CROSS TALK

PATENTS . . . In a recent issue of the *Official Gazette* of the U. S. Patent Office is a decision of the U. S. Court of Customs and Patent Appeals in an interference case involving an electron multiplier. We found this interesting reading in spite of the peculiar language of the revered judges. One statement was particularly interesting in view of our recent addition of a department to ELECTRONICS dealing with new patents, and the accompanying job of trying to find out from the single claim published in the *Gazette* the aim of the patents in question.

This statement says, "It may not be overlooked that it is a condition precedent to the obtaining of a patent that the applicant shall, in his written application, describe his claimed invention or discovery in 'such full, clear, concise, and exact terms as to enable a person skilled in the art * * * to make, construct, compound, and use the same.'"

Now it seems to us that if this rule were followed, the *U. S. Patent Office Gazette* would be the most exciting reading possible for any engineer in any profession. Instead, it is a deadly bore because of the fact that most of the claims of most of the patents published are completely non-understandable without a great deal of study. These claims are written by lawyers and not by engineers and do not seem to be written with the idea of disclosing some new invention or discovery but to prevent its disclosure. Every time we think we are about to learn something, about to get to the crux of the patent, we are shunted off into generalities and really are as much in the dark as ever.

For example, let us apply the rule of "clear, concise, exact" language to the following claim in a patent allowed for making selenium rectifiers.

"1. The method of manufacturing selenium-coated electrical devices of the general character indicated, which includes applying amorphous selenium to an auxiliary member, heating an electrode member, applying a selenium-coated side of said auxiliary member to said electrode member, subjecting the selenium to a formation process, and then removing said auxiliary member, all of the above-mentioned steps being performed in a partial vacuum."

Now we gather from this that the invention consists of making a selenium rectifier *in a vacuum*. If the individual steps or a summation of these steps described here is the invention, it is described in such general terms that anyone "applying amorphous selenium to an auxiliary member", or "heating an electrode member", or "applying a * * * side of the auxiliary member to the electrode member", or "subjecting the selenium to a formation process" (undescribed), or "removing auxiliary member" in a vacuum would infringe this patent.

Here is another, this one dealing with electric welding. The claim states:

"4. An electric welding system comprising, in combination, a welding circuit including a movable electrode and the work, electrically operable means for advancing said electrode toward the work, said means receiving energy solely from said welding circuit; and a control device, operable to establish the flow of current to said means only when the welding voltage exceeds a preselected value."

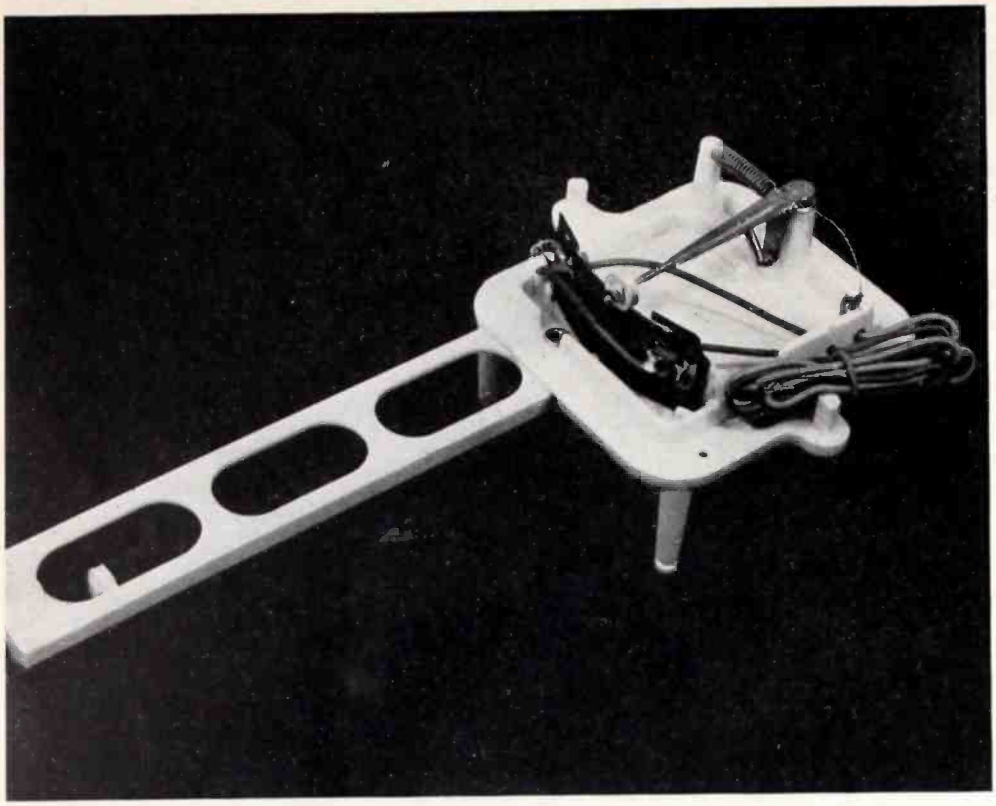
The crux here seems to be "a control device" (not described) to establish flow of current when the voltage is at some pre-determined value.

Could anyone skilled in the art "make, construct, compound, and use" what is described in these claims? We doubt it. Not enough information is given; too much is claimed. Certainly if someone doped out a "control device" to establish flow of current etc., he would infringe this claim, if we read the thing correctly.

We are not unmindful of the fact that but a single claim has been read, and that the forematter of most patents gives real information; or that we may misunderstand the function of the *Gazette*. But we also remember that the British publication corresponding to the *Gazette*, which no longer reaches us due to the war, gave much more readable information, enough in fact that one not too highly skilled in the art could tell what the inventor had invented.

We wish to encourage "full, clear, concise and exact terms" in describing inventions, and we gather that in the interference case, which brought up this present matter, the inventor had not used such language in his patent but that he had "implied" certain matters which were adequately described in a brief submitted in the interference but which were not so described in the patent claims.

It is our belief that if patents in this country were written in "full, clear, concise and exact terms", much less intentional or accidental infringement would occur, because the purpose of the invention and the means employed would be so easily understood there could be no equivocation about it.



Plastic molding insulating support for radio sonde equipment

PLASTIC

By **JOHN SASSO**
Product Engineering

IN preparing to design a product consisting wholly or in part of plastic material, the engineer must investigate: (1) The physical, thermal, electrical and chemical properties of the plastic, to determine whether it will withstand the specified operating conditions to which it will be subjected, and its expected service life. (2) Design limitations of the plastic material, which relate somewhat to its physical properties but which to a great extent, will depend on the method of production of the finished part. (3) Economy of production, which takes into consideration the cost of molds and tools, the time involved in tooling, and the expected quantity of parts to be obtained from the initial tooling. (4) The cost of the plastic product in relation to the market of similar products made of other materials, considering what advantages the plastic product may have in structural qualities, lightness of weight, and appearance. In many instances, it may be possible to sacrifice strength considerations for appearance.

The wide range of plastic materials, some available with special physical properties to meet certain application requirements, makes the choice of a proper material difficult for the designer not too well versed in the plastics field. Much data has been published on the various materials, their properties and characteristics, but the mass of it is so great and the field of application so broad that it is hard for the engineer to get a clear definitive picture that will enable him to evaluate plastic materials in relation to the particular design problem at hand.

One method of classifying the plastic of interest to the engineer is to divide the available materials into thermosetting and thermoplastic groups. Progress in the chemistry of plastics and in the development of new fillers has been so rapid, however, that there are types which can fall into either group. Hard and fast distinction cannot always be made.

For the purposes of definition, it may be said that a thermosetting material is one that under the application of heat and pressure "polymerizes" into a hard infusible product which will not soften to any extent on reheating and cannot be remelted and remolded. A thermoplastic material can be softened by heat and rehardened into solid state by cooling. The most obvious distinction between thermosetting and thermoplastic materials is that the latter may be remelted and remolded many times.

The effect of heat on the two types should be made apparent. Because a material is thermosetting, it does not necessarily follow that it is particularly resistant to heat. Nor does it necessarily follow because a thermoplastic can be softened by heat, that thermoplastics have no heat resistance. Working temperatures for both may approach 200 deg. F. At higher temperatures the thermosetting material may char, then decompose; the thermoplastic material will soften until fluid, then perhaps decompose if the temperature rises high enough.

Plastics are derived from synthetic resins, cellulose derivatives, natural resins, and protein substances. So many types are available commercially that it is difficult to classify them simply. For the purposes of a brief consideration of those plastics on the market at present, classification is made with respect to their origin and to whether they are thermosetting or thermoplastic. The table covers only those plastic materials derived from synthetic resins and cellulose compounds. Groups not considered are the proteins (casein) and natural resins (shellac, rosin, asphalt, pitch).

Thermoplastic	Thermosetting
SYNTHETIC RESINS	
Polystyrene	Phenol- or Cresol-aldehydes
Polymethyl methacrylate	Urea-aldehydes
Polyvinyl chloride-acetate	Melamine-formaldehyde
Polyvinyl chlorides	Aniline-formaldehyde
Polyvinyl acetate	Glyceryl-phthalates
Polyvinyl acetals	
Vinylidene chloride	
CELLULOSE DERIVATIVES	
Cellulose nitrate	
Cellulose acetate	
Cellulose acetate-butyrate	
Ethyl cellulose	

*The material in this article has been condensed from Mr. Sasso's forthcoming book, "Plastics for the Mechanical Engineer", McGraw-Hill Book Co.

in the ELECTRONICS FIELD

With the vast demand for military purposes, plastics are filling an increasing need for an insulating and structural material in the electronics and communications field. How to make the best use of these materials is the subject of this article

Binders, fillers, plasticizers, dyes, lubricants, and solvents are among the various basic substances which are used in the production of plastic molding materials. This listing is theoretically inaccurate, since it is by no means complete, and different substances can serve multiple purposes in the formulation.

Plastics used widely in electrical applications are phenol formaldehyde with special fillers, laminated phenolic (paper or fabric base), urea formaldehyde and the new urea-melamine formaldehyde. These are compression-molded thermosetting materials. Of the injection-molded thermoplastic materials, polystyrene, ethyl cellulose, vinyl copolymers methyl-methacrylate and cellulose acetate are widely used.

Many factors affect the properties of molded plastics such as the method of compounding, types of fillers used, and ambient temperature, and humidity. Those that principally affect electrical properties are types of fillers used, ambient temperature and humidity conditions. Thus the data presented in this article are of value principally on a relative basis for a given property. The data were obtained for the most part under standard ASTM test conditions. It cannot be assumed that a material which shows a dielectric strength of 250 volts per mil under standard test will show that same dielectric strength for a different thickness under different conditions of temperature and humidity. Comparative presentation enables how what compromise may be necessary.

Fillers

Added to resins, fillers make a wide range of properties possible. Thus special fillers may be compounded with the resin to obtain special high electrical, chemical, and impact resistance, or to improve moldability. Fillers are especially important in the phenolic materials, and they make possible the hundreds of formulations offered by materials manufacturers. Typical fillers for phenolics include wood, flour, cotton, fabric, graphite, asbestos, mica. Urea resins are generally compounded with purified wood cellulose (alpha-cellulose).

Effects of Fillers

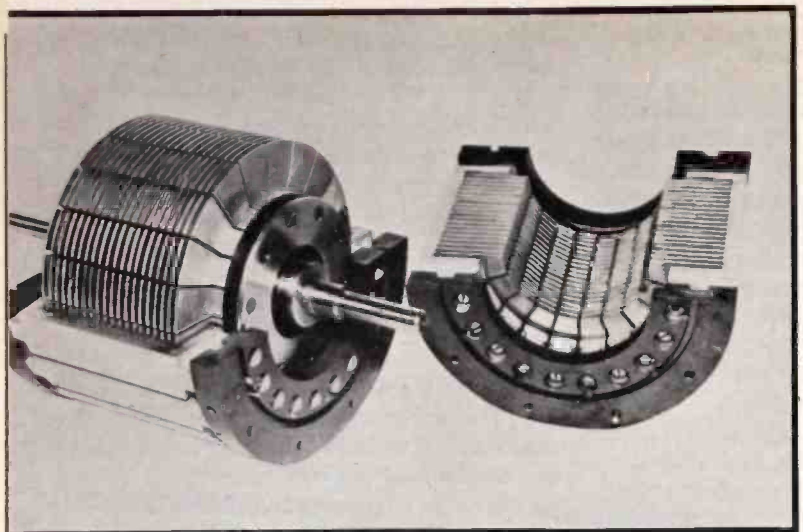
Wood flour is the most common filler used in phenolic materials. This filler has a low specific gravity, therefore the number of moldings per pound is higher. Other advantages of its use are good moldability, good appearance of the molded surface, low heat conductivity. However, wood filled phenolics have only fair impact strength and are subject to shrinkage in service. Applications of the general-purpose wood-filled phenolics are limited only by strength and heat resistance.

Cotton fillers improve impact strength and increase impact resistance. Although for higher impact strength rag filler is used, cotton flock is widely used for parts requiring medium impact strength. Parts made of cotton filled phenolic can be easily buffed and polished, and can be tableted easily — an important factor in maintaining high hourly production rates in compression molding operations.

Rag fillers increase impact strength, the increase depending on the length and type of fiber. This increase in strength is obtained at the expense of other properties, notably poor surface finish, and poor machinability. Intricate parts have relatively poor flow in the molding operation.

