohms; harmonics usable to 1000 mc.
- ★ Built-in balanced Mixer, to determine unknown external frequencies up to the kilomegacycle region.
- ★ Self-contained Power Supply.

MATCHING ACCESSORY: 100-KC PHASE-STABLE DIVIDER

A companion instrument to give an additional fundamental frequency (100 kc) with jitter-free *pulse* and *sine-wave* outputs. Incorporates its own mixer and beat-frequency amplifier; also usable as an independent 100-kc Oscillator.

Manson offers to Engineers and Technicians a rewarding present and attractive future in suburban Connecticut.

Write today for Details

Designers and Builders of Specialized Electronic Equipment.

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ENGINEERED FACILITIES

FOR HIGH RELIABILITY RESISTOR PRODUCTION ONLY!

(Environmental production testing optional, but recommended)

- Hermetically Sealed Deposited Carbon Resistors
- Sealed Resistor Networks
- Encapsulated Precision Wire Wound Resistors

MEPCO INC., MORRISTOWN, NEW JERSEY

CIRCLE 238 ON READER-SERVICE CARD FOR MORE INFORMATION

Vitramon® CAPACITORS

will help you build MINIATURE . . . circuit systems

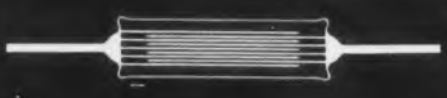
Sheer bigness . . . great in Texas . . . has no place in an electronic circuit. VITRAMON capacitors save you space and deliver critical electrical performance at the same time.

MINIATURE? **YES!** PLUS . . .

RUGGED LOW LOSS STABLE
WIDE TEMPERATURE RANGE
LOW NOISE VAPORPROOF

VITRAMON capacitors are as small as this

Life Size Photograph



Two materials — a monolithic block of porcelain enamel and fine-silver electrodes — fused into one strong, stable, efficient and effectively homogenous **RELIABLE** unit.

The biggest names in electronics use VITRAMON capacitors in guided missiles, jet ignition, proximity fuses and in radar, servo, guidance, fire control, telemetering and carrier telephone systems.

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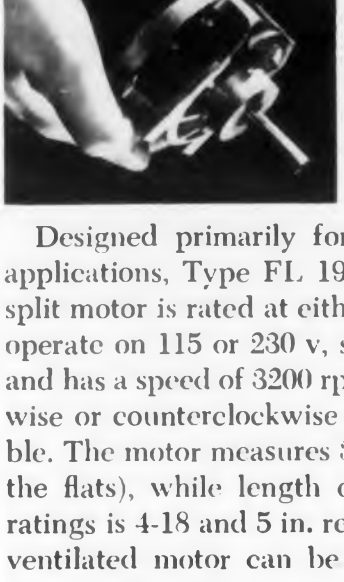
New Products



Capacitor Motor
Reversible

Designed primarily for small business machine applications, Type FL 19-frame 2-pole permanent-split motor is rated at either 1/40 or 1/20 hp. It will operate on 115 or 230 v, single phase, 50 or 60 cps, and has a speed of 3200 rpm. It will run either clockwise or counterclockwise and can be made reversible. The motor measures 3 in. diam (2-3/8 in. across the flats), while length of the 1/40- and 1/20-hp ratings is 4-18 and 5 in. respectively. The open, self-ventilated motor can be mounted rigidly, or provided with rubber rings for resilient mounting. A pinion that is integral with the shaft can be supplied on request. Bearings are of the self-aligning, oil-impregnated porous-bronze type. Rotors and end brackets are die-cast.

Westinghouse Electric Corp., Dept. ED, P.O. Box 2099, Pittsburgh 30, Pa.

CIRCLE 142 ON READER-SERVICE CARD FOR MORE INFORMATION

Low Pass Filter
Cutoff of 20, 30 or 40 cps

A line of data-filters combines galvanometer damping resistors with a low pass filter housed in standard damping resistor plug-ins. They attentuate unwanted high frequency components or noise at a rate approaching 12 db per octave above standard cut-off frequencies of 20, 30, or 40 cps. Units are designed to operate in conjunction with the 7-315 and 7-318 types of galvanometers. A typical application of these units is the removal of high frequency vibration when making oscillographic recordings of motion accelerations.

United Telemetering Co., Dept. ED, 1632 Pico Blvd., Santa Monica, Calif.

CIRCLE 143 ON READER-SERVICE CARD FOR MORE INFORMATION

CIRCLE 144 ON READER-SERVICE CARD

Microwave Noise Source

To Check Receiver Performance

The Type TE10 noise tube provides a stable noise source of small size and weight which can be built into X band systems to provide a regular check on receiver performance. The waveguide mount is fitted with a three screw matching section which is normally set for operation at 9375 mc with a vswr of 1.01. Under these conditions the vswr with the tube in operation is less than 1.25 over the range 8900 to 9800 mc, with a noise output of 15.5 db and a nonoperating insertion loss of less than 0.2 db. The matching section can be tuned to a center frequency anywhere in the band 8500 to 10,500 mc. A simple resonant circuit provides for striking and operating the tube from a 150 v 35 ma dc supply.

Ferranti Electric, Inc., Dept. ED, 30 Rockefeller Plaza, New York 20, N.Y.

CIRCLE 146 ON READER-SERVICE CARD FOR MORE INFORMATION

Position Indicator

3 Per Cent Accuracy

A transmitter-receiver system for remote angular position indication. One transmitter can serve any number of receivers with no loss of linearity or accuracy over the 320 deg range. The transmitter has standard bushing type mounting, with positive mechanical stops. Two separate adjustments are provided for zeroing-in at either end of scale. A linear type dial is calibrated from 0 to 100. Requires only two wires from the transmitter. Additional receivers may be connected in parallel. Over-all accuracy is 3 per cent, with no loading error. Weight of the transmitter is 29 oz, and of the receiver is 20 oz. Adjustable signal or limit switch contacts can be provided at either or both ends of the receiver.

Certi-Fact Engineering, Inc., Dept. ED, P.O. Box 774, Sherman Oaks, Calif.

CIRCLE 147 ON READER-SERVICE CARD FOR MORE INFORMATION

New Products

Subsonic Analyzer
Resolution of 0.5 Cps

Features resolution of 0.5 cps over the full frequency range from 0.5 to 2250 cps and 0.1 cps resolution up to 225 cps. Six different sweepwidths which may be centered at almost any point. A heterodyne type analyzer, the LF-2 automatically presents a permanent paper recording of the frequency and amplitude of waveform components. It is used for vibrations and sound analysis of large structures or devices in which members rotate or oscillate at approximately the same or multiples of the same rate. The instrument has a scan range selector providing sweepwidths of 2 to 500 cps and a variable center frequency control. Resolution is adjustable in steps from 0.1 to 20 cps. Selectable amplitude scales (20 db linear and 40 db log) permit a broad range of comparative analyses.

Panoramic Radio Products, Inc., 10 S. Second Ave., Mount Vernon, N.Y.

CIRCLE 151 ON READER-SERVICE CARD FOR MORE INFORMATION

Filtered Grille Assemblies for 19 In. Racks

Available for relay racks without louvres to be used as an outlet for air if the rack is pressurized and as an inlet for air if an exhaust fan is used. When used with a metallic permanent filter it is useful as an rf shield as well as a filter. Disposable filter is available.

The assembly is fabricated in standard modular heights of 5-1/4, 7 and 10-1/2 in. for 19 in. standard racks. The grille is of polished stainless steel to harmonize with all racks to match the inlet grilles on the company's packaged blower and fan assemblies for relay racks. The filter may be removed without removing the assembly.

McLean Eng. Labs., Dept. ED, 70 Washington Rd., Princeton, N.J.

CIRCLE 152 ON READER-SERVICE CARD FOR MORE INFORMATION

Differential DC Amplifier

Temperature Compensated

Draft is minimized to less than 3 μv over the temperature range of −50 to +120 F in the Model 73-R Amplifier. The amplifier has been packaged to permit rack mounting. The integral power supply is designated for direct operation from a 115 v unregulated power source at any frequency between 50 cps and 400 cps.

Bandwidth extends from dc to 50 kc. Gain is adjustable in five steps from 20 to 500 and the output is ±5 volts, either differential or single-ended. This compact amplifier features low noise and high transient response with gaussian fall-off and high common mode rejection.

Video Instruments Co., Dept. ED, 2430 Sawtelle Blvd., Los Angeles 64, Calif.

CIRCLE 155 ON READER-SERVICE CARD FOR MORE INFORMATION

VSWR Measuring System

8400 to 12,000 Mc Sweep

The Model 160 sweep-frequency vswr measuring system is a direct-reading, X-Band instrument. Employing a backward-wave oscillator, the unit can sweep all or any portion of its range at rates of 0.02, 0.1, 1.0, and 3.0 cps. It contains a 5 in. oscilloscope with its graticule scaled directly in vswr in two ranges: 1.02 to 1.20 and 1.1 to 2.1. Presentation is duplicated on a 4 in. meter, and for permanent records, a recorder with charts ruled in vswr is available as an accessory.

The system uses a bi-directional coupler having 16 db of coupling and over 45 db of directivity in each arm. Also included are a wavemeter to provide a frequency marker pip accurate to 0.08 per cent and an adjustable 19 in. front panels if rack mounting is desired. Total height is 33-1/4 in. The waveguide assembly is 32 in. long including the wavemeter.

California Technical Ind., Dept. ED, 1440 Old County Rd., Belmont, Calif.

CIRCLE 156 ON READER-SERVICE CARD FOR MORE INFORMATION

For the sake of brevity, the separate bulletin sheets in the Sigma Relay Catalog give only the operating power levels for each adjustment (and not the operating currents for *each* coil resistance in *each* adjustment). There were complaints. In this case, brevity was the sole of nitwits. Customers were suffering from Ohm's Law Exhaustion just to buy one relay; so the problem was to devise a device devised to provide a fast, correct answer. And there you have it pictured above, at slightly less than half actual size.

That took care of the front. On the reverse side miscellaneous information and scales were placed, which are not usually found together. This—we divined—would make the SC attractive to you who never lost a second's sleep over what the operating current of a Sigma relay is; would get our name on your desk—and let us charge off a fair chunk of the cost to advertising.

For a limited time only, you can get a Slidechart free if you will ask for it *on your company letterhead*. We reserve the right to sell them at some later date.

You don't need a company letterhead (or even a job) to get a reprint of our current directory advertisement which seems to be a handy guide for those who wonder what we make in terms of what they need. Just ask for EBG* reprint.