TABLE I—DIELECTRIC CONSTANTS

Code	Name of Material	Dielectric Constant at Frequency of 60 cps	10^3 cps	10^6 cps
A	Phenol formaldehyde			
	wood flour filler	4.12	4 – 8	4.5 – 8
	fabric filler	5 – 10	4.5 – 6	4.5 – 6
	mineral filler	5 – 20	4.5 – 20	4.5 – 20
B	Phenol furfural	5.1	5.0	4.9
C	Cast phenolic	5 – 10		5 – 7
E	Urea formaldehyde	6.6 – 8.6		6.6 — 7.7
F	Urea melamine-formaldehyde	11.5		
G	Polystyrene	2.6	2.5	2.5
H	Cellulose acetate	3.5 – 6.4	3.5 – 6.4	3.2 – 6.2
I	Methyl methacrylate	3 – 3.7	3 – 3.5	2.8 – 3.3
J	Ethyl cellulose	2.7	3.7 – 4.0	3.2 – 3.5
K	Vinyl co-polymer	3.2 – 3.6	3.2 – 3.4	3.0 – 3.4
L	Vinylidene chloride	3 – 5	3 – 5	3 – 5
*	Hard rubber	2 – 8	2.8 – 3.4	3



An important feature of plastics is the facility with which they may be machined. In this example, machined annular rings are used as insulating supports for metallic elements

Equally important is the ease with which metal inserts may be incorporated, in the molding process, to form a complicated insulating element with conducting parts

and even polymerization. These will all cause slight shrinkage when they occur. The effect of these variables can be minimized by proper design.

It will be found that temperature has a decided effect on other properties of plastics, reducing electrical properties, lowering chemical resistance, and as mentioned previously, exerting considerable influence on physical properties.

Electrical Properties

Plastics are used in many electrical applications as, for example: radio parts, aircraft and switch mountings, and housings. They serve both structural and insulating purposes, and in addition offer the advantages of quick assembly and good appearance.

Electrical properties of plastics in service depend to a great extent upon proper design, operating temperatures, and conditions of humidity. Many times it will be possible by proper design to obtain better electrical performance of the part. Generally speaking, high temperature adversely affects electrical properties. Dielectric constants of the phenols change considerably with increase in temperature. At high operating temperatures dielectric strength is adversely affected, as is insulation resistance. Moisture also affects electrical properties. Dielectric constants and power factor of phenolic molded increase often in proportion to the amount of water absorbed. The water absorption of some of the plastic materials reduces surface resistivity. Obviously, it is to the interest of the designer to make a thorough investigation of service conditions and to test thoroughly the plastic materials before final specifications.

Six characteristic factors are usually studied before specifying a plastic material for an application where electrical properties are of paramount importance. These are dielectric constant, dielectric strength, power factor and loss factor, insulation resistance, arc resistance. They are not necessarily listed in order of importance as the particular application will determine this. And, of course, temperature and moisture conditions must be brought into the analysis before final choice and design is made.

The dielectric constant, or ratio of the capacity of a condenser with a given dielectric to its capacity with air as the dielectric, is usually measured at 60 cycles, 10^3 cycles, and 10^6 cycles. These constants are of particular importance in radio circuits. They are tabulated below for comparative analysis; the values given are based on manufacturers' literature.

TABLE IV—WATER ABSORPTION

Code	Name of Material	Per Cent Water Absorption in 24 Hours
A	Phenol formaldehyde	
	wood flour filled	0.2 – 0.6
	fabric filled	0.5 – 2.5
	mineral filled	0.01 – 0.3
C	Cast phenolic	0.01 – 0.5
D	Laminated phenolic	
	paper base	0.3 – 9.0
	glass fabric base	0.3 – 0.5
E	Urea formaldehyde	1.0 – 3.0
F	Urea melamine-formaldehyde	0.2 – 0.5
G	Polystyrene	0.0
H	Cellulose acetate	1.2 – 6.8
I	Methyl methacrylate	0.4 – 0.5
J	Ethyl cellulose	0.5 – 1.5
K	Vinyl co-polymer	0.05 – 0.15
L	Vinylidene chloride	0.0

Dielectric strength, or the maximum voltage that a material will withstand before puncture, divided by the thickness of the material, is expressed in volts per mil. Two factors seriously affect this measure: the rate of voltage increase and the thickness of the material under test. Three methods of testing are approved and have been standardized by the A.S.T.M. These are short-time test, step-by-step method, and endurance test. Of these, the easiest to apply and the most commonly used is the short-time test, where the applied voltage is increased at the rate of 0.5 kilovolts per sec. until puncture occurs. Material thickness is measured at point of failure. Dielectric strength is a function of temperature; the higher the temperature the lower the dielectric strength. With laminated plastics, tests made parallel to the laminations will give lower dielectric strengths. As frequencies increase, dielectric strength decreases.

Other factors that influence dielectric strength are fillers (mica-filled phenolics are high, graphite-filled low), manufacturing variables, exposure of material to high humidity. Table II shows the approximate dielectric strengths available in materials customarily used.

Power factor, or ratio of power ls in watts to the volt-amperes rough a capacitor in which that terial is the dielectric, is import in the design of radio frequency ulators. Moisture absorbing chareristics of the materials are imrtant, as the power factor may inge with absorption of water. For s reason, polystyrene has attained de acceptance in the electrical field; moisture absorption is negligible. Phenolic materials of the "lowls" type have mica-fillers and are efully dehydrated, but they can compare with the polystyrene ich has a power factor of 0.0001 at cps. Ethyl cellulose shows up well this test, and is reported with a wer factor of 0.0007.

Loss factor, or the product of ver factor and dielectric constant y be of help in comparing mateals, since it gives an idea of the at generation rate per unit volume certain test conditions.

nsulation resistance of plastic terials is fairly high and ranges m 10^{18} ohms per cm cube for polyrene to 10^{10} for phenolic. Surface ditions will affect the insulation istance, as will moisture and high peratures. Moisture and temperare are particularly critical. Here in, the engineer will do well to ke careful tests before proceeding far. The A.S.T.M. has devised s to be made under certain speci conditions of temperature and midity. These will serve as a good sure of the materials' ability at temperature and humidity condi of the test. As to behavior at ated temperatures, further test and experience of others are the guides available. Much work been done on this subject, and engineer will do well to consult h manufacturers before proceed too far with his design.

rc resistance is a measure of the avior of the material under a er arc, to determine the amount arbonization. It is important to ult the manufacturer if arc reance is a requisite of the design. resistance is of particular imance in switch design. Proper neering can do much to reduce danger of tracking.

Moisture Resistance

he amount of moisture absorbed affect dielectric qualities, appearance, and sometimes dimension of the molded part. Polystyrene and vinylidene chloride show the least moisture absorption of all the plastics, the cellulose acetates behaving poorly in this respect. Some of the laminated phenolics are compounded for low water absorption to obtain better electrical properties.

After these properties are studied, strength, moldability around inserts, heat and moisture resistance, dimensional change on aging must be considered before the final choice of material is made. It may be possible to use laminated phenolic sheet or tubing, and machine it to shape, thus obviating the high expense of molds. If, however, the part must be molded there are certain points in design that must not be overlooked: (1) Draft of 3 deg. should be allowed to permit easy withdrawal of part from the mold. (2) Avoid undercuts or side holes; they increase mold cost and production cost. (3) Avoid sharp corners in the part. They cause concentrated stresses, and they are difficult to machine in the mold. Fillets help flow of material. (4) Wall thicknesses should be uniform, to allow uniform curing, otherwise shrinkage stresses, gas pockets and undercuring may occur. (5) Use round inserts protruding from the piece so that the material will not be able to flow into the thread. This will eliminate rethreading after molding. (6) Place plenty of material around inserts, use fillets instead of sharp corners. These precautions will prevent cracking around inserts. (7) Avoid holes or inserts that require long slender core pins which might break under molding pressure. (8) Make sure that the arc will break in the air against a sharp corner of a metal insert rather than against the plastic. (9) Design so that the accuracy of the finished instrument does not depend directly on the molded part, which may age or shrink and affect instrument accuracy. (10) Check design by machining out a model. This will save many hours in locating changes that are not apparent on the blueprint. This is particularly true where convex and concave surfaces are involved, requiring an assembly of irregularly shaped pieces.

TABLE V. LAMINATED PHENOLIC ELECTRICAL PROPERTIES

Based on NEMA Standards

NEMA Grade of phenolic laminate	Power Factor at 10^6 cycles per sec.		Dielectric constant at 10^6 cycles/sec.		Dielectric Strength (VPM) Short time	Step by step	Water Absorption 24 hrs.— % (Sample 3"x1"x1/16")
X	......		....		700	500	4.0
P	......		....		700	500	3.0
XX	0.040	0.062*	5.0	4.3*	700	500	1.3
XXP	0.040		5.0		700	500	1.3
XXX	0.032		4.8		650	450	1.0
XXXP	0.027	0.045*	4.5	3.8*	650	450	1.0
C	0.10		7.0		200	120	3.0
CE	0.055	0.055*	5.5	4.0*	500	300	1.5
L	0.10		7.0		200	120	2.0
LE	0.045		5.0		500	300	1.2
Dielectene 100†	0.0062	0.0032*	3.6	3.6*	640	410	0.08

* At 10^8 cycles per second.
† Data for samples 1/8-in. thick.

DIRECTORY OF TRADE NAMES AND SUPPLIERS

In the following listings, only the more usual plastics materials are listed by trade name and manufacturers. No attempt has been made to include all types of plastics materials, as that is beyond the scope of this article which is concerned principally with plastics for industrial uses.

Molding Materials, by Code, Type of Material, Trade Name, and Manufacturer

A PHENOLIC MATERIALS

Bakelite	Bakelite Corp., N. Y. C.
Coltrock	Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.
Durez	Durez Plastics & Chemicals, Inc., N. Tonawanda, N. Y.
Haveg	Haveg Corp., E. Newark, Del.
Heresite	Heresite & Chemical Co., Manitowoc, Wis.

(*Continued on page* 64)

HEARING AI

The human ear loses its hearing ability from a variety of causes and it is the problem of th hearing aid designer to determine the nature of the disability and apply the proper correc tive steps. The electron tube is ideally suited for this purpose because of its amplificatio characteristics and a very small unit can be built.

By IRA KAMEN

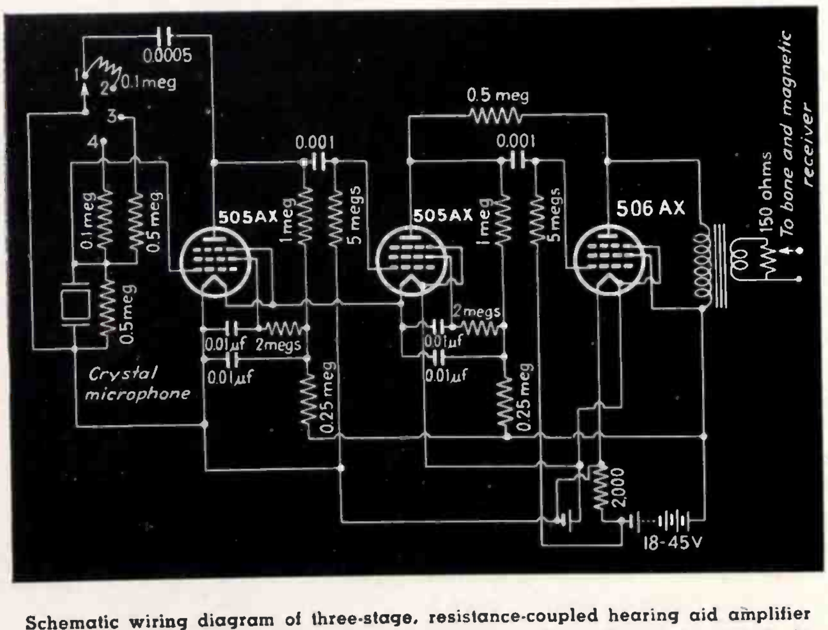
THE design of suitable hearing aids for various types of deafness requires a knowledge of the natures of sound, hearing and deafness as well as the principles of electronics. It is the purpose of this article to review briefly the several types of deafness, how these types may be detected and measured, and to discuss the design of a typical hearing aid unit.

There are three types of deafness in humans which can be counteracted by the use of a hearing aid. They are conductive, nerve, and cortical deafness. A combination of two or three of these basic types of deafness is called mixed impairment and is the most common hearing disability. Conductive deafness is the result of an impairment of the middle ear mechanism. It may result from hardening of the drum-skin, fixation of the ossicles, or from a catarrhal condition. This type is usually caused by sickness such as the common cold or inflammation of the sinuses, or from an accident. The symptoms of conductive deafness are a feeling that the ears are stuffed with cotton and quite commonly by the presence of head noises.

Nerve deafness is a condition in which the inner ear or cochlea is defective. Childhood diseases are frequently the causes of damage to the inner ear and in a large percentage of the cases such damage does not become evident for some years after the illness has passed. The nerve deafened ear cannot hear low level of sound. Let it be assumed that th threshold of audibility is about 5 db below the normal threshold. A sound pressure is increased, however its intensity response increases s that with an increase of 10 db, th intensity response may be only 30 d below normal, and with an increas of 20 db, it may be only 12 db belo the normal. An increase of 30 d may cause a perfectly normal in tensity response, but with addition increases in pressure the nerv deafened ear responds more acutel than the normal, so that increase b another 15 db may cause the thresh old of pain to be reached, wherea in the normal ear it would requir another 55 or 60 db increase. The in crease in pressure necessary to reac the level at which an intensity re sponse equivalent to the normal i achieved, is called the recruitmen factor. The hearing of a person wit nerve deafness is characterized i intensity by a recruitment facto which may vary markedly wit change of frequency, and the r sponse of the nerve deafened ear ma also vary greatly with frequency.