* Electronics' Bar & Grill

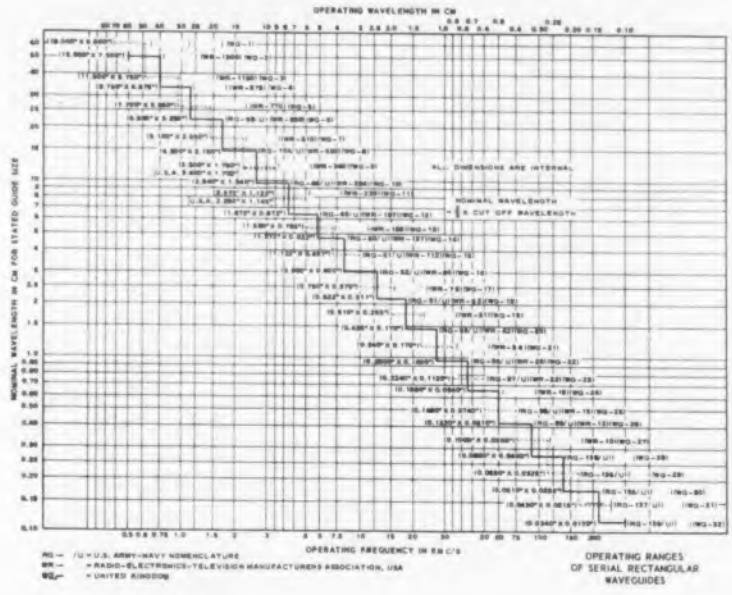
SIGMA INSTRUMENTS, INC.
91 Pearl Street, So. Braintree 85, Mass.

CIRCLE 159 ON READER-SERVICE CARD FOR MORE INFORMATION

New Literature

Waveguide Standards **161**

"Your Guide to Waveguide Standards" is a new brochure which can be adapted to a wall chart. It outlines the story behind the company's services in microwave production and presents seven useful charts of specifications: RMA Standards for rigid rectangular waveguides, Guide to selection of standard waveguide flanges, Waveguide assemblies, Waveguide flanges, Guide to



selection of standard rigid rectangular waveguides (physical dimensions), Rigid rectangular waveguides, and Operating ranges of serial rectangular waveguides, the last of which is here reprinted. Budd-Stanley Co., Inc., 43-01 22nd St., L.I.C., N.Y.

Tubular Capacitors 162

Detailed information on six up-right mounting paper or Mylar dielectric tubular capacitor types are described in brochure just released.

The illustrated models in the brochure are described in full and in each case, the applications, characteristics are included. Good All Electric Mfg. Co., 120 First St., Ogallala, Neb.

Adhesives and Sealants 163

In an 8-page brochure, a complete line of epoxide adhesives, cements and sealants is covered. The advantages, uses and properties of each type are described along with instructions for applying it. Prices of the above and other products are listed. The bulletin also contains a revised list of standard available products. Emerson & Cuming, Inc., 869 Washington St., Canton, Mass.

Induction Heating Review 164

This review, No. 1—Feb. 1957, will be printed periodically for those who are interested in simplifying any of the operations where heat is required.

The illustrated pamphlet shows many typical applications, schematics and tables. Lepel High Frequency Labs. Inc., 55th St., and 37th Ave., Woodside 77, N.Y.

Rack Mounting Oscillographs 165

Multi-channel rack mounting oscillographs are described in an eight-page folder just released. The instruments permit simultaneous recording of up to eight phenomena in clearly legible chart form.

Accurate and permanent records are thus immediately available for analysis. These oscillographs feature an electrically-controlled transmission which allows instantaneous switch selection of 16 different chart speeds ranging from 10 in. per sec to 10 in. per day. When used with amplifiers, recordings may be made over a frequency range extending from dc to 100 cps.

The illustrated folder gives details on many of the instruments features and covers engineering and operating information. Brush Electronics Co., 3405 Perkins Ave., Cleveland 14, Ohio.

Unparalleled savings for parallel resistor-capacitor applications

Centralab TUBE-R-Cap*

ACTUAL SIZE

Saves Space!

Combines a high-quality ceramic capacitor and a built-in fixed resistor in the space of a tubular capacitor alone.

Saves Initial Cost!

Costs you less than an equivalent combination of individual resistor and capacitor.

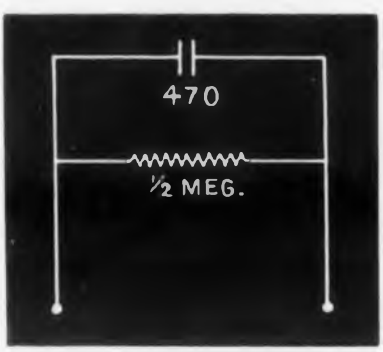
Saves Handling Costs!

Only one piece to insert, instead of two; only one piece to carry on inventory.

Provides any normal capacitor specification through 4700 mmf. and any resistance value from 100 ohms through 3 megohms (with ±20% tolerance up through 1 megohm . . . ±30% or wider above 1 megohm).

6,000,000 Tube-R-Caps are now in use, in antenna-line and many other applications. Lead spacings provided for any printed-circuit board. (See illustration below.)

Write us for further information. Or have the nearby Centralab representative tell you more. If you don't know who he is, ask us for his name.



TYPICAL EXAMPLES

DA620
Max. length, .530" — max. diam.,.260"
470 mmf., ± 20%, 500V
470 K ohms, ± 20%

DA625
Max. length, .810" — max. diam.,.260"
1000 mmf., ± 20%, 500V
330 K ohms, ± 20%

DA632
Max. length, .900" — max. diam.,.280"
470 mmf., GMV, 1500 VAC (UL rated)
.3 to 1 megohm

Available with crimped leads, for printed wiring board insertion

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CIRCLE 171 ON READER-SERVICE CARD FOR MORE INFORMATION

New Literature

Electromagnetic Controls 173

Six electromagnetic control catalogs are available either individually or bound as a composite. Catalog 57-S1, 56 pages, provides complete information on mechanically and magnetically held automatic transfer switches. Described are switches for all classes of load. Catalog 57-S2, 34 pages, covers a line of remote control switches which are mechanically held and available for all classes of load. Catalog 57-S3, 27 pages, describes magnetically held contactors available for all normally open and normally closed classes of load. Catalog 57-S4, 41 pages, describes magnetically and mechanically held relays obtainable in unlimited pole combinations. In addition, this catalog covers special purpose relays. Catalog 57-S5, 12 pages, lists a variety of ac and dc solenoids. Catalog 57-S6, 12 pages, describes electric plant controls, including complete systems, paralleling, changeover and alternating panels, load demand controls, battery chargers and adapter units.

Catalog 57-S, the complete Electromagnetic Control Catalog, combines all six catalogs, with an inclusive index. In each of the booklets, a comprehensive text is amply illustrated with photographs and diagrams.

Requests for these catalogs must be on letterhead stationery. Automatic Switch Co., 50-56 Hanover Rd., Florham Park, N.J.

Battery Guide 174

A 1957 comparative guide to portable radio batteries has been issued in wall chart form. To details on the battery components of more than 600 portable radio models is added a section on "transistor batteries". Ray-O-Vac Co., 212 E. Washington Ave., Madison, Wis.

Shop Problems 175

Simple shop setups to eliminate special tooling and cut production time and costs are discussed in a booklet of 6 pages entitled "Solving Shop Problems". The article describes and illustrates some typical problems and how they were handled. Servo Corp. of America, New Hyde Park, N.Y.

Dynamotors 176

Engineering design and performance data on a line of dynamotors are available in a 1-page information sheet. The units described cover a wide range of input and output voltages and power outputs and have a brush life of 1000 hours. The literature is illustrated with a graph and dimensional diagrams. Induction Motors Corp., 570 Main St., Westbury, N. Y.

Modular Digital Instruments 177

A four-page, illustrated catalog gives brief specifications for a series of modular digital instruments. The booklet describes available units and shows how they can be combined into single-purpose instruments such as digital voltmeters, digital ohmeters, digital ratiometers or complete check out systems. Electro Instruments, Inc., 3794 Rosecrans, San Diego, Calif.

University Training Reactor 178

The University Training Reactor, designed to meet the needs of nuclear engineering curricula in college and university, is the topic of a 16-page brochure. The booklet lists specifications and shows a cutaway view of the reactor and a typical layout for the arrangement of facilities. American-Standard Corp., Atomic Energy Div., Redwood City, Calif.

Timing Devices 179

In concise form, Catalog Sheet BX-219 provides basic engineering data on a series of timing devices. Shown on an illustrated chart are a variety of switching arrangements and features. The 2-page sheet also contains mounting illustrations and dimensional drawings. M. H. Rhodes, Inc., 29 Bartholomew Ave., Hartford, Conn.

Silicone Applications 180

An 8-page catalog, CDS-97, describes 115 applications for silicones, including resins for electrical insulation. Qualitative dielectric characteristics, service life, power/weight ratio, and moisture and corrosion resistance information is given. Resins providing class H insulation are denoted. General Electric Co., Silicone Prods. Dept., Waterford, N.Y.

ONE OF THESE 4 PACIFIC

Accelerometers

CAN PROVIDE RELIABLE ACCELERATION MEASUREMENT FOR YOUR OWN NEEDS!

Four basic Pacific Accelerometer types — already designed and developed — can be used to meet practically any acceleration measurement requirement! Send for complete data sheets!

HIGH ACCURACY POT

Single or dual potentiometer pick-off and/or switches . . . automatic caging mechanism. A unique torsion-bar suspension and restraining system provides very low hysteresis with exceptionally rugged, long life. Available in a wide variety of G ranges.

SERIES 4202

LIGHTWEIGHT, MINIATURE

accelerometer combines a wide flexibility of design and performance characteristics with a proven, high production instrument. Potentiometer pick-off... wide selection of G ranges with an operating range of 0 — ± 1 G to 0 — ± 50 G.

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HIGH ACCURACY AC OUTPUT

linear accelerometer designed for high response systems requiring AC signal. This unit provides an accurate, large output AC signal while maintaining a high natural frequency and low cross talk. Temperature compensated fluid damping provides exceptional dynamic characteristics *without* heater.

SERIES 4204

NO CROSS TALK

due to uni-directional design this instrument measures acceleration in one direction only, and cannot produce any output signal from cross accelerations. Pot pick-off . . . available in a choice of many G ranges.

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CIRCLE 183 ON READER-SERVICE CARD FOR MORE INFORMATION

New Literature

Aluminum Dip Brazing 185

Bulletin 23 describes Alumibraze, an alloy in a form that offers an improved method for joining aluminum parts. Well illustrated, the four-page bulletin gives step-by-step details on dip brazing with this powdered aluminum-silicon alloy which is applied to the joint in the form of a paste. It also describes design techniques, fixturing arrangements and salt-bath requirements to produce strong, dependable joints in various aluminum alloys. Handy & Harman, 82 Fulton St., New York 38, N.Y.

Plastic Rods and Tubing 186

In Bulletin 105, dimensional tables cover tubing and rod made of nylon, cellulose-acetate-butyrate, methacrylate (lucite or plexiglas), polyethylene, polystyrene and vinyl. The eight-page illustrated booklet lists rods in coils, reels and straight lengths. It also points out the characteristics of the aforementioned plastics. Tables show ID and OD dimensions, wall thickness and weight per 100 ft for each material. Jessall Plastics, Inc., Kensington, Conn.

Coil Bobbin Data 187

Covered on a single-page data sheet is a line of one-piece molded nylon coil bobbins. In addition to tabulating complete dimensions of all available round standard bobbins, the sheet shows a number of standard variations which the user may specify without incurring tool costs. Also available are standard drawings of square, rectangular and oval coil bobbins. Gries Reproducer Corp., 400 Beechwood Ave., New Rochelle, N.Y.

K and RK Connectors 188

Catalog K6 provides 64 pages of information on K and RK electrical connectors designed for use in aircraft, radio, and many types of instruments and general electrical equipment. Listed are seven basic shell types with eight insert sizes, or more than 220 arrangements. Television connectors and hermetic-sealed types are included in this edition. Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif.

Transistor List

As a service in the electronic component field a new subscription plan beginning with the second edition of the Transistor list of April 1957 has been announced. Issued in complete form every six months, the subscription plan will provide continuity of the latest information available on all American and a substantial number of foreign transistors. More than 350 transistors will appear in the April issue, reflecting at least 175 additions, revisions, or deletions since the first edition in July 1956. The second edition and future lists will also include many suggestions of present users; such as derating of maximum collector dissipation; material used—germanium or silicon; as well as distinct symbols indicating new transistors, revised data, and foreign types. Transistor List subscriptions, beginning with the second edition in April are available at $12.00 per year. Derivation and Tabulation Assoc., Inc., 67 Lawrence Ave., West Orange, N.J.

Optical Tooling 190

An illustrated catalog listing complete line of optical tooling equipment has just been released. It lists such standard items as jig transits, alignment telescopes, and paragon tilting levels, together with a large number of accessories, instrument stands, fixtures collimators, scales, targets, and optical attachments, including the optical square. Keuffel & Esser Co., Hokoben, N.J.

Plastic Capacitor Chart 191

Quickly available capacitor data comes on a 7-5/8 x 4-1/8-in. plastic card. The handy reference chart shows dielectric qualities and temperature coefficients of tubular and disc Ceramicons and maximum available nominal capacities in micromicrofarads. The reverse side of the card gives dimensions of Ceramicons and PAC's. Erie Resistor Corp., Electronics Div., Erie, Pa.

Metal Film Precision Resistors 192

In 4 pages, Bulletin B-3 presents comprehensive data on the construction, applications and characteristics of several types of metal film precision resistors. Detailed performance charts are presented along with dimensional diagrams and graphs. International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.

Fast Response

Air temperature sensing device as mounted on an aircraft.

Convair-developed fast-response thermocouple.

BASED on a growing need during extended flight instrumentation programs for a very-fast, temperature indicating device that will measure rapidly changing air temperatures, Convair's electronics test laboratory has developed a thermocouple which provides the fast response needed to register the changing air temperatures encountered by modern supersonic aircraft. These varying temperatures might be caused by maneuvers, explosions, or rockets passing through the air. Thus, the hot air region encountered would be narrow and its temperature quite high in comparison to the ambient air temperature.

Suppose there is a region of air at 560 F which is 100 ft. wide. An aircraft flies through it at Mach 1. The ambient air might be at —60 F. Then the change in temperature would be 500 F. The total time that the airplane would be in this hot region would be 0.091 sec. Therefore, in order for aircraft systems to have time to adjust to this large air temperature change, the sensing element should be able to give a total response in 0.01 to 0.02 sec.

To reduce the thermal mass to an absolute minimum, evaporated metal film junctions were tried. The use of evaporated metal films permitted junctions to be prepared with small amounts of metal, and, yet still conduct electricity. These junctions, however, are too thin to support themselves and must be put on a suitable base.

This base material must meet very stiff requirements. Only glass and wood meet these requirements. Some plastics such as the Epoxy resins can be made to have expansion characteristics similar to metal but when this is done the heat conductivity is too high to be useful. Glass is fragile when made into a shape that would give good heat transfer to the thermocouple and its heat conductivity coefficient is rather high compared to wood. Wood appears to be the best choice.

Tests were made with hard and soft woods. The soft woods have lower rates of heat transfer but they do not produce good conducting vacuum metallized films. The wood which was finally selected was somewhat by chance. Bamboo was selected when it was noticed that it could be made

Get $10.00 plus a by-line for the time it takes you to jot down your clever design idea. Payment is made when the idea is accepted for publication.

Thermocouple

very thin and still be quite strong as in saxophone reeds. It was also found to have the very dense structure needed to produce a very smooth surface for good conducting metallized films. Its only disadvantage is its fairly high specific heat, but this is partially compensated by making the base thin.

Probe Design

The present design is shown. It consists of a bridge shaped bamboo section which is made very thin under the junction area, a plastic base on which the bridge is mounted, copper and nickel wire leads and the copper-nickel vacuum metallized junction. The bamboo section is perforated with a number of small holes to allow the air to circulate through it and thus produce a much thinner boundary layer. The area and thickness of the metallized junction can be varied, and at present the metal films are about 5,000 A thick. Special techniques have been devised for thermocouple fabrication.

Since thermocouples characteristically have an exponential response, it is customary to refer to a time constant. This time constant being the time required for the thermocouple output to reach 63 per cent of its final value with step input conditions. It is relatively easy to obtain time constants of 0.08 sec while time constants of 0.05 sec have been reached. The conventional temperature probes tested do not approach this response—being about 0.2 sec.

Applications

This probe could find use in electronically controlled air conditioning systems where the air temperatures must be held within very close limits such as in some laboratory applications. It could be used as the sensing element in crystal oven control circuits where the crystal temperature has to be very constant in order to maintain the crystal frequency accurately. It could be used to evaluate heat transfer through air boundary layers since it measures the temperature at the probe's surface. The junction area and the heat capacity of the probe would have to be known for heat transfer studies.—*R. J. Reid, development engineer; W. M. Gross, chemist; Convair, San Diego, Calif., Div. of General Dynamics Corp.*

Ideas for Design

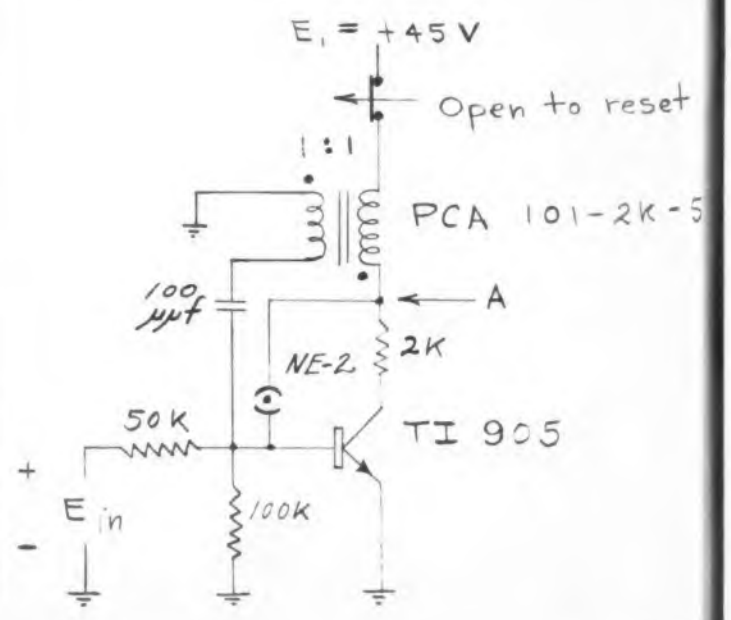
Transistor "Thyratron" Circuit

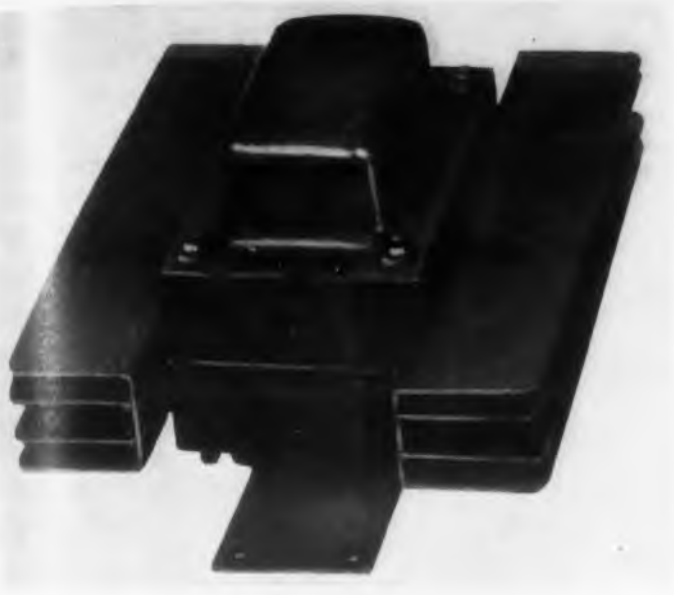
The circuit shown in the figure provides a thyratron-like latching action using a neon bulb and transistor, with the advantage of insignificant standby power consumption. The action of the circuit is as follows.

The supply voltage E_1 is chosen to lie about halfway between the circuit extinction and firing voltages, so that when power is initially applied to the circuit (with the input voltage zero) no current will flow in the load. The circuit extinction voltage and the neon extinction voltage should be the same. The circuit firing voltage, however, will be lower than the firing voltage of the neon alone, since the neon will furnish some "dark" current to the transistor base and cause the circuit to fire and latch at a voltage lower than that required to fire the neon itself. Because of the variation between neons, it may be convenient in some applications to furnish voltage E_1 from a variable regulated source. Such a source may be easily constructed using a low current potentiometer bleeder and emitter-follower regulator combination.