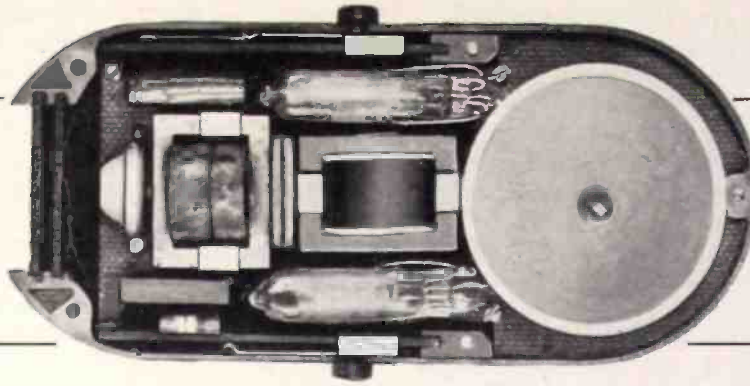
Cortical deafness does not actuall involve the ear mechanism, but is condition which occurs in the highe brain centers. The greatest numbe of cases are those of senile deafnes (deterioration of brain cells becaus of advanced age) and few men fail t develop this disability with age. En cephalytis and cerebral strokes, sinc they attack the brain centers, als cause cortical deafness.

The prime result is loss of the so called "language factor" or the abil ity to interpret sound. The ear mech anism may be in perfect condition but the brain fails to translate th



Schematic wiring diagram of three-stage, resistance-coupled hearing aid amplifier with feedback and adjustable frequency compensation selected by switch in upper left corner

DESIGN



Full size illustration of hearing aid. Note small size of tubes, transformers, and other components

d waves into frequency, amplii and timber. In such cases, it een noted that slow, crisp artic- speech at a normal level will rally, be well understood. It is speech takes on its habitual ing of sloppiness, speed and dison that the person with cortical ess is completely helpless. The neer can do little to remedy this ulty inasmuch as he can neither ate the speaker to precise speech affect speech in such a way that slowed down and broken up into nct syllables. He can work only the hearing aid and the ear in r to overcome the defects of the r. The engineer recognizes that an be of some help by provid- device which will raise the level eech for the deafened and comate for any coincident defects of ear, thereby allowing complete entration on interpretation of h.

onductive and Nerve Deafness

type of cortical deafness called sion deafness can result from cted conductive or nerve deaf- or a combination of the two. use of a prolonged period of ess, loss of sound memory oc- Conditions of this nature, con- to those previously outlined, e eliminated after a period of ise. Compensation for the type afness which originally caused ortical condition is first neces- to permit restimulation of the centers which have been dor- This, quite naturally, requires but in most cases renewed ng is the result. In cases of al deafness resulting from sen- or encephalytis, there is no known method of rehabilitation. The reader is referred to "Electronics in Auditory Research" by David M. Sleeper which apeared in the September 1941 issue of ELECTRONICS.

Audiometry

The development of the vacuum tube hearing aid created the need for relatively accurate tests and measures of deafness. Such tests would have proved useless earlier, for the engineer was unable to compensate for pre-determined failures in hearing. As a matter of fact audiometers and other test equipment have been in active use by doctors since the middle twenties, but it was the entrance of the vacuum tube hearing aid several years ago which caused hearing aid manufacturers and consultants to use them.

The audiometer is a calibrated oscillator designed to oscillate in multiples of two in the audio spectrum. (128, 256, 512, 1024, 2058, 4096 and 8192 cps). The output of a particular instrument varies in steps of 5 db from a predetermined threshold of audibility to the brink of the threshold of pain. The output of this audiometer is fed into a calibrated receiver and both the oscillator circuit and the receiver are designed for maximum output at a minimum of distortion. The audiometer determines hearing losses between 128 and 4096 cps quite accurately. At 8192 cps, however, standing waves are set up and readings are not easily duplicated. It is not necessary to use the audiometer in a sound room when people hard of hearing are being measured. Tests have been made on the same patients in a quiet office and a sound room and variations in the readings obtained were neglible.

Curves are taken with both an air receiver and a bone conductor and the audiometer can be used effectively to detect nerve or conductive losses. A specially compensated amplifier circuit is employed to compensate for the erratic behavior of the bone conductor. The output of the bone conductor can be varied from threshold to threshold, but it is calibrated only between 256 and 4096 cps because readings at 128 cps are too distorted and readings at 8192 cps are inaccurate due to the rising impedance of the head and mechanical limitations in the bone conductor design. The bone conduction reading of the audiometer is not a precise one. It does provide sufficient information, however, so that correlated with the air response reading, a fairly accurate estimate of the type of deafness and the response curve of the ear is obtainable.

Test for Conductive Deafness

A simple and obvious test for nerve or conductive deafness consists of setting the audiometer at 1024 or 2048 cps and adjusting the attenuator for maximum output. Should the case be one of nerve deafness, the threshold of pain is certain to be reached and the receiver will undoubtedly be thrown or pulled sharply away. The person with conductive deafness will merely hear the signal at a level of 100 db, less his own loss.

In recent years, manufacturers have developed a number of measuring devices which differ in one way or another from the audiometer. One such device is calibrated like the audiometer, but employs a loudspeaker instead of the receiver. Tests with this equipment should be conducted in a sound room or in one which employs drapes, rugs, etc. to reduce reflections. A curve is first made of the deafened ear and another is made while the hearing aid is used. A comparison can then be made between the two curves, indicating, approximately, the benefit derived from the hearing aid.

A calibrated microphone and the audio amplifier of the audiometer can be used to detect a case of cortical deafness. Such a condition would invariably escape undetected by an audiometer test, since the pure tones can readily be heard by the person with a cortical condition. It is the loss of the language factor which must be perceived and by raising the output of the amplifier to compensate for the hearing loss and by then talking into the microphone, the language loss can be determined.

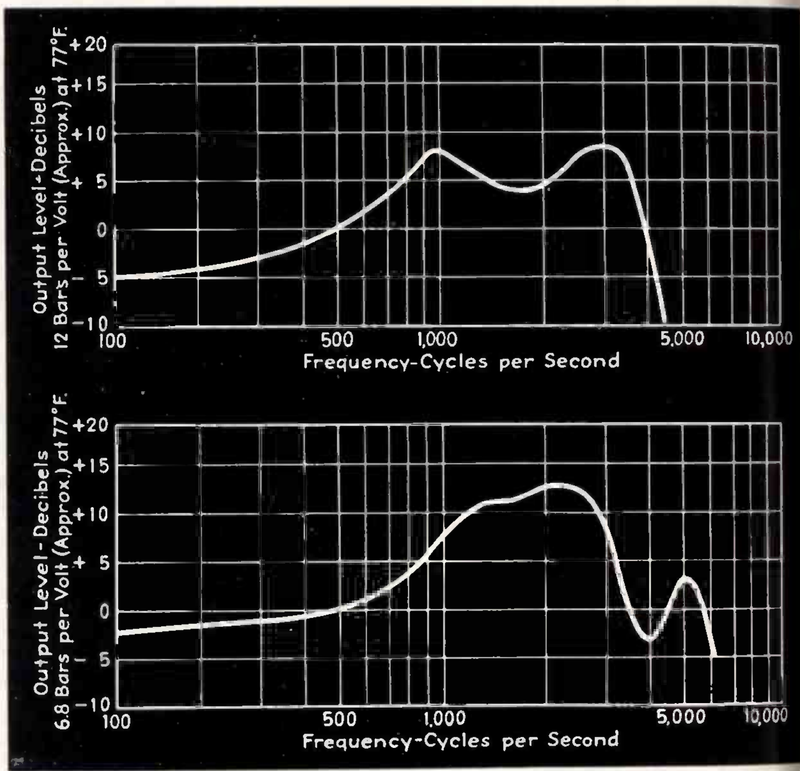
The Vacuum Tube Hearing Aid

The engineer works with three elements in the design of the vacuum tube hearing aid. These are the microphone, the amplifier and the receiver. His objective is to obtain a flat response from the combination of the three since, when this is accomplished, it is a simple matter to change the total response, to compensate individual cases, by changing the characteristics of one of the components. The engineer may attempt to accomplish this by designing all three components to have a flat response, he may design two components to compensate for the defects of the third, providing a total flat response, or he may design one element in terms of the other two, obtaining as a product of their combination, the desired flat response.

Since it is essential to efficient and consistent production that a minimum of variables exist, the usual procedure is to establish two elements as stabilized factors and to design the third element to compensate for them. The choice of the element which is controlled depends again upon production considerations. That element which can be most easily controlled is generally the one selected. Different plants with different conditions of production and different personnel find it desirable to choose different factors. In this article, we shall concern ourselves with the design and control of the amplifier in terms of the microphone and receiver.

The condition which is peculiar to the complete hearing aid is the absolute need for a limited frequency response. Frequencies below 500 and above 3,500 cps contain a major portion of the background noise, hiss and noise created by the rubbing of the instrument against the wearer's clothing. These noises greatly discomfit and annoy the deafened. It is necessary to reproduce frequencies as high as 5,000 cps to provide the harmonics of speech which permit distinguishing one voice from another. High amplification between 3,500 and 5,000 cps must be avoided if hissing and room noise are to be minimized. Limiting the hearing aid response to 500 cps is necessary, not only to eliminate the street rumble which occurs below that frequency, but also to permit the manufacture of a physically small unit. For reasons of vanity on the part of the wearer, the receiver must be so small that it cannot readily be noticed. Of course, such a unit is inefficient at low frequencies.

The hearing aid is designed, then, to have a flat response from 500 to 3,500 cps and a drop in response between 3,500 and 5,000 cps. A frequency response control is essential to change the flat response to compensate for the particular case which is to be fitted.



Typical frequency response curves for two different models of hearing aids. Molded earpiece of hearing aid and an artificial ear were used in determining the data from which these curves were plotted

Three types of receiver are in common use today; the magnetic and crystal (both air receivers) and the bone receiver. By use of an ear mold the crystal and magnetic receivers fit into the outer ear, and both transmit sound impulses by way of the middle and inner ear to the brain. The bone conductor is placed on the mastoid bone and circumvents the middle ear by transmitting impulses through the inner ear to the brain.

The bone conductor is a magnetic device in which the armature reaction causes the container to vibrate. When the container is placed on the mastoid bone (held with light pressure by a headband), the vibrations act upon the cochlea, setting the hearing mechanism into operation.

One bone conductor unit has a response of approximately ±5 db between 500 and 2,500 cps but between 2,500 and 5,000 cps, a continuously sharp drop occurs. When placed on the mastoid, this drop is accentuated because the impedence of the head increases with a rise in frequency. Were a flat response fed into the bone conductor, little if any of these frequencies would be heard. It has been indicated before that a flat response between 2,500 and 3,500 cps and a drop between 3,500 and 5,000 cps is desired. This latter characteristic is a compromise between eliminating hiss and introducing the harmonics of speech. The input to the bone conductor must, therefore, have a considerable rise between 2,500 and 5,000 cps to produce a curve which is practically flat between 500 and 3,500 cps and which has just the right drop between 3,500 and 5,000 cps.

The frequency response of the midget magnetic receiver can be controlled in design by mechanical adjustments such as varying the size of the acoustic cavity, floating the diaphragm, changing its thickness or loading it. The limitations in design are only those of production. It is essential that each receiver manufactured have the same response; therefore, critical factors in production must be minimized. The various magnetic receivers manufactured have different characteristics because of the varying controls exercised by design engineers and the amplifiers of each manufacturer are then designed to modify the eccentric response of the receiver to obtain the desired flat response.

The crystal receiver, in general use today, has a relatively flat characteristic but in certain uses may have a sharp drop at the low frequencies (around 500 cps). Little change is made by most hearing aid manufacturers in the crystal receiver when designing for production. The crystal microphone is the only small microphone with an essentially flat response and sufficient output to satisfy the requirements of the modern vacuum tube hearing aid and is, therefore, used by all manufacturers.

Description of a Typical Hearing Aid

The vacuum tube hearing aid amplifier described here incorporates the most recent and important design features. It is a three-tube high gain amplifier to allow for inverse feedback and losser methods of time correction. Self bias is achieved without use of a coupling condenser across R_1. The condenser would have to be in the order of microfarads to bypass the resistor and prevent degeneration at the low frequencies. Such a condenser would be too large for the limited space available in the case. As the battery voltage drops from 45 volts, the voltage drop across R_1 decreases, decreasing the bias on the grid of the output tube and regulating the total current flow. Consequently longer battery life is possible. Constant current inverse feedback is a by-product of this type of self bias. It reduces harmonic distortion but makes necessary a higher gain circuit. This type of inverse feedback also causes the plate impedance to rise, producing frequency distortion because the secondary load also varies in its impedance.

Compensation for the disadvantages of constant current inverse feedback is obtained with constant voltage inverse feedback (R_3) which permits use of a volume control to vary the secondary load of the output transformer. The inverse feedbackback network is absolutely essential in cases of senile deafness since even the slightest distortion would cause a considerable decrease in hearing.

Hearing Aid Features Automatic Volume Control

The automatic volume limitation (R_2) control is manually operated by the wearer of the hearing aid. Once set at a maximum level, it does not permit sounds louder than that level to be transmitted to the ear, regardless of the level of input to the amplifier. By eliminating the possibility of reaching the threshold of pain, this control proves of tremendous advantage to the nerve deafened user of the hearing aid. The resistor R_2 loads the circuit, preventing changes in frequency response due to the operation of the volume control.