As the input voltage and transistor base current increase, a critical point is reached. The usual blocking oscillator action occurs at the critical input and produces a negative pulse at point *A*. The positive overshoot of the negative pulse produced at point *A*, superimposed on the supply voltage E_1, is sufficient to fire the neon. Because the supply voltage E_1 is greater than the neon extinction voltage, the neon remains fired after the blocking oscillator pulse is over. The neon furnishes base current to the transistor and latches the circuit in the "on" condition. To reset the circuit, it is necessary to reduce the input below the critical value and temporarily interrupt the supply voltage E_1. Typical circuit values are shown. At input of +4 v, this circuit will fire and latch, providing 15 ma to the 2000 ohm load.

W. F. Nielsen, Sandia Corp., Albuquerque, N.M.





Fin-cooled power transformer.

Fin-Cooled Power Transformer

This fin-cooled power transformer for television receivers developed by Zenith Radio Corp. solves its own heat dispelling problem and effects savings of about 10 per cent in cost. By using a multiple-fin construction in the transformer, the surface area has been increased by 185 per cent. This steps up the rate of heat dispersal by 50 per cent, permits a substantial reduction in the amount of iron and copper used, and markedly reduces the weight of the transformer itself.

Zenith mounts this transformer on the TV chassis in such a way that it acts as a pump, pulling cool air in from a vent located on the under side of the chassis. The air rises through the vertical chimney-like fins, cools the transformer and escapes at the top of the cabinet back.

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Here is my design idea for possible publication in your *Ideas For Design* department. I can expect $10 for this idea if accepted for publication.

(Ideas suitable include: *1.* new circuits or circuit modifications, *2.* new design techniques, *3.* designs for new production methods, *4.* clever use of new materials or new components in design, *5.* design or drafting aids, *6.* new methods of packaging, *7.* design short cuts, or *8.* cost saving tips)

STATEMENT OF THE PROBLEM—

MY SOLUTION, AND WHY— (Please be explicit. Include sketches or photos that will help get the idea across)

Signed_____
Title_____
Company_____
Address_____

(Place illustrations on separate sheet if necessary)

Electronics Engineers

▲ Plant of Westchester manufacturing subsidiary, Pleasantville Instrument Corporation; additions are under construction.

Latest GPL engineering building, for which ground was broken recently. ▶

◀ Plant of Bloomfield, N. J., manufacturing subsidiary, Simplex Equipment Corporation; added in 1957.

New GPL environmental test lab, most modern of its kind, now nearing completion. ▼

GPL keeps GROWING

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Patents

Dynamic Amplifier

Patent No. 2,779,921. R. C. Hawes. (Assigned to Beckman Instruments, Inc.)

The amplifier serves to measure a small input current signal. The input signal circuit has a vacuum tube with a control grid and an anode. A switch connects the positive terminal of a plate voltage supply to the anode. A signal input capacitor is provided in series between the grid and the anode. The output circuit includes an output capacitor and a current measuring device in series. The anode is connected to the output circuit so as to control the current in the latter. One of the terminals of the output capacitor is connected to a point between the switch and the anode.

Self-Latching Oscillator

Patent No. 2,778,939. J. A. Haddad. (Assigned to International Business Machines Corp.)

The patent is directed to an electrical oscillating circuit having an electron discharge tube and the circuit oscillates when the tube is conducting. A control circuit provides a negative bias for the tube to maintain the tube in a non-conductive condition. The application of a pulse drives the tube into a conducting condition. A gaseous discharge tube is energized by the output of the oscillating circuit and controls electrical means which overcomes the bias of the control circuit to maintain the oscillating circuit in an operating condition.

Magnetic Memory System

Patent No. 2,776,419. J. A. Rajchman and M. Rosenberg. (Assigned to Radio Corporation of America)

The invention is directed to a magnetic memory system having a plurality of saturable magnetic cores. To a selected core only a magnetomotive force of core saturating strength is applied through suitable coil means. The saturating magnetomotive force is applied to the core successively in one sense and then in the opposite sense to complete a cycle. A winding is coupled to all of the cores, and an integrating circuit is coupled to receive the output of this winding and to integrate it over the complete cycle.

Oscillating Control Apparatus

Patent No. 2,778,574. W. Moore, Jr., and R. J. Ehert. (Assigned to Minneapolis-Honeywell Regulator Co.)

A circuit for the control of an oscillator is described. The circuit includes one or more tubes, and a pair of tank circuits. One tank circuit is connected to the output of the tube or tubes and the other tank circuit is connected to the input. A single inductive element is common to both circuits. A vane is provided which varies the effect of the inductive element on the oscillating circuit and causes the latter to go into and out of oscillation in accordance with its relative position with respect to said inductive element. An additional variable coupling is inserted between the inductive element and the input which varies the coupling in the oscillating circuit.

Automatic Beam-Centering Circuit for Cathode-Ray Devices

Patent No. 2,779,894. C. A. Gallagher. (Assigned to Servo Corporation of America.)

The cathode-ray deflection means of the patent has a centering control for the beam which includes a four-element bridge. One pair of diagonal corners is connected to a source of direct current supply. A third corner of the bridge is connected to an input terminal of each of the usual deflection systems and a capacitor is provided between the third and fourth corners. A potentiometer, across the dc source, is connected to the other terminal of each of the usual deflection systems.

Measurement Standards

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Model 459 (TS-330/TSM) covers 1-15 mc frequency range for crystals having resonance resistances from 0 to 9900 ohms. Price $695.

Model 1207 (AN/TSM-15) covers frequency range of 75-200 mcs for 10-125 ohm crystals. Crystal voltage at series resonance is measured and power calculated. Built-in ohmmeter.

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CIRCLE 206 ON READER-SERVICE CARD FOR MORE INFORMATION

Patents

Cascode Circuits

Patent No. 2,775,659. E. K. Nelson. (Assigned to Standard Coil Products Co. Inc.)

The patent describes a television receiver circuit which will receive an upper and a lower frequency band and also a new wide band high frequency amplifier circuit having general application as well as being advantageous in the receiver circuit. The amplifier circuit includes a first triode having a grounded cathode and a second triode having a grounded grid. A network automatically tunes the amplifier to the frequency spectrum in the upper and lower frequency bands and includes an inductance between the plate of the first triode and the cathode of the second triode. The value of the inductance is selected so that it provides parallel resonance with the plate interelectrode capacitance of the first triode at the high frequency portion of the upper frequency band and series resonance with the cathode interelectrode capacitance of the second triode at the low frequency portion of the band. In the amplifier the second triode is connected as a cathode-input grounded-grid stage with its cathode having a predetermined capacitance to ground. The first triode is connected as a grid-input grounded-cathode driving stage.

Television Scanning Unit

Patent No. 2,777,089. K. E. Farr. (Assigned to Westinghouse Electric Corp.)

An improved beam deflection system for a cathode ray tube is illustrated and described which uses a transformer having a primary winding and a pair of secondary windings. One of the secondary windings provides current through a deflection coil of the CR tube. The other secondary winding supplies current through a rectifier to an anode of the CR tube. One end of the primary winding is coupled to one end of the

first secondary winding by a condenser and the other end of this secondary winding is connected to the negative pole of a direct current source. The positive pole of the source provides current to the primary winding through a rectifier to induce substantially saw-tooth current waves in the deflection coil. A variable inductor in series with a second condenser connects this same end of the primary winding with the negative pole of the current source.

Coherent Radar System

Patent No. 2,776,425. F. J. Altman. (Assigned to International Telephone and Telegraph Corp.)

A radar system includes a transmitter for radiating oscillatory energy toward a mobile reflecting object and a receiver for receiving waves reflected by said object. In the system of the patent the difference in phase between the transmitted energy and the reflected energy is detected and fed to means which obtains the difference in frequency between the transmitted wave and the reflected wave. A control voltage is then derived which is responsive to the detected difference in frequency. Means responsive to this control voltage locks a variable oscillator to the detected frequency difference.

Cascade Multivibrator

Patent No. 2,778,935. R. L. Ropiequet. (Assigned to Tektronix, Inc.)

The trigger-actuated multivibrator uses a plurality of tubes arranged in a normally conducting side and a normally non-conducting side. One side of the multivibrator consists of a pair of tubes with the cathode of the first tube connected to the plate of the second tube. The other side includes a pair of tubes with the plate of the first tube and the grid of the second tube connected through suitable means to the other side of the multivibrator. The other electrodes of each tube are connected to a source of operating potential. The triggering signal is applied to the connection between the cathode and plate of the first pair of tubes.

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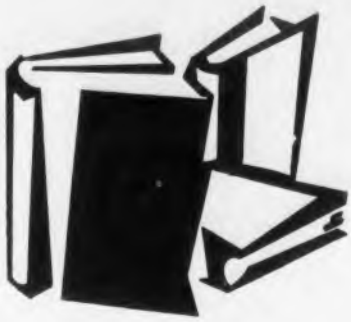


Books

Television Receiving Equipment

W. T. Cocking, Philosophical Library, Inc., 15 East 40 St., New York 16, N.Y. 454 pages, $15.00.

In preparing this fourth edition of "Television Receiving Equipment" Cocking has rewritten approximately three-fourths of his original text, in order to keep up with rapid developments in television.

Band III reception is thoroughly treated as well as the increasing problems of attaining freedom from interference combined with high definition. Magnetic deflection has been expanded to five chapters and synchronizing methods are fully discussed, including flywheel sync. Automatic gain control systems are explained in detail.

The book assumes that the reader will have a fair knowledge of ordinary sound-radio technique, which is a necessary preliminary to an understanding of television. The treatment is largely non-mathematical, but formulae useful to the designer have been collected in the appendices. Two chapters on faults and servicing which appeared in previous editions have been omitted.

Proceedings of the 1957 National Nuclear Instrumentation Conference.

Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa., $5.00.

A complete source of nuclear instrumentation information is contained in the published proceedings of the Instrument Society of America's National Nuclear Instrumentation Conference held in Atlanta April 10, 11 and 12. The papers included cover seven major session headings including two separate meetings on Reactor Instrumentation, and additional sessions on Industrial Nuclear Instrumentation, Basic Problems in Nuclear Instrumentation Health Physics Radiation Instrumentation, University Nuclear Instrumentation Program, and Nuclear Instrumentation in the Medical Field.

VHF Television Tuners

D. H. Fisher. Philosophical Library, 15 East 40 St., New York 16, N.Y., 136 pages, $6.00.

The treatment of television tuners by D. H. Fisher is divided into three sections: Tuner Design; Tuner Construction; Tests, Measurements, and Servicing. Theoretical factors are considered first. Section I gives a complete introduction to the problems to be solved and an understanding of the reasons underlying the choice of a particular unit. In Section II the practical considerations of tuner construction are discussed. The intention is to show what is being done and why. Laboratory, production and service problems are studied in Section III.

The Heating Ventilating & Air Conditioning Guide

1957, 35th edition published by American Society of Heating and Air Conditioning Engineers, 1250 pages, $12.00.

Electronic engineers concerned with the control of industrial environment should find Chapter 44 of this text interesting. A new method is described for establishing standards to indicate heat stress. A chart, which is presented, permits combining the effects of various factors into a single heat stress index. Methods discussed for controlling heat exposure include: control at source; exhaust ventilation; radiation shielding; and local relief. Methods also are given for controlling air contaminant concentrations.

What the Russians are Writing

J. George Adashko

RADIO ENGINEERING

(Contents of Radiotekhnika No. 10, 1956)

Pulse Detector

Pulse Detector with LCR Filter, E. L. Gerenrot, (8 pp, 4 figs).

The transients in an ideal detector with an LCR filter are investigated with proper allowances for the internal impedance of the current source (of the current-generator equivalent of the signal voltage). The effect of the inductance on the "overshoot" that accompanies the detection of a rectangular pulse is discussed. Simple computation methods and analytic expressions are derived for the detection of other waveforms.

Transistor Circuits

Graphical Design of Temperature Compensated Resistance-Coupled Transistor Amplifiers, G. V. Voishvillo, V. S. Davydov, (7 pp, 6 figs).

Essentially based on the analytical derivations contained in Shea, "Principles of Transistor Circuits," Keonjian, "Temperature-Compensated DC Transistor Amplifier" (*Proc. IRE*, April 1954), and Oakes, "DC Stability of Transistor Circuits," (Wireless World, April 1955). The family of transistor static characteristic is used to determine the shift in the operating point caused by temperature fluctuations. The inverse problem, that of using the static characteristics to establish the circuit elements for which the temperature drift will lie within a specified range or vanish entirely, is also treated.

Equivalent Circuit of Semiconductor at High Frequencies, I. I. Litvinov, (5 pp, 7 figs, 1 table).

Another attack on this popular problem, based this time on using the approximate operator equation

$$h(p) = A\frac{1}{p^2 + 2ap + c^2}$$

for the transfer function of the transistor equivalent circuit. The constants A, a and c^2 are evaluated for several Russian transistors.

Oscillator

Self-Oscillating Systems with Two Degrees of Freedom, and with Common-Multiple Natural Frequencies, G. M. Utkin, (11 pp, 1 fig).

The simple circuit shown in Fig. 1 can oscillate at two simultaneous frequencies that are common multiples of each other, provided the circuits parameters are properly chosen. An extensive analysis of such circuits is given, and their performance in frequency multiplication and division circuits and in frequency modulation is discussed.

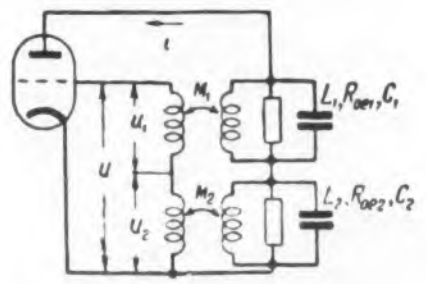


Fig. 1. Simple multiple-frequency oscillator

Audio Power Amplification

Pulse Methods in Audio Frequency Power Amplification, V. V. Malanov, (9 pp, 8 figs).

A theoretical analysis, giving no circuit data, of a scheme whereby the audio signal is pulse-width modulated, amplified, and demodulated in a selector-modulator circuit, which separates the modulating frequency from the higher harmonics in the amplifier output. These harmonics can be rectified and supply part of the amplifier power. The idea was first proposed by Prof. D. V. Ageev (presumably of the Gor'ki Polytechnic Institute, where the work abstracted in the article was done as a Candidate's thesis project) in 1951 and was independently suggested in France by R. Charbonnier (neither date nor reference cited). It is shown that this method becomes attractive only at high powers (above 20 watts) and apparently for voice frequencies only.

Panoramic Receiver

Choice of Intermediate Frequency in Panoramic Receivers, N. I. Svetlov, (19 pp, 3 figs, 5 tables).

The design of a panoramic receiver involves the simultaneous determination of several parameters, including the choice of first and second IF's, choice and design of the f-m heterodyne circuit, the compensation of the frequency characteristics of the wide-band channel, and the choice of the pass band and of the type of filter used in the second IF amplifier and sweep-frequency generator. The article deals only with the choice of intermediate frequencies and with the prevention of cross-modulation effects.

RADIO ENGINEERING

(Contents of Radiotekhnika No. 11, 1956)

Filters

Bandpass Filters with Constant Shape of Frequency Characteristic, I. M. Simontov, (3 pp, 3 figs).

Essentially intended for long-wave receivers.

Charts for Design of Filters for Specified Characteristic Parameters, M. M. Shenberg, (6 pp, 2 figs).

A single chart makes it possible to determine the parameters of matched filter elements for a specified attenuation and effective bandwidth. A nomogram is also given to obtain the frequency characteristic of the insertion loss of the filter in the attenuation band.

Quality Control

Choice of Parameter Tolerances for Radio Circuits, N. F. Vollerner, (10 pp, 6 figs, 1 table).

A quality-control discussion, showing the effects of maximum deviations of various parameters of radio circuits on the overall performance of the apparatus.

Radio Interference

Radio Interference Produced by Gas-Filled Rectifiers in the Transmitter, G. S. Shul'man, (2 pp).

This interference can be filtered out, like all other static, with a grounded-center capacitor network.

Phase Detector

Practical Elimination of "Inverted Operation" of an Amplitude-Phase Detector in the Presence of Pulsed Noise, Iu. S. Lezin, (8 pp, 4 figs).

An analysis of the same circuit, but in the presence of fluctuating noise, was given by the author in *Radiotekhnika i Elektronika* for March 1956 and abstracted in the December 15, 1956 issue of ELECTRONIC DESIGN. "Inverted operation," whereby noise causes the signals to reverse polarity, can be eliminated considerably by making the bandwidth of the detector grid circuit much narrower than the bandwidth of the receiver.

Circuit Design

Design of Certain Circuits Based on Their Response to a Unit Step Voltage, V. V. Zgirskis, (8 pp, 4 figs).

Straightforward procedure for synthesis of a resonant or aperiodic L-pad for a specified response to a unit step function. The transfer function is obtained by determining graphically from the response curve the frequency and attenuation factor which, together with the initial and final values of the output voltage, are used to determine the transfer function in operator form.

Miscellaneous

The Averaging Method and Its Application to Certain Non-Linear Problems in Electronics, Iu. N. Bakaev and P. I. Kuznetsov, (10 pp, 3 figs).

The "averaging method" is one developed by N. N. Bogoliubov to obtain approximate integrals for differential equations with slowly-varying nearly-sinusoidal and quasi-linear parameters. These equations are used in electronics for the analysis of various non-linear circuits, such as the exponential detector and similar devices.

Comparison of Statistical and Non-Statistical Prediction, R. A. Kazarian, (5 pp, 1 fig).

The criterion of comparison is the least-squared error. The article proves that no linear physically-realizable prediction network can yield a smaller least-square error than is obtainable by statistical prediction. Refers to Westcott, "Criteria of Prediction and Discrimination," (*Transactions IRE*, Prof. Group on Inform. Theory, 1, 1953) and to Bode and Shannon, "A Simplified Derivation of Linear Least Square Smoothing and Prediction Theory," (*Proc. IRE*, Vol. 38, No. 4, 1950).

Noise Rejection of a Radio Receiver at High Fluctuation-Noise Level, A. G. Ziuko, (2 pp, 2 figs).

Given here is a brief statistical discussion in which a comparison is made of several types of modulation. The effects of highly fluctuating noise levels on the noise rejection capabilities of a radio receiver are discussed.

Russian Translations

Radio Engineering #11 Cont.

TV Synchronization

Determination of the Stability Region of an AFC System of Television Synchronization, Iu. N. Bakaev, P. I. Kuznetsov, (8 pp, 5 figs).

The differential equations of the system are solved to a higher order of approximation than employed by Preston and Fellier ("The Lock-In performance of an AFC Circuit," *Proc. IRE*, No. 2, 1953) or Gruen ("Theory of AFC Synchronization," *Proc. IRE*, No. 8, 1953). The use of the small-parameter method is proposed for the investigation of the aperiodic state of the system.

Transistor Circuits

Practical Video-Amplifier Transistor Circuits, T. M. Agakhanian, Iu. A. Volkov, (7 pp, 11 figs).

Continuing the work described in an earlier article (Reduction of Pulse-Front Distortion in Junction-Transistor Video Amplifiers, Radiotekhnika, Sept. 1956, (*ED*, June 15, 1956) the authors show how the common-emitter amplifier incorporating with a network to redistribute the current carriers near the base, can be used as a practical video amplifier. Fig. 2 shows three types of single-stage amplifiers, and Fig. 3 shows a four-stage amplifier, with an amplification factor of 750 and a 550 kc bandwidth. Russian type PIE transistors are used.

Frequency Converters

Pentode Frequency Converters for Meter Waves, I. I. Levenstern, (7 pp, 7 figs).

Discusses several versions of pentode converters, their operating features at meter waves, and experimental results on the converter shown in Fig. 4.

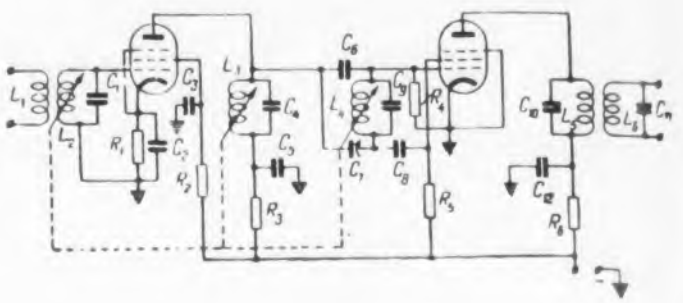


Fig. 4. Pentode converter preceded by hf stage. The tube characteristics are: $E_p = 250$, $E_{g2} = 150$, $E_f = 6.3$, $S = 5$ ma/v, $R_i = 0.5$ Meg. $C_{in} = 6.5$ μμf, $C_{out} = 1.5$ μμf, $C_{pg} = 0.025$ μμf, $r = 1500$ ohm ($f = 70$ mc). The computed amplification and conversion coefficients for 70 cycles were 12.9 and 12.7 respectively, while the measured values in the 66-73 mc band were 11 to 14 and 10 to 11 respectively.