Filter networks R_4C_3 and R_5C_2 prevent circuit oscillation due to dropping battery voltage and the resultant development of internal resistance in the battery. They accomplish this by preventing the internal resistance from acting as a coupling medium between stages.

Position 1 of the tone corrector connects a condensor across the first stage, attenuating the high frequencies. This makes the magnetic receiver low in pitch and the bone conductor extremely low pitched.

Position 2 flattens the peaks in the magnetic receiver and raises, slightly, the low pitch of the bone conductor by adding R_8 in series with C_1.

Position 3 connects R_7 in parallel with the resistor loading the crystal microphone to decrease the load and attenuate the low frequencies. This flattens the response of the bone conductor and causes the magnetic receiver to be high pitched.

Position 4 introduces R_6 into the circuit. This resistor is of lower value than R_7 and accentuates the results achieved in position 3. Therefore, it results in a high pitched bone conductor and an even more highly pitched magnetic receiver.

The development of the modern vacuum tube hearing aid has been made possible by the development of extremely small, efficient, tubes, chokes, and transformers. In the three tube amplifier, two tubes are used for voltage amplification. They require ⅝ volt on the filament and the two filaments are placed in series across a 1½ volt battery. All hearing aid tubes are of the filament type because the current and heating must both be extremely low. The drain of the ⅝ volt tube is approximately 30 ma. at 1.25 volts (across the tubes in series). The drain of the output tube is also 30 ma, but it is a 1.25 volt tube. The average dimensions of the hearing aid tube are 1 inch in length and ⅜ inch in diameter. The tubes have an expected life of two thousand hours and they are very stable in operation. Although filament type tubes are inherently microphonic, the manufacturers have developed dampers which load the filaments and prevent vibration.

Special core material is employed in hearing aid transformers and chokes to obtain high impedance within small magnetic circuits. The chokes and transformers are approximately ¾ x ⅝ x ⅝ inches in size and most hearing aid concerns have found it necessary to manufacture these parts themselves. Hearing aid batteries are normally supplied in an external pack. The B battery is generally rated, under normal temperatures, with a life expectancy of 350 hours, when draining 1 ma for four hours a day at a drop from 1.5 volts to 1 volt per cell. The A battery under a drain of 60 ma for four hours a day, at normal temperatures has a rated life expectancy of 85 hours during the time it drops from 1.5 volts to 1 volt.

A Flexible Equalizing Amplifier

Frequency response can be varied over a wide range . . . Adjustable networks in feedbac loop . . . Response curve may be peaked at one or more points . . . Used for equalizing loud speakers, recording heads, playback equipment, or telephone lines . . . In broadcast servic it may be used to obtain improved frequency response with existing equipment

By E. G. COOK
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New York City

THE principle of equalization is very old in the communications art. Equalizers of sorts were developed and put into use not long after the telephone itself. Nevertheless today's engineer is still confronted with about the same situation as that which existed twenty years ago. If he must have an equalizer, he must also have available a means of amplifying the equalized signal.

The equalizer-amplifier which is the subject of this article has been found to be completely satisfactory in operation over an appreciable period of time, and to possess those characteristics which the author has found to be most desirable for broadcasting, recording, or related audio services. It is believed that the equalizer contains improvements which have not been considered in other equalizers which have been described.

The equipment here described is suggested as a compact flexible unit which performs the duties of both amplifier and equalizer, and requires no more space than an amplifier alone. It is contained, complete with power supply, on an 8¾-inch standard rack panel. The construction of this electronic equalizer requires no special technique. Cost of parts exceeds that of the equivalent straight amplifier by perhaps twenty percent.

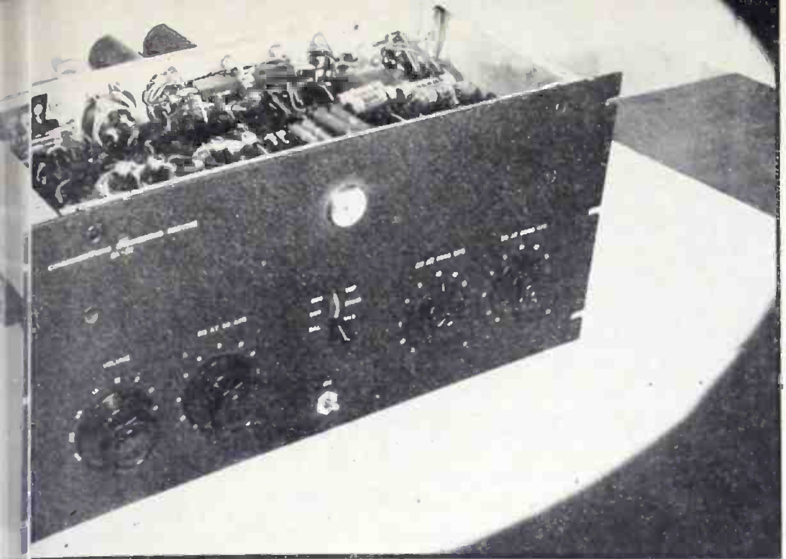
Design Considerations

For maximum operating flexibility the ideal all-purpose equalizer should include the following simple characteristics:

1. An overall net frequency gain rather than loss.
2. A mid-frequency gain which remains constant as the frequency response is adjusted.
3. Switching arrangements which permit adjustments while in use.
4. Provision for adjustment of the frequency characteristic at both ends of the spectrum and in several different types of curves.
5. Constant and resistive input and output impedances.

In undertaking the design of an equalizing amplifier which fits these requirements it must be decided at what power level the output is to be operated, at what power level the input is to be operated, and whether the amplifier is to be single-ended or push-pull. This latter question is mainly one of economics. In some ways, a single-ended equalizing amplifier (with phase inversion in the output stage) is more easily designed for certain types of curves. However, for really low noise level and distortion, the balanced design is recommended.

The unit described here is a push-pull, high level amplifier. As a result, it may be put to a diversity of uses. It performs outstandingly as a sound effects equalizer, recorder cutting head driver, playback equalizer, or loudspeaker equalizer driver. It may be used to lift or lower the high end of the frequency spectrum in calibrated steps at a known frequency. Any specified low frequency may be lifted in the same manner. The input impedance is constant in both magnitude and phase angle and its output impedance is very nearly so. It has a gain of 65 vu, a maximum output level of 12 watts and its input may be operated at a level of −40 vu while still maintaining a noise level 65 vu below the output. One of the most interesting applications for this unit is the equalization or pre-equalization of telephone cable circuits. In broadcast work it is often possible to purchase a lower grade service than the regular broadcast quality line, and equalize this service to the equivalent of a quality line. To do this requires a rather sharp peak in the frequency characteristic of the equalizing equipment.



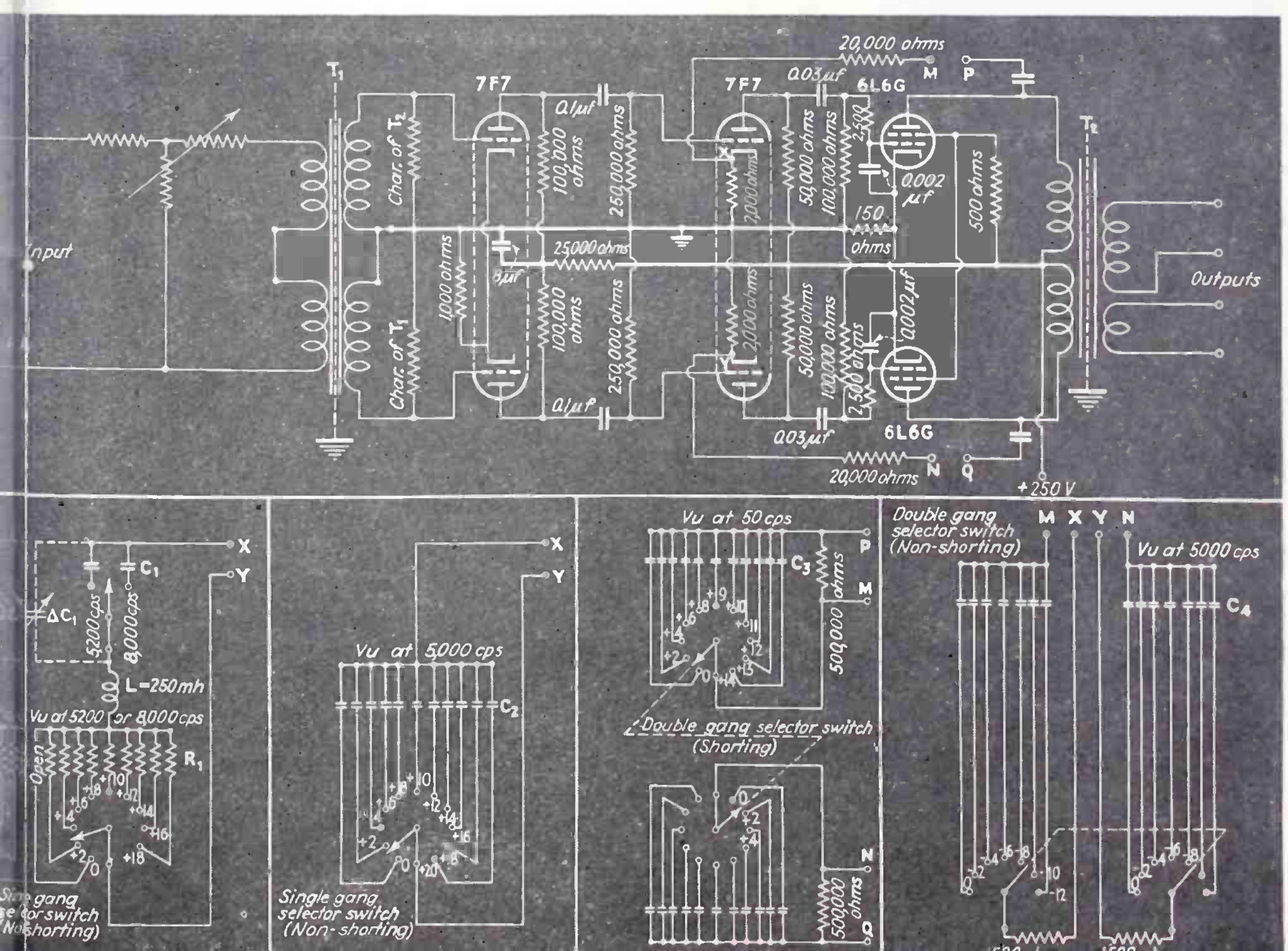
IG. —Front view of the equalizing amplifier which may be used wherever it is esi d to change the characteristics of an audio signal, such as for sound effects, driving a recording cutting head, or a loudspeaker

e significant portion of the qu izing amplifier is the last two ta s as shown in Fig. 2. The first ta is only for the purpose of pro- idig an extra 30 vu or so of gain. he last two stages in the normal at or "no equalization" position om rise a simple and rather con- en onal feedback amplifier. The olt ge amplification of the A, or m fying, circuit is approximately 0 n the mid-frequency range. A im e calculation shows that the numeric value of β, the feedback circuit gain at a mid-frequency point, is 0.091. The $A\beta$ product, which is the significant quantity to be considered when dealing with feedback amplifiers is, therefore, about 23 in the mid-frequency range.

The principle of equalization employed in this amplifier is fundamentally as follows. The $A\beta$ product which determines the overall gain of a feedback amplifier is varied with respect to frequency in a predetermined manner. This is accomplished by means of inserting in the feedback loop frequency discriminating networks which have the effect of changing both the magnitude and the phase of the feedback. In an amplifier with heavy feedback the gain is $\frac{1}{\beta}$, that is, primarily dependent upon the complex quantity β. If β varies with frequency, the gain of the amplifier as a whole will vary with frequency in the opposite manner. Therefore, if it is desired to change the high frequency response of the amplifier in a general sort of way, it is necessary only to adjust the transmission loss characteristic of the β circuit in an inverse manner. The same is true of the low frequency end of the spectrum.