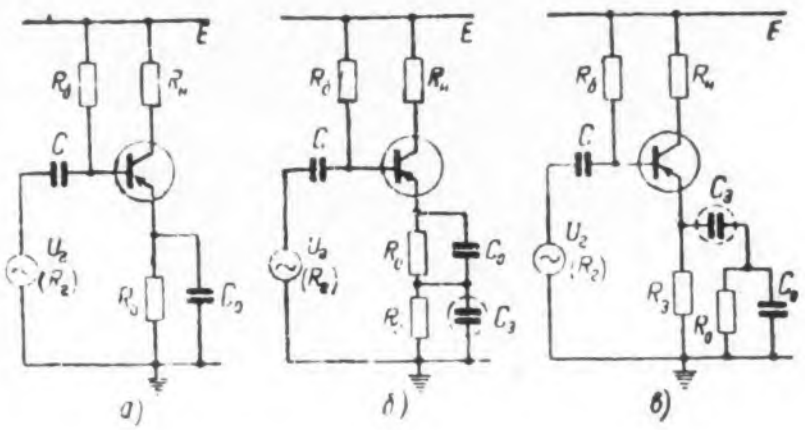


Fig. 2. Three types of single-stage transistor video amplifiers. Circuit *a* is simpler, but has the disadvantage that the base-circuit resistor R_b must be selected by trial, for even transistors of the same type show enough variation in their parameters to necessitate different resistor values. Circuits *b* and *c* are free of this shortcoming and are somewhat more stable.

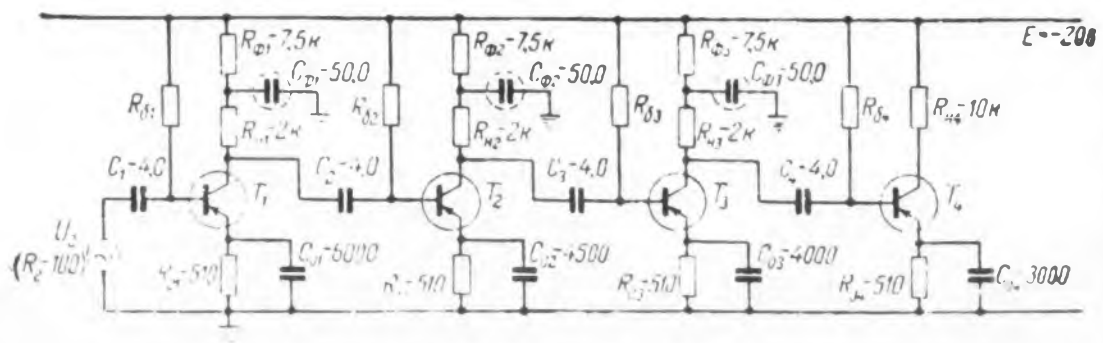


Fig. 3. Four-stage amplifier using Russian type PIE transistors (Note — capacitor values are in micromicrofarads, except for electrolytics, identified by dotted circles, which are in microfarads.

Miscellaneous

Reflection of Normally-Polarized Plane Wave from Wire Grid, V. G. Iampolski, (5 pp, 3 figs).

It is known that wire grids are strong reflectors of electromagnetic waves polarized parallel to the wires but when the polarization is perpendicular to the axes of the wires, the field is barely reflected from the grid. Parallel polarization was thoroughly treated in the literature many years ago. This article is devoted to normal polarization for wire diameters much smaller than the wavelength.

Concerning the Geometric Proof of the Shannon Theorem, E. L. Blokh, A. A. Kharkevich, (12 pp, 7 figs).

Previous attempts to formulate a geometric proof of Shannon's theorem on the bandwidth of a channel have led to disagreement with Shannon's results. Further investigation has shown that these discrepancies were due to an incorrectly assumed geometric model.

AUTOMATION AND TELEMECHANICS

(Contents of Avtomatika i Telemekhanika No. 11, 1956)

Servomechanisms

Use of Non-Linear Correcting Devices in Second-Order Automatic Regulation Systems, G. M. Ostrovski, (6 pp, 5 figs).

Discusses conditions under which the response of second-order linear servomechanisms can be improved by introducing special non-linear elements. Refers to Neiswander & MacNeal, "Optimization of Nonlinear Control Systems by Means of Nonlinear Feedback" (*Trans. AIEE*, vol 72, 1953) and West, Douce, and Naylor, "The Effect of the Addition of Some Nonlinear Elements on the Transient Performance of Simple RPC System Possessing Torque Limitations," (*Proc. IEE*, No. 80, 1954).

Stability Criteria for Two-Phase Induction Servomotor, E. I. Slepushkin, (9 pp, 4 figs).

The servomotor is considered here as an element in an open-loop automatic-control system, and the response of the system to changes in line voltage and in phase angle is analyzed in terms of generalized parameters of the equivalent circuit of the motor. The author indicates the range of voltage and phase-angle variations for which no special closed-loop regulation system is needed for stable motor operation. Reference is made to Koopman, "Operating Characteristics of Two-Phase Servomotors," (*Trans. AIEE*, vol 68, 1949), and to two Russian articles by Kasprzhak from Avtomatikai Telemekhanika No. 7 and No. 9, 1956, abstracted in *ED* in the January 1, 1956 and May 1, 1956 issues.

Russian Translations

Cybernetics

On Certain Regularities in the Work of a Human Operator, S. S. Medvedev, (15 pp, 12 figs).

Right elegant and sophisticated cybernetic study of a man matching the pointer of a meter against a moving index. Results obtained testing four operators are given, together with a mathematical analysis of the experimental results (using both statistical theory and analysis in the frequency domain), leading to an equation describing the average reactions of the operator. Refers to Tustin, "The Nature of the Operator's Response in Manual Control," *Jl. IEE*, vol. 94, part IIA, No. 2, 1947.

Relaxation Oscillator

Controllable Relaxation Oscillator Using Glow-Discharge Tube, S. V. Svechnikov, (6 pp, 6 figs).

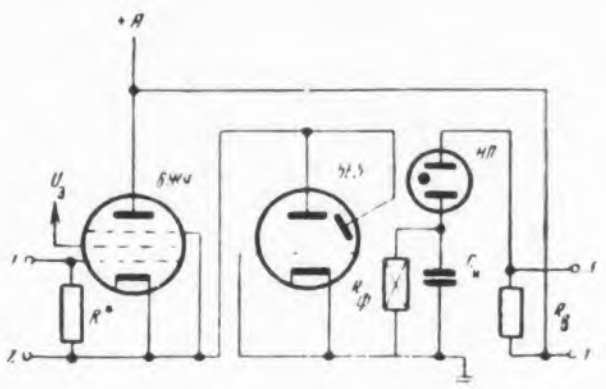


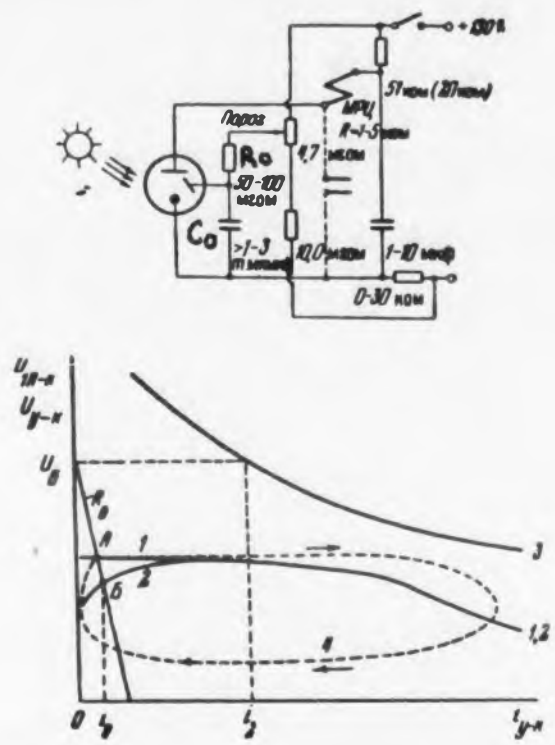
Fig. 5. Relaxation oscillations are produced in this interesting circuit by a neon tube (a cold-cathode thyratron or a voltage-regulator tube will do just as well) in conjunction with cadmium-sulfide photoresistor acting as a contactless potentiometer, the resistance of which is varied by changing the brightness of a tuning-eye tube (6E5) operating as a diode with a variable load, namely the pentode. Terminals 1 and 2 are the input, 3 and 4 are the output (picked off load resistor R_B).

Relay Systems

On Periodic Operating States of Relay Systems with Internal Feedback, N. A. Korolev (10 pp, 6 figs).

Another theoretical paper, which considers the periodic operating states (either self-oscillations or forced oscillations) in relay systems with internal feedback. It is shown that relay systems using delay feedback (also called relaxation, inertia, or time-lag feedback) can become oscillating in response to an abrupt change in the derivative of the input signal from the relay element.

Ionic Photorelay, L. N. Korablev, (2 pp, 3 figs).



Figs. 6 and 7. The feature of the circuit shown is that a single three-electrode cold-cathode tube serves simultaneously as a photocell as well as an ionic relay. The voltage applied to the anode of the tube is less than the firing voltage, but higher than the glow voltage. If the tube is not illuminated, the current-voltage characteristic of the discharge between the anode and cathode is represented by curve 1 of Fig. 7. If the tube is illuminated, the corresponding characteristic is curve 2. These curves intersect the load line R_o at points A and B, respectively, but the slopes of the characteristics are such that point B (dark) is stable, point A (illuminated) is not. If C_o is large enough, and the tube is illuminated, the capacitor is charged to a value A, which, being an unstable point on the cell characteristic, will cause the tube to ignite and the relay to operate.