The general procedure as outlined above is not applicable to an accurate analysis of the behavior of the equalizing amplifier at the extreme ends of the spectrum. This is due to the fact that the gain of a feedback amplifier is not accurately represented by $\frac{1}{\beta}$ when the $A\beta$ product is relatively small. $A\beta$ becomes relatively small at frequencies where the rise in gain is pronounced, and we

IG. 2—Circuit diagram of the equalizing amplifier together with ev al networks used for altering the characteristics of the signal. The networks are connected to the amplifier in the feedback loop or across the cathodes of the second stage



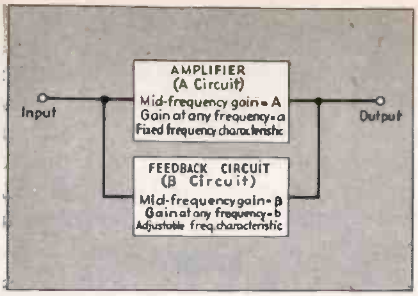


FIG. 3—Block diagram of the amplifier and the feedback loop. The frequency characteristic of the output is approximately the inverse of the feedback loop

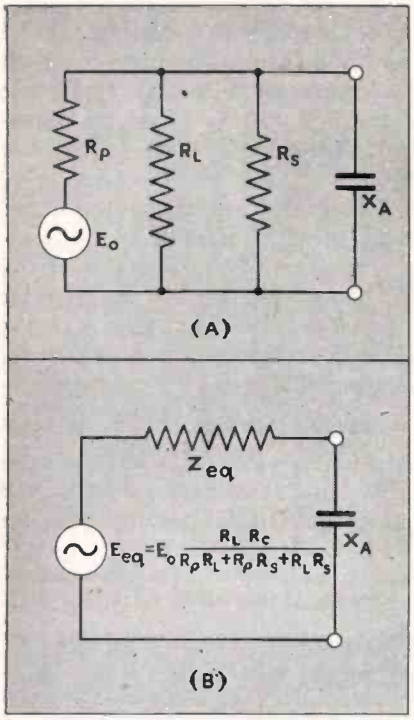


FIG. 4—The interstage coupling network and its equivalent circuit

must, therefore, substitute the fundamental equation:

$$\text{gain} = \frac{a}{1 - ab} \qquad (1)$$

where a is the gain of the amplifier without feedback at any frequency and b represents the transmission loss of the feedback network at any frequency. This relation applies at all times regardless of whether the ab product is large or small. To substitute for the values a and b in this expression it is necessary to analyze the transmission loss relations of both the amplifier without feedback and the feedback network by itself. In analyzing the former we shall take into consideration the characteristic of the last two stages of Fig. 2 only. Any variation in high frequency response from the mid-frequency value will be occasioned by the interstage coupling network. This coupling network may be symbolically shown as in Fig. 4A. By means of Thévenin's theorem this may be redrawn in the form of Fig. 4B. By the application of simple resistance coupled amplifier theory the high frequency gain of this network may be shown to be

$$a = \frac{A\ X_A}{Z_A} = A \sin \phi_A \qquad (2)$$

where a is the gain at a high frequency,

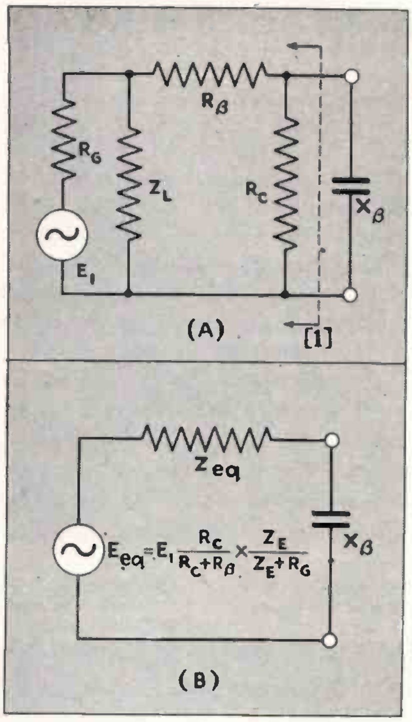


FIG. 5—Circuit and its equivalent used to compute the high frequency gain of the feedback circuit

A is the gain at a mid-frequency,

Z_A is Thévenin's impedence formed by X_A and the combination of R_p, R_L, and R_s all in parallel.

In the same manner it is possible to compute the high frequency transmission loss characteristic of the β circuit. This may be redrawn as shown in Fig. 5A, and again converted by means of Thévenin's theorem to the configuration of Fig. 5B. The high frequency gain of the feedback circuit will be

$$b = \frac{\beta X_\beta}{Z} \times \frac{Z_E}{Z_E + R_G} = \beta \frac{Z_E}{Z_E + R_G} \sin \phi_\beta \quad (3)$$

where b is the feedback at any frequency,

β is the feedback at a mid-frequency,

Z_E is an equivalent impedance formed by the parallel combination of Z_L and the two resistances R_c and R_β in series.

Z_β is Thévenin's equivalent impedan[ce] formed by X_β and the impedan[ce] looking to the left of (1) in Fi[g.] 5A with the generator shorted.

Therefore the overall gain of th[e] feedback amplifier at any high fr[e]quency referred to a mid-frequenc[y] will be found by substituting in th[e] relation

$$\text{relative gain} = \frac{\dfrac{a}{1 - ab}}{A} = \overline{1 - A\beta}$$

or,

$$\text{relative gain} = \frac{(1 + A\beta) \sin \phi_A}{1 + A\beta \sin \phi_A \sin \phi_\beta \dfrac{Z_E}{Z_E + R_G}}$$

Now with small error if $A\beta$ [is] large, and since Z_E/Z_E+R_G is prac[tically] constant,

$$\text{relative gain} = \frac{K \sin \phi_A}{1 + K' \sin \phi_A \sin \phi_\beta}$$

where K and K' are constants. Th[e] principal reason for developing thi[s] relation is to show that the fre[quency] characteristic of an equal[ized] feedback amplifier depends upon both the amplitude and the phase characteristic of not only the β circuit, but also the A circuit. Observ[e] that the only variables in Eq. (6) are ϕ_A and ϕ_β, the phase angles of equivalent impedances derived from constants of the A and β circuits respectively.

In referring to Fig. 6 it will be seen that a rise in gain of some 30 vu is obtained at about 10 kc on one of the curves. This brings up the question of the possibility of self-oscillation. Peterson, Kreer and Ware (Regeneration, Theory and Experiment, *Proc. I.R.E.*, October 1934) have established that the criterion for oscillation in a feedback amplifier is that when the complex quantity $A\beta$ is vectorially plotted as a function of frequency on rectangular coordinates with the real part along the abscissa and the imaginary part along the ordinate, the resulting curve encloses the point 1,0. Thus we see that it is possible to have a certain degree of positive feedback or regeneration without encountering self-oscillation. Precautions to avoid enclosing the point 1,0 must be taken in both the A and the β circuits. By referring to Fig. 2 it will be seen that the A circuit includes only one reactive element, namely, capacitance. Thus no resonances may occur involving a rapid asishift. At the same time, the ∙quacy response of the *A*, or am-fyig circuit, is purposely wrecked th high end by inserting an *RC* twik in the 6L6 grid circuit. This twik has the additional function atailizing the tube, which, with vly high transconductance, will on scillate parasitically. The re-tir frequency characteristic of nplifier minus feedback is wiin Fig. 7.

Feedback Networks

Th feedback or β circuit PMX NY (Fig. 2) is designed in h way that a number of differ- pes of frequency discrimi-tin networks may be simultane-dy pplied. These are shown indi-ua in the lower portion of Fig. Th are to be connected as indi-ed y the lettered terminals and l used separately or simultane-ly o produce composite curves. k B as shown in the lower Fig. 2 consists of a series of deiers which may be connected os he 7F7 cathodes to shunt the h equencies. This changes the equency magnitude and phase us increasing the overall am-lca on (Fig. 6). By the same en etwork C is a series of con- which can be connected be-en he points P—M and Q—N. hanges the magnitude and f *b* at low frequencies, hence ng the overall amplification sh n in Fig. 8. Network D is th same general character as B. It is a pair of condensers from M to X and N to Y h reduces the high frequency response in the same manner as that in which the section B increases it. Curves for determining the proper values of condensers for networks B and C are shown in Figs. 9 and 10 respectively. The curves of Fig. 9 apply roughly to network D also, if C_2 is multiplied by a factor of 1/5. It will be noted that networks B and C are calibrated in vu at their respective frequencies of 5,000 cps and 50 cps. The first position, labeled 0, is the flat, or unequalized, position. In network B, C_2 is inserted in this position and has a value necessary to give flat high frequency response. If none is necessary the position may be left open. In network C the first position should be filled with whatever condenser is required to produce a flat low frequency response. Usually this position may be shorted (infinite capacitance). No great amount of ingenuity is required to combine networks C and D into a single switch with a center zero position if a coarse adjustment of this type of equalization is permissible.

With a simultaneous application of networks B and C, a frequency characteristic which is a composite of Figs. 6 and 8 may be obtained. The low frequency equalization may be adjusted without materially affecting the high frequency response, and vice versa. These curve families are useful for equalizing loudspeakers, recorder cutting head drivers, playback equipment or turntables, and, to a certain extent, open-wire telephone lines. Since the mid-frequency gain remains essentially constant as the equalizer switches are

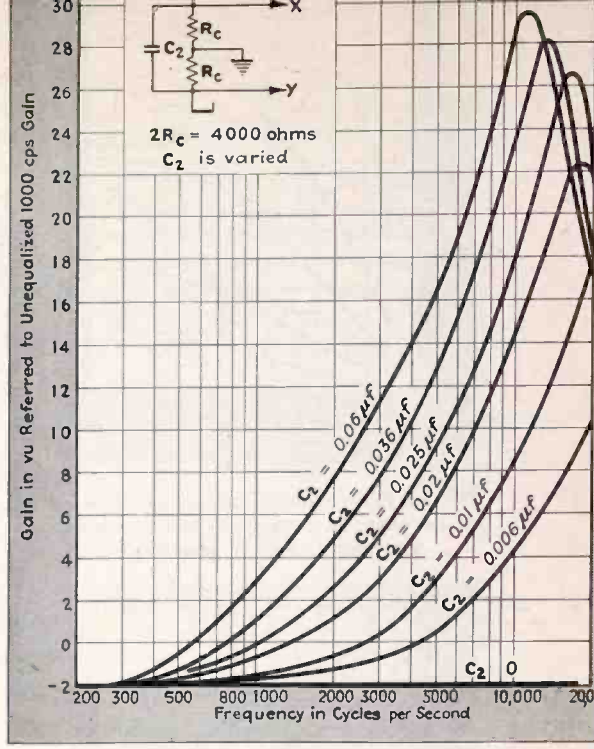
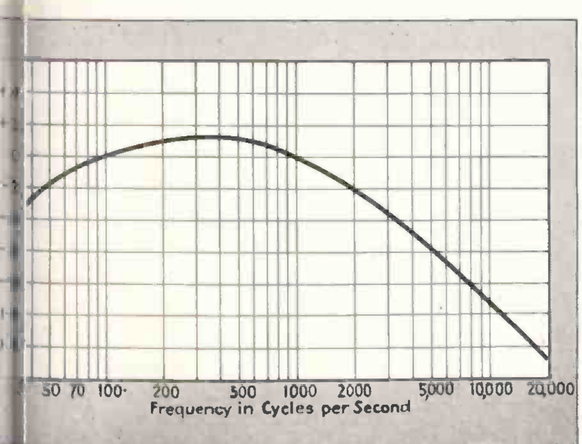


FIG. 6—Curves showing the increase of gain at the high frequencies obtained by the use of network B of Fig. 2

rotated, adjustments may be made while the amplifier is in use. One important detail in connection with section C is the use of the shorting type selector switch. Were a non-shorting type switch used, the feedback would be removed between steps as the switch was rotated, causing abrupt fluctuation of gain.

To provide constant and resistive input and output impedances for the ideal equalizer, isolation pads must be inserted at both input and output terminals. The T-pad volume control shown at the input (Fig. 2) should serve this purpose. If constant output impedance is required,



7—Frequency response of the amplifier without the feed-lp. It is purposely made very poor by the RC network in the 6L6 grid circuit

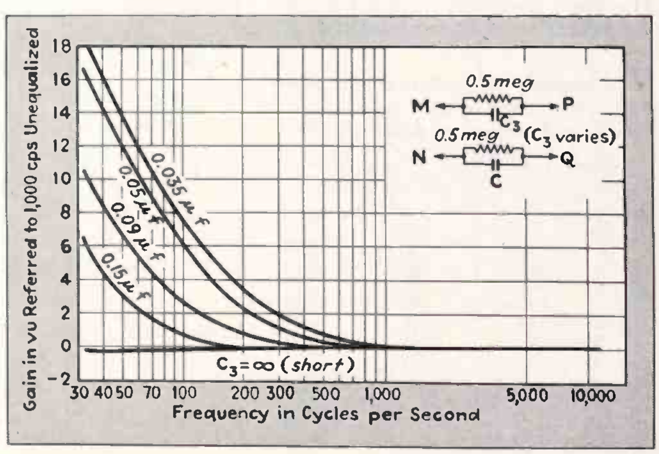


FIG. 8—Curves showing the increase of gain at the low frequencies obtained by connecting network C of Fig. 2 in the feedback loops

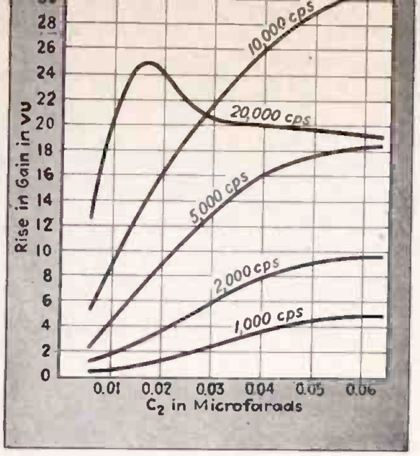


FIG. 9—The proper values of condensers to be used in network B for increasing the high frequency response

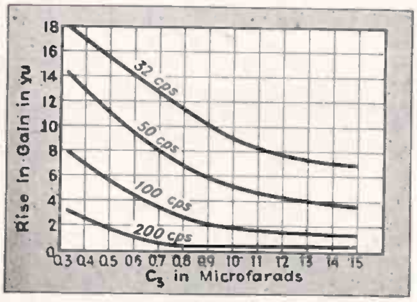


FIG. 10—The proper values of condensers to be used in network C for increasing the low frequency response

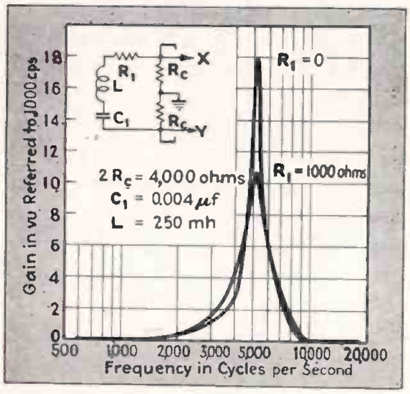
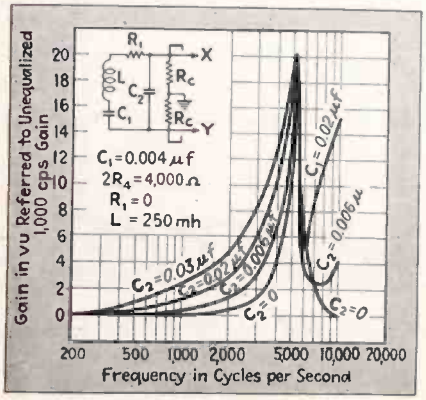


FIG. 11—The frequency characteristic may be peaked by the use of network A

FIG. 12—Frequency response curve produced by a combination of a type A network and a type B network



such as for line driving, the secondary winding of T_2 should be followed by a 6 to 10 db pad.

Distortion

To reduce distortion to an absolute minimum, the two 20,000-ohm feedback resistors (Fig. 2) might each be composed of a 15,000-ohm fixed resistor in series with a 5,000-ohm variable resistor. A balance may then be forced between the two push-pull sections while the amplifier is being measured for distortion. This unit was measured at 0.1 percent distortion or less at all frequencies below 1,000 cps with all equalizing positions set at 0 and at an output level of 10 watts. The noise level was measured at 75 vu below the 10-watt reference level. The adjustment of a low noise level is due only in part to feedback. Considerable care must be taken in filtering and isolating the plate supply for the various stages. Grounding and shielding should not be haphazard, but systematic, with an individual common ground for each stage connected in turn to a common point on the chassis. The mechanical construction shown in Fig. 1 is not necessary but is recommended as a way of isolating the heat generated by the rectifier and power tubes from the electrolytic and impregnated condensers. Placement of the chassis at the top rather than the bottom of the rack panel permits transformers and condensers to be mounted underneath, preventing dust accumulation. Tubes are easily accessible at the rear, while servicing may be accomplished by merely removing the "bottom plate," which is actually at the top.

Referring again to Fig. 2, the first 7F7 cathodes are tied together into a common unbypassed resistor, as are the two 6L6 cathodes, for the purpose of helping to force a balance between the two sections. Any tendency on the part of one side of the push-pull section to have more gain than the other will produce a resultant voltage across these cathode resistors. This voltage will in turn act to produce degeneration within the stage itself, tending to reduce the initial unbalance. If there is no initial unbalance there will be no net voltage across these cathode resistors, thus it will be useless to bypass them. The 0.03 μf coupling condenser between the last two stages of this amplifier is too small to give a good low frequency response in a normal amplifier. However, if a large condenser is used trouble may be experienced with self-oscillation at a very low frequency. If trouble of this sort is encountered, reduction in the value of these condensers is recommended. To further force a balance between the two sides of the push-pull amplifier the two 6L6 screens are tied together and receive and supply voltage through a common resistor. Any tendency toward a push-pull self oscillation or unbalance in the output stage immediately appears as a resultant voltage across this resistor and tends to cancel. The d-c blocking condensers leading from the output plates to points P and Q should be low-leakage, high-quality components. If these condensers have an appreciable amount of leakage objectionable pops will be heard when rotating the C switch; indeed, the whole amplifier may become unstable.

Peaked Characteristics

If it is desired to produce a peak in the high frequency response such as might be required for the equalization of loaded cable circuits the 7F7 cathodes may be shunted by one or more resonant circuits of adjustable Q. An example of this sort of equalizer will be found in Fig. 2 in section A. It consists of L, C and R in series between the two cathodes.

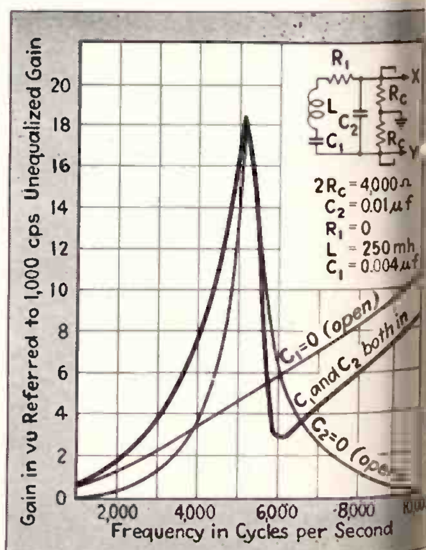


FIG. 13—Rough analysis of the curves of Fig. 12. Below resonance network A is dominant and above resonance network B is dominant

ıe resistance may be varied by ıeans of a tap switch arrangement, ıoducing the effect of varying the (Other switches and trimmers may l used to adjust the frequency of ısonance. If the series resistance , is zero and if the d-c resistance (L is negligible in comparison with ıe two 7F7 cathode resistors, the ıse in gain at the resonant fre- (ency will be numerically equal to ıe product $A\beta$. At that frequency ıe amplifier will act as though all edback had been removed. The ıarpness of the resonant peak so ıoduced is necessarily limited by ıe overall Q of this network, includ- ıg the 7F7 cathode resistors. In ıactice a rise in gain at the reso- ınt frequency of the order of 30 vu ı possible with this amplifier. In]g. 11 a rise in gain of 18 vu was ıtained when R_1 was made zero ıis means that the residual resist- ıce of the inductance was fairly ıgh. The resulting curve is some- ıat similar to the type of resonant ırve which might be obtained in a ıventional resonant circuit with a (of about 14.

In Fig. 12 will be found the result (combining sections A and B. This ınily of curves is obtained by vary- ıg the capacitance used in network ı An illustration of how this takes ıce is shown in Fig. 13. Here the ırves for the resonant network A ıd non-resonant network B, to- ıther with the composite curve, are ıperimposed for several different values of C_2. In a rough sort of way one might say that on the low frequency side of resonance network B holds control of the frequency response, and in passing through resonance network A dominates. After resonance has occurred the output drops below that which would be produced by network B alone and then rises approaching the network B curve as an asymptote.

In Fig. 14 are shown the characteristic curve of network D and the same curve with section A added. One marked difference between this type of curve and those of Fig. 6 is its performance after resonance. The same overshooting of the resonant curve will be observed and at higher frequencies it will again tend to return to the network D curve as an asymptote. In the practical case, however, even these curves are not sufficiently complex to correctly equalize within tolerable limits low grade wire service. When it is desired to lease a low grade service, and make it perform as a high quality line, one must be prepared for almost anything.

Two or more type A networks may be required in equalizing either the sending or receiving points or both. The number of different types of curves that can be obtained by such a procedure is so large that any attempt to comprehensively illustrate them would be futile in this space. In Fig. 15 will be seen a representative example of what may be obtained. By using two type A networks, one set to resonate at 2,000 cps with very low Q, the other spotted at 5,200 cps with higher Q, together with a mild application of network D, this composite is obtained. The height of either peak may be adjusted by changing the Q of the appropriate resonant circuit. The trough depth at 4,000 cps may be adjusted by setting network D. The broadness of resonance of the 2,000 cps type A network is occasioned by the 6,000-ohm series resistance. This resistance is necessary with section A wired as shown to limit the peak to 2½ vu. However, a sharper 2,000-cps 2½ vu peak may be easily produced by lowering the value of this 6,000-ohm resistor and tapping both ends of the 2,000-cps type A network, down on the 7F7 cathode resistors.

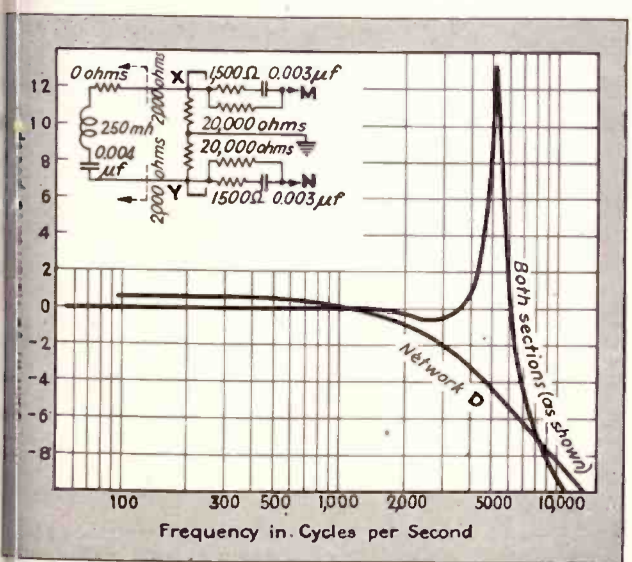
As a matter of passing interest the equation for the resonant equalizer corresponding to Eq. (6) for the type B equalizer is

$$\text{relative gain} = \frac{K \sin \phi_A}{1 + K' \sin \phi_A \dfrac{Z_R}{Z_T}} \qquad (7)$$

where Z_R is the impedance of the resonant circuit replacing the capacitance X_B in Fig. 5, and Z_T is an equivalent impedance formed by Z_R and the other impedance of Fig. 5B.

The mathematics as outlined herein is not intended for use as accurate design information, but merely as an indication of the procedure if

(*Continued on page* 91)



F. 14—Frequency response curve with network D alone and ·h network A added. After resonance the A-D curve overshoots the D curve and then returns to it asymptotically

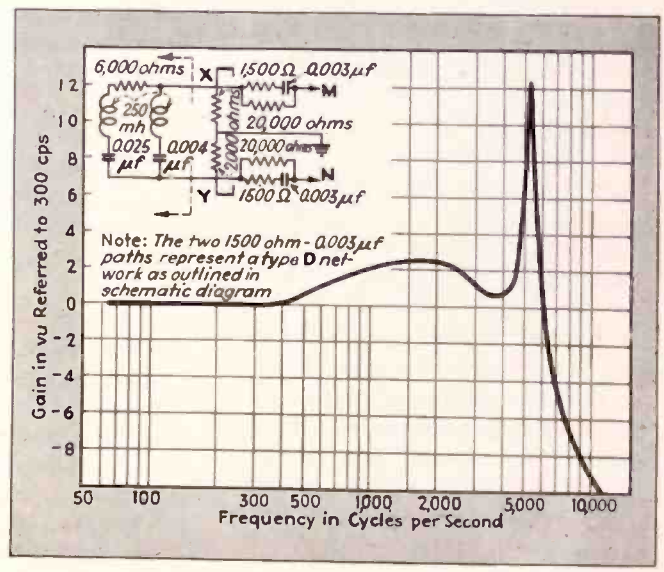


FIG. 15 —Two or more networks may be used to obtain the desired results. Here two type A networks are inserted in the amplifier to produce a double peaked response curve

The CONTROLLED Transitron Oscillato

Increased flexibility of operation of the transitron oscillator using only RC circuit elemen is provided by the use of a variable resistor. Adjustments of frequency and condition oscillation are made independent. The improved circuit, suitable for audio frequency us may be used as a frequency selective amplifier as well as an oscillator

By **STANLEY R. JORDAN**
Dayton, Ohio

THE transitron[1] oscillator has been used with success to produce stable sine wave oscillations at both high and low audio frequencies in a simple circuit. Since only resistance and condenser elements[2] are used, the oscillator is linear to a high degree, capable of producing sine waves with a remarkably low harmonic content at the low audio frequencies, and insensitive to magnetic coupling. Briefly, the transitron oscillator uses a tetrode with the inner grid used as an anode, the outer grid used as a control grid with negative transconductance to the anode grid, and the plate used as a collector anode. A pentode may be used with the inner control grid held at a fixed voltage close to cathode potential or actually tied to the cathode. This latter arrangement has been used in circuits which do not employ extreme values of R or C.

It is the purpose of this paper to discuss the circuit due to Delaup,[2] modified by the substitution of a volume control with shunting rheostat for the single resistor which he used in coupling to the outer control grid, and to develop basic design principles so that the various elements may be properly proportioned to obtain most satisfactory results from the working circuit which is shown in Fig. 1.

To analyze the operation of the circuit of Fig. 1, let

$R_1 = R_3R_4/(R_3 + R_4)$ represent the total equivalent resistance of volume control element, shunted by that part of rheostat in circuit.

$R_2 = R\,r_p\,/\,(R + r_p)$ represent the total equivalent resistance of R in parallel with anode-grid plate resistance, r_p,

r_p = be the resistance between cathode and second grid used as a plate,

E_G = be the voltage to cathode of outer control grid,

E_C = be the voltage to cathode of collector anode.

E_{AG} = be the voltage to cathode of anode grid, and

E_B = be the voltage supply to R

The tube may be a type 58 with possible values of: R_1 = 100,000 ohms, R_2 = 25,000 ohms, E_G = +20 volts, E_G = 4.5 volts, E_B = +115 volts, and E_{AG} = +40 approx.

The values of C_1 and C_2 depend upon the desired frequency and are related by the formula

$$f = \frac{1}{2\pi\sqrt{R_1\,R_2\,C_1\,C_2}} \qquad (1)$$

For the conditions cited r_p is such that $R_2 \cong$ 10,000 ohms and if C_1 and C_2 are equal their capacitances, in μf, are given by

$$C_1 = C_2 = \frac{10\sqrt{10}}{2\,\pi\,f}$$

For f = 15 cps, $C_1 = C_2$ = 0.336 μf.

The equivalent circuit is shown in Fig. 2. The voltage, e, across R_1 (or a definite fraction of it as determined by the setting of R_4) is applied to the outer control grid which has negative transconductance to the anode grid, that is, as the outer grid goes positive the anode grid receives less current and is, therefore, carried positive. It will be seen that a reduction of volume control setti is exactly equivalent to a reduction the absolute value of the transco ductance and hence permits a vari tion of the transconductance ind pendent of the plate resistance of t anode grid. This permits adjustme of the grid excitation to just th value required for oscillation a hence permits excellent waveform all frequencies. The purpose of t shunting rheostat, R_3, is to perm adjustment of R_1 and hence of t oscillating frequency. This may used for purposes of calibration to give continuous control of fr quency between condenser steps in multi-frequency oscillator. It will noted that feedback and frequen adjustments are independent.