Miscellaneous

"Certain Problems in the Development of Automation in the Czechoslovak Republic," Iu. Benesh (5 pp). "On the Stability of Automatic Regulation Systems Containing a Single Regulating Element," B. S. Razmukhin, (11 pp). (Highly theoretical treatment, using Liapunov's theory.) "Frequency-Analysis Method of Determining the Derivatives of the Transfer Function," V. M. Kagan, (3 pp.) "Wattmeter with Rectifier Elements for Power Telemetering," Sh. Iu. Ismailov, A. V. Fremke (2 pp, 2 figs). "Experimental Determination of Stiffness of Rubberized-Cloth Membranes," V. P. Temnyi, (4 pp, 4 figs). "Use of Computing Devices in Automatic Systems," A. A. Fel'dbaum, (11 pp, 13 figs). (Survey of the state of the art, citing many American references.) "Theory of a Control Element of the 'Nozzle-Gate Valve' Type Operating in Oil," A. G. Shashkov (20 pp, 15 figs).

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For example, precision thermometers are used, since they are far more stable and reliable than thermocouple or thermistor temperature-indicating circuits. The high accuracy of the MC-1B is maintained without frequent calibration.

Our Calorimetric Wattmeter consists of two units—a liquid circulator and a water load termination. The circulator unit controls the flow of metered amounts of distilled water through the termination, where RF output is converted to heat by means of a water load. Heat absorbed by the distilled water calorimetric fluid is measured on precision thermometers. A power scale on the termination permits direct, precise power readings in watts.

Distilled water is used as calorimetric fluid because of its high dielectric loss characteristics above 1000 mcs. The circulator permits visual monitoring of the fluid flow rate at all times. All parts of the circulator are designed and fabricated to prevent fluid contamination.

Through the use of RF adapters, a match better than 1.15 in VSWR from 2600 to 26,500 mcs is achieved without problems associated with the excitation and propagation of higher order waveguide modes.

Metered fluid flow, precision temperature readings and well designed control of heat transfer permit extreme accuracies of power measurement.

Cubic Calorimetric Wattmeters are being used extensively by industrial and government laboratories. For example, RCA has over 30 of these instruments in use to check out and calibrate magnatrons and radar systems. Hughes Aircraft Company uses them in the same manner.

Cubic's Calorimetric Wattmeter will *prove* its accuracy—as no other wattmeter can—in your laboratories, in your plant, or in the field.

For a prove-it-yourself demonstration of how you can obtain consistent, repetitive results in RF measurement, telephone or write . . .

CUBIC

CUBIC CORPORATION
5575 Kearny Villa Road, San Diego 11, California

CIRCLE 551 ON READER-SERVICE CARD FOR MORE INFORMATION

Honeywell's Variable Inlet Diffuser
Controls Keep the "Hustler" Hustling

ENGINEERS
SCIENTISTS

WORK ON ADVANCED PROJECTS LIKE THIS

As mach numbers advance, even fractional errors in inlet-air diffuser positioning reduce thrust tremendously.

Yet a fixed diffuser designed for optimum pressure at a given high mach number may be so inefficient at a lower mach number as to render it impossible for aircraft to reach design speed.

In the U.S.A.F.'s first supersonic bomber, Convair's B-58 Hustler, this problem was solved by Honeywell's variable inlet-air diffuser systems—the most accurate known. They are automatically controlled to the proper parameters to achieve maximum pressure recovery and mass air flow matched to engine requirements.

The Challenges to Come!

Variable inlet diffuser systems are just one of 114 research and development projects in which Honeywell Aero is engaged. These projects are in the basic areas of:

INERTIAL GUIDANCE • FLIGHT CONTROL SYSTEMS • LIQUID MEASUREMENT SYSTEMS • VERTICAL, RATE AND INTEGRATING GYROS • DIGITAL AND ANALOG COMPUTERS • JET ENGINE CONTROLS • AIR DATA COMPUTERS • BOMBING COMPUTERS TRANSISTOR AMPLIFIERS • INSTRUMENTATION

Each of these projects offers exceptional career opportunities for capable engineers and scientists.

And Honeywell's rapid growth assures you of early advancement. Engineering personnel at Honeywell Aero has tripled in the last 5 years, is still growing faster than the avionics industry average. Supervisory positions open quickly, are filled from within. The first-rate salary you start with at Honeywell is *just the start.*

Write today!

For more information concerning these opportunities, send your inquiry or résumé to: Bruce D. Wood, Technical Director, Dept. TA20E, Honeywell Aero, 1433 Stinson Boulevard, Minneapolis 13, Minn.

Honeywell
Aeronautical Division

CIRCLE 554 ON READER-SERVICE CARD FOR MORE INFORMATION

MISSILE GUIDANCE AT Bendix IN SOUTHERN CALIFORNIA

In connection with its long range Missile Guidance programs Bendix-Pacific has excellent positions for Electronic Test Equipment Designers, Circuit Designers and Microwave Engineers.

Bendix also has unusual engineering positions in electrical and mechanical design of airborne radar and telemetering.

You are invited to consider becoming a member of this far sighted engineering organization in Southern California.

Please fill in the coupon or write us for complete information.

W. C. Walker, Engineering Employment Manager
Pacific Division, Bendix Aviation Corp.
11606 Sherman Way, North Hollywood, Calif.

Please send information.
I am a graduate engineer with ____ degree.
I am not a graduate engineer but have ____ years experience.

Name _____
Address _____
City _____ Zone ____ State ____

CIRCLE 557 ON READER-SERVICE CARD

GUARDIAN OF MILLIONS— THOUSANDS OF MILES AWAY

Silently and dependably, Crosley RADAR stands guard against hostile action — "watching" in every direction, every moment.

Here are new and challenging projects for Engineers. Crosley Division, AVCO Manufacturing Corporation, is contributing electronic know-how of a high order in this field.

Why not investigate your professional growth with AVCO? Find out how *you* can fit into our continuing expansion programs.

HERE ARE FIELDS OF CURRENT ACTIVITY:

1. Ground Radar
2. Airborne Defense Systems
3. Antenna and Micro-Wave Equipment
4. Computer and Analytical Services (Design and Development) (Programming and Application)
5. Communications (Airborne Transmitters and Receivers)
6. Airborne Fire Control
7. Servo-Mechanisms
8. Transistorized Equipment
9. Guided Missiles

Write us for complete details. We'll send you literature and we'll tell you about the advantages of family living in Cincinnati — "Queen City of the West, Closest to the Heart of America". There are numerous company benefits and you will be paid generous relocation expenses.

Send a Resume to:

Mr. Nick M. Pagan
Technical and Professional Employment Office, Dept. FF

AVCO MANUFACTURING CORPORATION
Crosley Division
1329 ARLINGTON STREET · CINCINNATI 25, OHIO

CIRCLE 558 ON READER-SERVICE CARD FOR MORE INFORMATION

project engineers

MECHANICAL, ELECTRICAL OR PHYSICIST

For engineering and development of advanced airborne navigation systems and related test equipment.

field service engineers AND technical representatives

For field service work on aircraft instrumentation and navigation systems. Requires electronic background with knowledge of electromechanical systems.

In Kollsman you find a company that is small enough to provide quick recognition and reward, yet large enough to assure stability now and in the future. You can take pride in working for the organization which designs America's finest aircraft instruments.

Please send resumes to T. A. DeLuca. Confidential interviews will be arranged.

kollsman INSTRUMENT CORPORATION

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ENGINEERS for GUIDANCE and NAVIGATION SYSTEMS

IMPETUS—

is the force that overcomes resistance to a solid body or, in the realm of thought, a new idea. At Sanders, it operates irresistibly whenever a new engineering concept encounters outmoded, textbook thinking.

Please address inquiries to D. H. Johnson.

SANDERS ASSOCIATES, INC.

NASHUA NEW HAMPSHIRE

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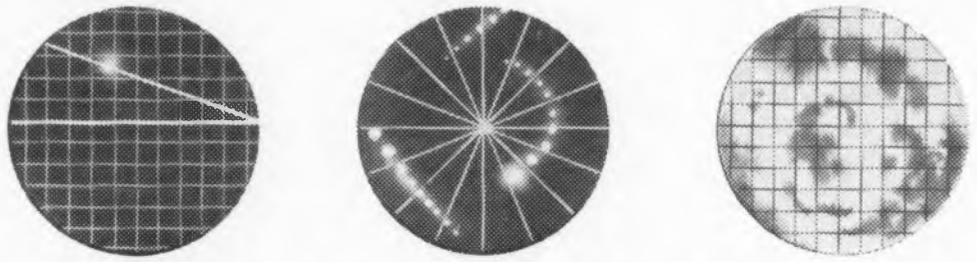

HOW'S YOUR RADAR DISPLAY DEFLECTION CIRCUITRY?

We have a requirement for a man with 5 to 7 years in Radar Display Deflection Circuitry.

We will expect this man to assume full responsibility for critical research work. If he thinks he has two or three assistants that can be helpful to him, we want to talk to them too.

We are a large corporation with a growing Research and Development Division. All our plants are included in a circle with a diameter of less than 10 miles. We recognize engineers and the work they do at the highest professional level. Though we are a large company, our division has no "LOST ENGINEERS."

We are located in the most desirable area in the country — less than 1 hour from New York City and all its advantages — less than 1 hour from beautiful ocean resorts — less than 1 hour from mountain regions and resorts. Beautiful suburban living in an area of good schools for your children and excellent advanced study facilities for yourself. No state income tax.

Write today in confidence.

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Unique opportunities for production engineers

at Honeywell Aero!

Honeywell Aero offers you a variety of exciting production engineering projects in the field of aeronautical controls—projects such as automatic control systems and components for more than 15 of the most advanced Guided Missiles, Ballistic Missiles and Rockets; plus Automatic Flight Control Systems for the F-100, F-101, CF-105 and B-66; and Fuel Measurement Systems for the T-37, XFY-1 Pogo, P6M Seamaster, C-130, Boeing 707, Douglas DC-7, Lockheed Electra, F11F and F-106.

Engineering personnel at Honeywell Aero has more than tripled since 1951. Honeywell sales have increased 600% in the last 10 years. Growth like this promises a future full of opportunities for you.

Here is a partial list of positions now open in Minneapolis

Bellows Specialist: Physics or M.E. Degree, 3 years' experience in high vacuum field.

Production Engineer: 2 years' experience on electromechanical devices, fine pitch gearing, motors and precision parts.

Production Engineer: 2 years' production processing on amplifiers, transistor units and servo mechanisms.

Senior Gyro Engineer: Engineering degree with 5 years' related production experience. Must have ability to lead program to produce new gyro or inertial platform designs.

Senior Electronic Engineer: E.E. degree with 5 years' related electronics production experience. To lead electronic production program.