By Kirchoff's laws.

$$i = i_1 + i_{R2} + i_{C2} = -eG_1$$

where G_1 is the conductance of t parallel combination of R_3 and The component currents are:

$$i_1 = \frac{e}{R_1},\quad i_{R2} = \frac{e_2}{R_2},\quad i_{C2} = C_2\frac{de_2}{dt}$$

$$e_2 = e + \frac{1}{C_1}\int\frac{e}{R_1}\,dt$$

and

$$\frac{de_2}{dt} = \frac{de}{dt} + \frac{e}{R_1\,C_1}$$

Hence, the equation for Fig. 2 is

$$\frac{e}{R_1} + \frac{e}{R_2} + \frac{1}{C_1\,R_2}\int\frac{e}{R_1}\,dt + C_2\frac{de}{dt} + \frac{C_2\,e}{R_1\,C_1} = -eG_1$$

or, written as a differential equatio

$$\frac{d^2e}{dt^2} + \left(\frac{1}{R_1C_2} + \frac{1}{R_2C_2} + \frac{1}{R_1C_1} + \frac{G_1}{C_2}\right)\frac{de}{dt} + \frac{1}{R_1R_2C_1C_2}\,e = 0$$

Ts is oscillatory if the coefficient t middle term is zero or negative nd the frequency is given by

$$2\pi f = \frac{1}{\sqrt{R_1R_2C_1C_2}} \qquad (7)$$

the limiting condition of oscillation is given by

$$|\,| \geq \frac{1}{R_2} + \frac{1}{R_1}\left(1 + \frac{C_2}{C_1}\right)$$
$$= \frac{1}{R_1} + \frac{1}{R_2}\left(1 + \frac{R_2C_2}{R_1C_1}\right) \qquad (8)$$

M h may be learned from the re ing equations. In order to vary e equency it is necessary to vary , l C_1, or C_2, or any combination t se. To avoid constantly changing e grid excitation setting it is sible to have the same limiting ndion of oscillation at different eq ncies. This may be achieved k ping the ratio C_2/C_1 constant if e lues of R and R_2 are to remain ns nt which is desirable from a the effective loading of R_1 on the oscillating circuit. Important parameters are the ratios $C_2/C_1 = K_c$ and $R_1C_1/R_2C_2 = K_r$. In operating circuits K_c has varied from ¼ to 10 and K_r from 0.7 to 20.

From the equations above it may be seen that, if R_1/R_2 is large and C_2/C_1 is not unduly large, R_2G should be kept constant for constant oscillating amplitude. If R is large relative to r_p then R_2 is nearly proportional to r_p which is nearly inversely proportional to G for the tubes concerned and the conditions are satisfied. Actually a somewhat smaller percentage variation of G than of r_p is required and conditions may be found for which this is true. This will give good waveform for varying supply voltage but will make the frequency fairly sensitive to supply voltage. A ten percent variation of tuned circuit of negative, zero, or low positive decrement and hence may be used as a very selective amplifier if properly adjusted. The controlled transitron RC oscillator described above has this desired feedback control. It may be used as a frequency selective amplifier by coupling the input voltage to the pentode inner control grid and by adjusting the grid excitation control to a value just under that for oscillation. The best overall operating characteristics of the circuit as a regenerator will be found with K_r near 1. As the feedback control is advanced toward the zero damping point there will be a marked increase of gain at the natural frequency of the system; in fact, high values of Q are avaliable. If the feedback is 0.9 of that required for oscillation (and $R_1C_1 = R_2C_2$) the equivalent Q is 5.5 and by increasing the feedback reasonably stable values up to 20 or 25 may be obtained. The question of phase is of interest. Since the inner control grid is supplying the little portion of G needed to make the damping zero at the natural frequency, then the voltages on the inner and outer control grids must be exactly 180 degrees out of phase at the natural frequency and the amplified voltage at the junction of R_1 and C_1 is available for connection to an amplifier grid.

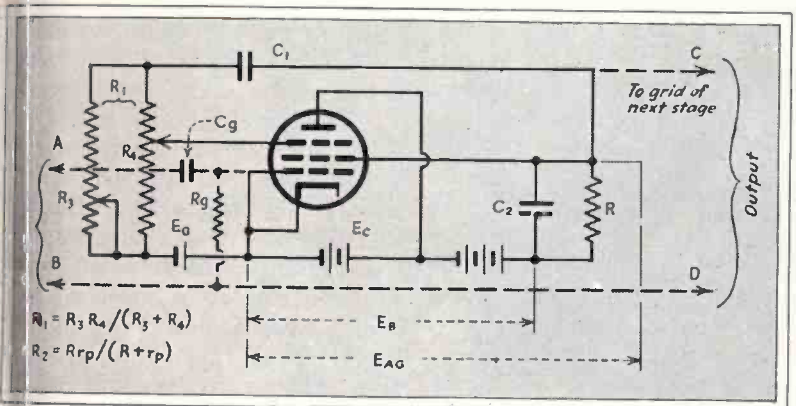
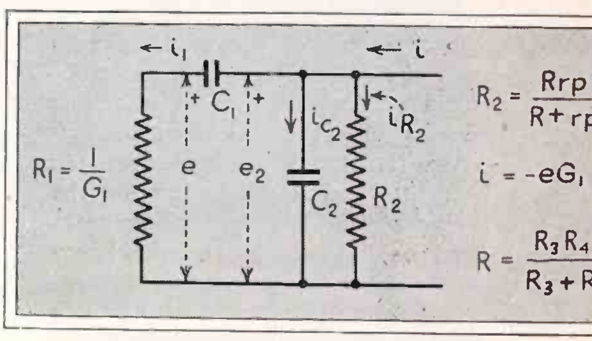


FIG. 1—The improved transitron oscillator with independent control of oscillation through the use of the variable resistor, R_3. The circuit may be used as a frequency selective amplifier by feeding the voltage to the terminals AB and taking the output from terminals CD

FIG. 2—Equivalent circuit of the RC transitron oscillator of Fig. 1



tal operating standpoint. The ximum theoretical value of R_2 is and its practical maximum value es than that, while its minimum ue 1/G even if R_1 is infinite. But iation of R_2 by a variation of R l fect the average operating nt which is undesirable if the ximum undistorted output is to be aird. The resistance R_1 has a ximum value determined by grid and bias variation considera- s. For practical purposes this stance may be taken as 500,000 s put of course it depends en- ly pon the tube and operating itions. The minimum value of determined by the values of R_2 G and also by the ratio of C_2 to It will be observed that this s a multiplying effect upon the supply will cause about a ten percent change of R_2 and hence about a five percent variation of the frequency. Since waveform, stability, frequency, and output are all dependent upon the supply voltages it is evident that a well regulated supply is essential. If this is provided high voltage output of excellent waveform may be obtained by the use of reasonably large values of R and R_1, an average value of R_1C_1/R_2C_2 near 10, and, especially, of the principle of frequency variation by change of both C_1 and C_2, keeping their ratio constant and near 1.

Any oscillator whose tendency to oscillate may be continuously varied from the normal slight negative damping through zero to slight positive damping is the equivalent of a

Thus the equivalent of a low frequency, high Q, tuned load, amplifier stage with f and Q continuously adjustable is available. This should be valuable in vibration and balancing studies.

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(1) C. Brunetti, Transitron Oscillator. *Proc. I.R.E.* Feb., 1939.
(2) Paul S. Delaup. ELECTRONICS, Jan., 1941.

Wave Form Circuits for CATHODE

Flexibility over a wide range of frequencies, rapidity in operation, and high impedance mak[e] the cathode-ray tube a universal tool of the communications engineer as well as of the servic[e] man. The uses of this important tube in waveform analysis are thoroughly covered in thi[s] two-part survey article of present day technique

By **H. M. LEWIS**

Consulting Engineer

PRIOR to the first World War the cathode-ray tube was a recognized but infrequently used tool for the study of voltage and current waveforms. During the nineteen twenties and thirties electronic television appropriated the cathode-ray tube to convert it to its own instruments of generator and reproducer of television images. In this effort a large number of workers here and abroad perfected a technique of generation and control of electrical waveforms which could meet rigid standards of operation. While broadcast television may mark time until the war ends, the technique it has perfected is being employed in almost endless fashion to win the war. Engineers and technicians from other fields who now are called upon to develop and operate these cathode-ray devices will find an enormous literature on the subject. The present article seeks only to illustrate, as space will permit, some of the principles of waveform generation and control which may be of service to these men.

Fundamentals of the C-R Oscillograph

Electrons emitted from the heated cathode of a vacuum tube may be focused by an electric or a magnetic field and accelerated by a d-c potential of several hundred (sometimes several thousand) volts to strike upon a fluorescent screen. The number of electrons in this so-called cathode-ray (i.e., the beam current) and its electron velocity due to the d-c potential will determine the brightness of the spot on the screen. When the spot, which normally is formed at the center of the screen, is deflected by an electric or a magnetic field the spot moves and we have a trace of light on the screen due to persistence of vision and the time required for the fluorescence to die out. Traces due to periodic signal waveforms are ordinarily formed on the screen as graphs of the instantaneous amplitude of the signal, plotted against time. This is accomplished by a periodic horizontal deflection which varies linearly with time from left to right; to provide a time scale, and a vertical deflection which follows instantaneously the amplitude of the signal.

A deflection field of saw-tooth waveform is employed to provide this horizontal time axis and when it is chosen with a periodicity equal to, or an integral submultiple of the periodicity of the signal waveform a stationary pattern is produced.

Since the theory of deflection is to be found in nearly every text, only a few points of practical intent need be noted here. The cathode-ray tube of Fig. 1 is of the more common electrostatically focused type. The first, A_1 anode potential is adjusted, relative to that of the second A_2 anode, to focus the spot on the screen. The grid, G, may be biased to adjust the brightness of the spot and a signal may be applied via the grid coupling circuit to modulate the brightness of the ray. Since circuits should always be complete, we show by dotted lines that electrons, equal in number to those striking the screen, leave the screen due to secondary electron emission and flow to the second anode. The second anode extends toward the screen to draw off these secondary electrons and to act as a shield against extraneous electric fields.

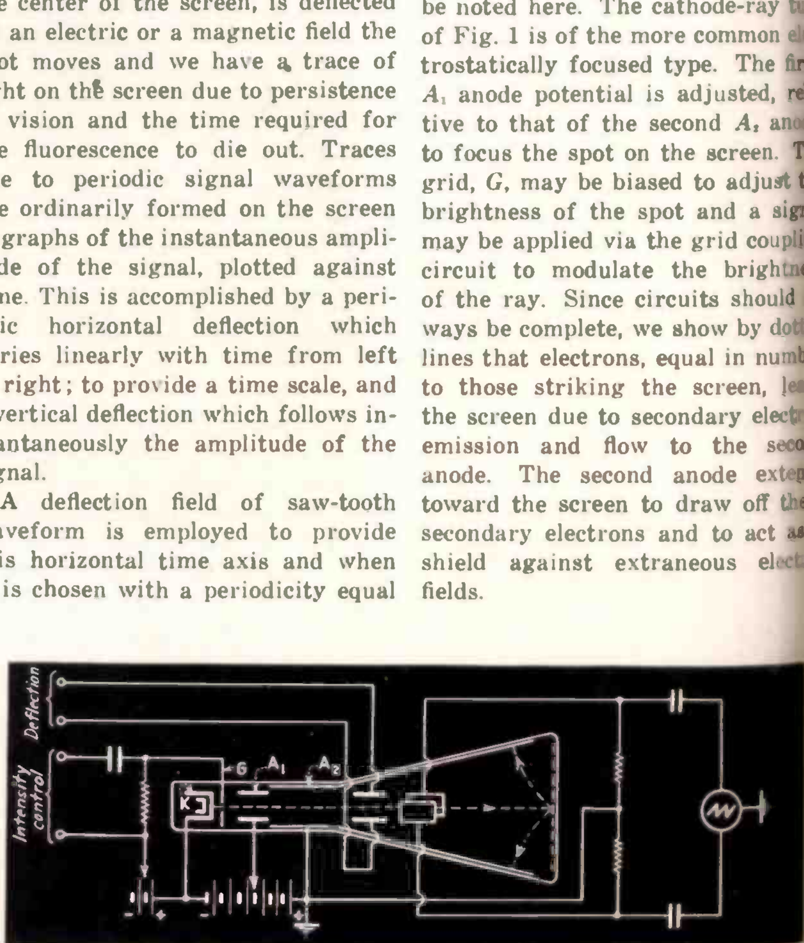


FIG. 1—Schematic wiring diagram of electrostatically deflected cathode ray tube. Cathode, grid, first and second anodes are shown respectively at K, G, A_1 and A_2

:AY TUBES . . . Part I

THE rapid growth of the application of cathode-ray tubes as devices for analyzing circuit operations is partly the result of recent television developments. But it is equally the result of the many circuit refinements which, coupled with improvements in the tubes themselves, make the c-r oscilloscope the most versatile piece of analyzing equipment for the electronics worker. At the request of the Editors, Mr. Lewis has prepared this timely survey of cathode-ray tube technique.

he saw-tooth deflecting voltage is pplied as shown to the horizontal de:cting plates and relative to the se nd anode voltage; hence the an le is grounded. The cathode may be grounded if the voltage supply, re esented for convenience by a ba ery, is suitably by-passed and th condensers coupling the deflec- tic voltage to the plates are chosen to ithstand the high anode voltage. Or of the plates may be connected di ct to the second anode and a "s gle phase" deflection voltage ap- pli l to the other plate. However th use of a balanced voltage source as llustrated is to be preferred to av d distortions. Similarly, the sig- na voltage is applied to one or both of he vertical deflection plates.

nce we are dealing with deflec- tic of a ray of negative electrons th motion of the spot is in the direc- tic of the electric field as shown in Fi 2A. For magnetic deflection the m on of the spot is normal to the di ction of the magnetic field as sh vn at Fig. 2B. With normally de gned tubes and deflector elements th displacement of the spot is di ctly proportional to the field st ngth and hence directly propor- tic al to the deflection voltage or de ction current as the case may be. F deflection in two dimensions by a ir of deflectors normal to each o r and of equal sensitivity the di lacement of the spot P is shown in Fig. 2C as the resultant of displacements x and y corresponding to the horizontal and vertical deflection fields respectively. The displacement of P may also be defined in polar coordinates by the angle θ and the radius vector ρ.