Production Engineer: B.S.M.E. or equivalent experience. 3 years' experience in processing electromechanical devices.

Production Engineer: B.S.E.E. or Physics degree. 3 years' experience in processing electronic devices. Magnetic amplifier experience preferred.

Production Engineer: B.S.M.E., B.S.I.E. or B.S.E.E. 3 years' experience in processing electromechanical assemblies.

WRITE TODAY!

If you are interested in any of the positions above, or want to learn more about other outstanding opportunities for Production, Research or Design Engineers at Honeywell Aero, send a brief résumé of your education and experience to Bruce D. Wood, Technical Director, Dept. TA20D, Minneapolis-Honeywell, Aero Division, 1433 Stinson Blvd., Minneapolis 13, Minnesota.

Honeywell

H Aeronautical Division

CIRCLE 564 ON READER-SERVICE CARD FOR MORE INFORMATION

ADVERTISING INDEX

July 1, 1957

(Use before Aug. 15th, 1957)

ELECTRONIC DESIGN

☐ I do design work
☐ I do no design work

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(Print or type all information)

Company

Company Address

For Change of Address: Old Company Name

Old Company Address | City | Zone | State

	10	20	30	40	50	60	70	80	90
	300	310	320	330	340	350	360	370	380	390
1	11	21	31	41	51	61	71	81	91	301	311	321	331	341	351	361	371	381	391
2	12	22	32	42	52	62	72	82	92	302	312	322	332	342	352	362	372	382	392
3	13	23	33	43	53	63	73	83	93	303	313	323	333	343	353	363	373	383	393
4	14	24	34	44	54	64	74	84	94	304	314	324	334	344	354	364	374	384	394
5	15	25	35	45	55	65	75	85	95	305	315	325	335	345	355	365	375	385	395
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7	17	27	37	47	57	67	77	87	97	307	317	327	337	347	357	367	377	387	397
8	18	28	38	48	58	68	78	88	98	308	318	328	338	348	358	368	378	388	398
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106	116	126	136	146	156	166	176	186	196	406	416	426	436	446	456	466	476	486	496
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108	118	128	138	148	158	168	178	188	198	408	418	428	438	448	458	468	478	488	498
109	119	129	139	149	159	169	179	189	199	409	419	429	439	449	459	469	479	489	499
200	210	220	230	240	250	260	270	280	290	500	510	520	530	540	550	560	570	580	590
201	211	221	231	241	251	261	271	281	291	501	511	521	531	541	551	561	571	581	591
202	212	222	232	242	252	262	272	282	292	502	512	522	532	542	552	562	572	582	592
203	213	223	233	243	253	263	273	283	293	503	513	523	533	543	553	563	573	583	593
204	214	224	234	244	254	264	274	284	294	504	514	524	534	544	554	564	574	584	594
205	215	225	235	245	255	265	275	285	295	505	515	525	535	545	555	565	575	585	595
206	216	226	236	246	256	266	276	286	296	506	516	526	536	546	556	566	576	586	596
207	217	227	237	247	257	267	277	287	297	507	517	527	537	547	557	567	577	587	597
208	218	228	238	248	258	268	278	288	298	508	518	528	538	548	558	568	578	588	598
209	219	229	239	249	259	269	279	289	299	509	519	529	539	549	559	569	579	589	599

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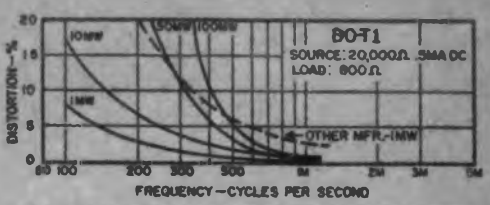
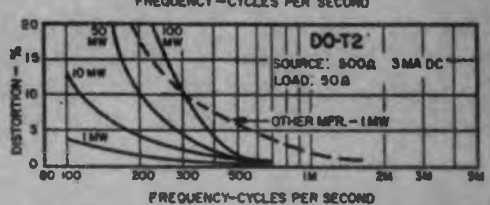
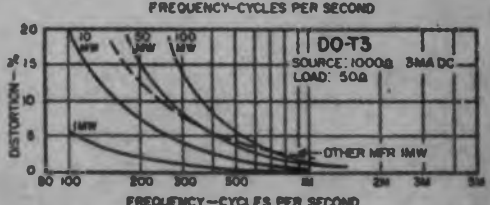
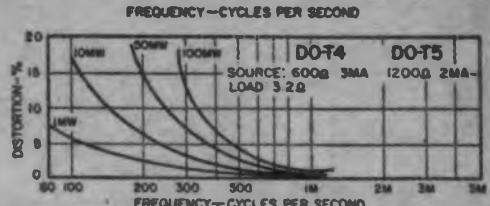
TYPICAL DO-T PERFORMANCE CURVES

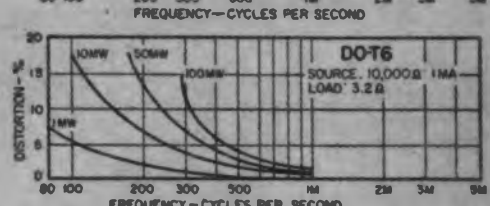
Power curves based on setting output power at 1 KC, then maintaining same input level over frequency range.

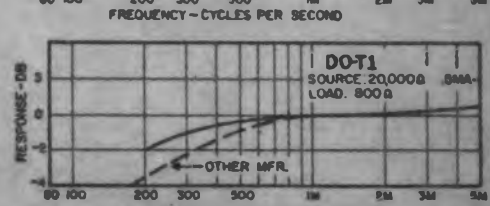


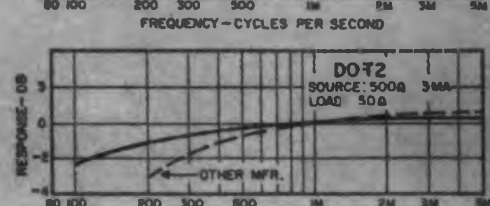


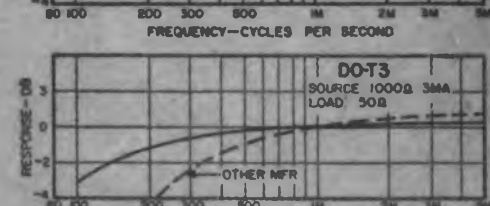


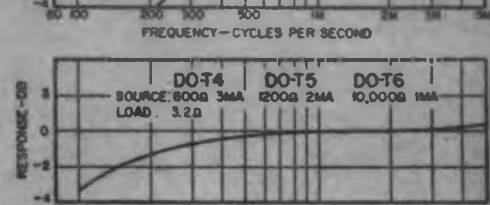












*DO-T units have been designed for transistor application only . . . not for vacuum tube service. **Pats. Pending

DO-T S

Power Transformers

Conventional miniaturized transistor transformers have inherently poor electrical characteristics, perform with insufficient reliability and are woefully inadequate for many applications. The radical design of the new UTC DO-T transistor transformers** provides unprecedented power handling capacity and reliability, coupled with extremely small size. Twenty-five stock types cover virtually every transistor application*. Special types can be made to order.

High Power Rating . . . up to 100 times greater.

Excellent Response . . . twice as good at low end.

Low Distortion . . . reduced 80%.

High Efficiency . . . up to 30% better.

Moisture Proof . . . hermetically sealed to MIL-T-27A.

Rugged . . . completely cased.

Anchored Leads . . . will withstand 10 pound pull test.

Printed Circuit Use . . . (solder melting) plastic insulated leads.

Type No.	MIL Type	Application	Pri. Imp.	D.C. Ma.‡ in Pri.	Sec. Imp.	Pri. Res.	Level Mw.
DO-T1	TF4RX13YY	Interstage	20,000 30,000	.5 .5	800 1200	850	50
DO-T2	TF4RX17YY	Output	500 600	3 3	50 60	60	100
DO-T3	TF4RX13YY	Output	1000 1200	3 3	50 60	115	100
DO-T4	TF4RX17YY	Output	600	3	3.2	60	100
DO-T5	TF4RX13YY	Output	1200	2	3.2	115	100
DO-T6	TF4RX13YY	Output	10,000	1	3.2	1000	100
DO-T7	TF4RX16YY	Input	200,000	0	1000	8500	25
DO-T8	TF4RX20YY	Reactor 3.5 Hys. @ 2 Ma. DC				630	
DO-T9	TF4RX13YY	Output or driver	10,000 12,500	1 1	500 CT 600 CT	800	100
DO-T10	TF4RX13YY	Driver	10,000 12,500	1 1	1200 CT 1500 CT	800	100
DO-T11	TF4RX13YY	Driver	10,000 12,000	1 1	2000 CT 2500 CT	800	100
DO-T12	TF4RX17YY	Single or PP output	150 CT 200 CT	10 10	12 16	11	500
DO-T13	TF4RX17YY	Single or PP output	300 CT 400 CT	7 7	12 16	20	500
DO-T14	TF4RX17YY	Single or PP output	600 CT 800 CT	5 5	12 16	43	500
DO-T15	TF4RX17YY	Single or PP output	800 CT 1070 CT	4 4	12 16	51	500
DO-T16	TF4RX13YY	Single or PP output	1000 CT 1330 CT	3.5 3.5	12 16	71	500
DO-T17	TF4RX13YY	Single or PP output	1500 CT 2000 CT	3 3	12 16	108	500
DO-T18	TF4RX13YY	Single or PP output	7500 CT 10,000 CT	1 1	12 16	505	200
DO-T19	TF4RX17YY	Output to line	300 CT	7	600	19	500
DO-T20	TF4RX17YY	Output or matching to line	500 CT	5.5	600	31	500
DO-T21	TF4RX17YY	Output to line	900 CT	4	600	53	500
DO-T22	TF4RX13YY	Output to line	1500 CT	3	600	86	500
DO-T23	TF4RX13YY	Interstage	20,000 CT 30,000 CT	.5 .5	800 CT 1200 CT	850	100
DO-T24	TF4RX16YY	Input (usable for chopper service)	200,000 CT	0	1000 CT	8500	25
DO-T25	TF4RX13YY	Interstage	10,000 CT 12,000 CT	1 1	1500 CT 1800 CT	800	100

‡DCMA shown is for single ended useage (under 5% distortion—100MW—1KC) . . . for push pull, DCMA can be any balanced value taken by .5W transistors (under 5% distortion—500MW—1KC)

UNITED TRANSFORMER CORP.

ELECTRONIC DESIGN

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