Fundamental RC and L/R generators

The generator of saw-tooth voltage or current to provide a time axis is of fundamental consideration and,

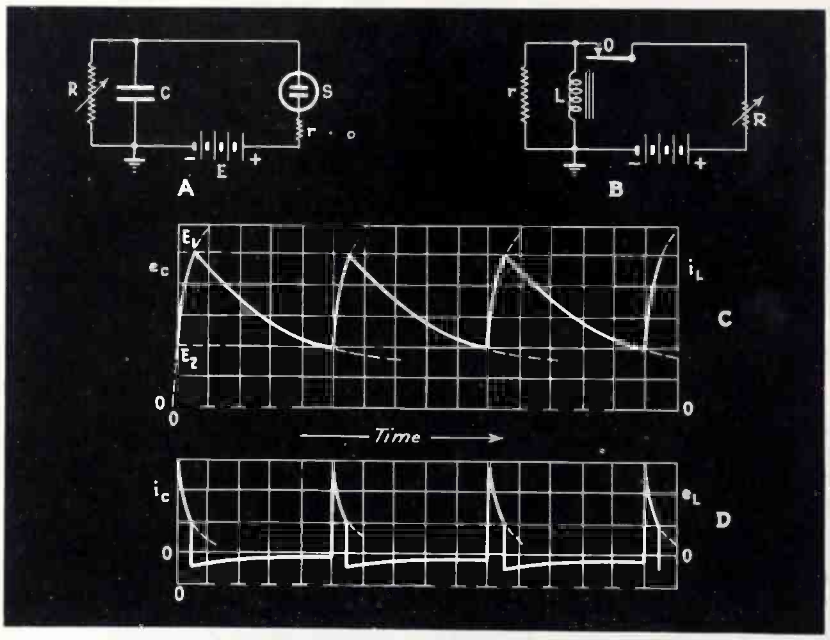
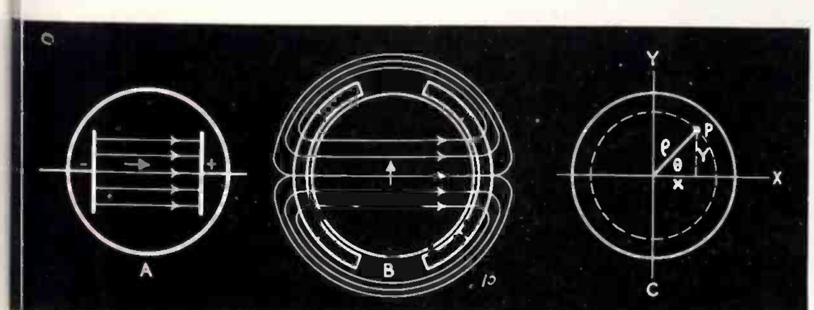
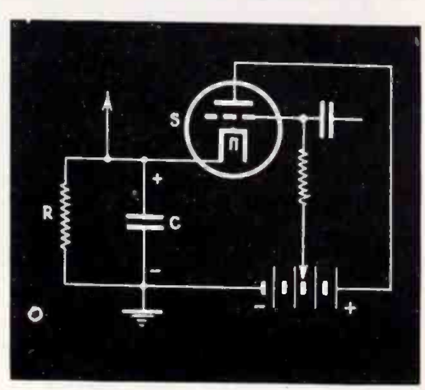


FIG. 3—(Above) Two saw-tooth circuits and wave forms produced

FIG. 4—(Below) Hot cathode gas tube in saw-tooth circuit, similar to that of Fig. 3A



Fi. 2—Electrostatic (A) and electromagnetic fields (B) (open arrows) produce electron motions (closed arrows) to produce spot, P, on screen (C)



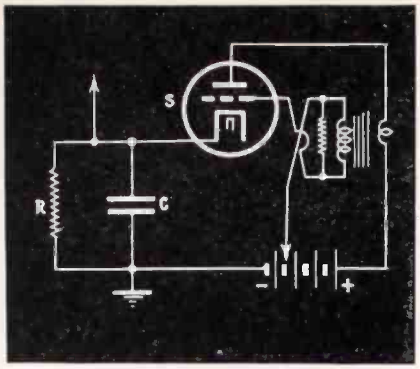


FIG. 5—Hot cathode gas tube used in circuit for producing saw tooth wave forms

is the basis of waveforms used in cathode-ray technique.

The fundamental form of saw-tooth voltage generator or *RC* circuit is illustrated in Fig. 3. The condenser *C* is rapidly charged by battery *E* through the device *S* and small resistance *r*. The device *S*, which we may term a shorting tube, has the property of being non-conductive until a predetermined voltage is applied across its terminals. It then passes current freely and continues to do so until the voltage

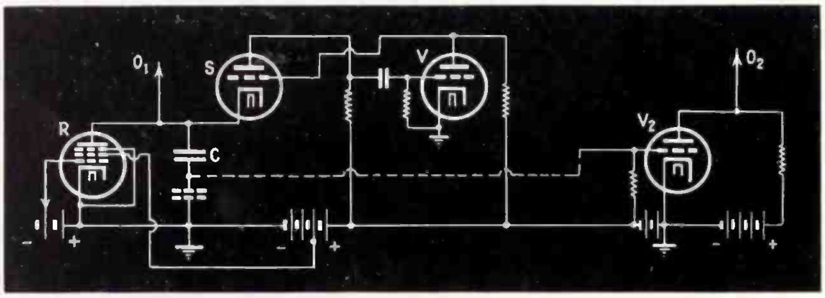


FIG. 6—Popular type of saw tooth generator with regenerative shorting tube, S

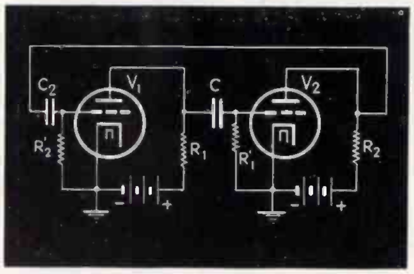


FIG. 7—The popular multivibrator type of circuit producing relaxation oscillations

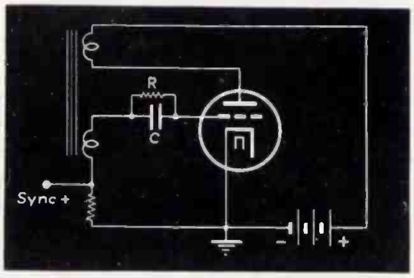


FIG. 8—Simple diagram of the blocking oscillator type of relaxation oscillator

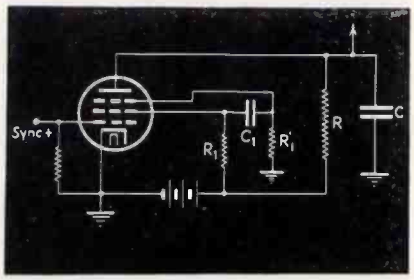


FIG. 9—A convenient saw tooth wave form generator using a single pentode

falls to a second predetermined but lower level. A two electrode tube containing a low pressure of gas (e.g. neon, argon or the like) has this property, there being an effective difference between the ionization and de-ionization or arc extension potentials. As condenser *C* charges, the voltage across it rises to oppose that of the battery *E* until the net voltage across *S* reaches the de-ionization level. At this point the tube *S* becomes non-conductive and condenser *C* discharges through the high resistance *R* until its voltage is decreased to a level where *S* again conducts current. The cycle then repeats and the periodic waveform of voltage across condenser *C* is shown as e_c of curve C. This wave is of saw tooth form but is not linear since the trace or slow part of the cycle is an exponential curve determined by the time constant *RC* and the retrace or rapid part of the cycle is a steeper exponential curve determined by the time constant *rC*. It will be evident that the periodicity or frequency of the wave will be chiefly determined by the slow trace part of the cycle.

The formula for frequency is,

$$= \frac{1}{CR \log \frac{E_1}{E_2} + Cr \log \frac{E - E_2}{E - E_1}} \quad (1)$$

where E_1 is the maximum voltage level.
E_2 is the minimum voltage level, and
E is the battery voltage.

The terms "charge" and "discharge," are entirely relative. For example the bottom connection of C may be brought to the $E+$ terminal of the battery without causing any difference in the waveform or de-level of the voltage between the top terminal and ground. In this case it would be more natural to say that the condenser *C* is slowly charged through *R* and rapidly discharged through *S* and *r*. We should note however that reversal of the battery *E* causes a reversal in polarity of the saw tooth waveform.

In applying this voltage for deflecting the ray we are not concerned about the rapid retrace since it is not used. Also fewer electrons strike a given spot on the screen and the retrace will be dim; it may also be blanked out by a negative pulse applied to the grid. The trace however should be linear to serve as a time axis and fair linearity may be achieved by making *E* a high voltage and making *R* as large as possible, thereby to effect operation over a small linear portion of the exponential curve.

The current through the condenser *C* will have the impulse waveform shown as i_c of curve *D*. Here we again have exponential trace and retrace portions of the wave joined by abrupt discontinuities. In practice these discontinuities can never be perfectly vertical changes of amplitude since nothing can happen in zero time. So we note mentally that a small slope exists wherever such waveforms are shown and that they could only be illustrated significantly by using a greatly expanded scale of time. The same is true of the points of inflection of the waveforms; they are actually curved changes of direction too sharp to be drawn on the scale employed. Most important to note is that the impulse wave is the mathematical derivative of the saw tooth wave; it represents the rate at which the curvature of the saw tooth is changing with time.

The fundamental form of saw tooth current generator or *L/R* circuit is illustrated in Fig. 3B. It is simply the familiar make and break or buzzer circuit. The spring contact *O*, (which we may term an opening device) is normally closed so that current change in the inductance is again an exponential curve determined by the time constant L/R. Here R is a small resistance and includes the coil resistance. The smaller we make the value of R, the more slowly the current increase. Here R determines the trace part of the cycle of i_L also represented by curve C of Fig. 3. The magnetic field increases with the current increase through L until at a predetermined maximum it pulls open the contact O. The current then decreases according to the steeper reverse exponential curve as determined by the time constant L/r. Since r will generally be the leakage resistance and very high, the current retrace will be rapid. The mechanical period of the spring contact O may determine the frequency, but assuming a device without such mechanical properties we note that the trace part of the cycle which chiefly determines the periodicity, is controlled by the choice of L and R. An increase in R results in an increase of frequency.

The voltage across an inductance is the mathematical derivative of the current through it and hence e_L is represented by the impulse waveform of Fig. 3D.

For magnetic deflection the coil L could be designed to serve as the deflection coils of Fig. 2B to provide time axis.

RC type Relaxation Generators

A number of circuit arrangements of ordinary vacuum tubes can be arranged to simulate the fundamental L/R circuit of Fig. 3B. In general it is easier to arrange vacuum tube circuits as RC type generators. These are also more useful in cathode ray technique and hence they alone will be discussed.

A gas tube having a hot cathode, plate and grid, such as the thyratron provides the most simple and, for many purposes, the most useful generator arrangement as shown by Fig. 4. The circuit is identical with Fig. 3A except that the gas tube replaces the device S and must be correctly connected in the circuit. The grid is connected to a point on the battery through a high resistor so that a synchronizing signal may be applied between grid and ground across the capacity shown. The connection of the grid to the battery to provide a suitable negative bias between grid and cathode of tube S, since the grid bias determines the voltage level at which the tube conducts current. This bias is negative, not positive, since it is comprised of the tapped portion of E and the average d-c potential across C. We have then in this circuit an additional control of frequency and linearity, since we may set the grid bias to determine one voltage level; that at which the retrace begins. Once the gas tube, S, becomes conductive the grid has no control and the charging of C continues until the net plate-cathode voltage reaches the extinctive level where the grid again takes control. It will be noted that here, and in the circuits of Fig. 5 and Fig. 6 which follow, the RC circuit is in the cathode-ground path where it affects both plate and grid circuits in determining the levels at which tube S operates. When possible this arrangement is to be preferred.

The circuit of Fig. 5 is like that of Fig. 4 but here the device S is a high vacuum triode. To obtain the equivalent of a gas ionization characteristic, and also to avoid the limitation of an appreciable time for ionization to occur, a feedback connection is provided. The transformer coupling plate and grid circuits serves then to provide a positive pulse of voltage on the grid when current starts to flow through the tube. Thus the resistance of the tube is sharply lowered to provide for the rapid charge of condenser C during the retrace interval. One or both windings of the transformer will ordinarily be damped as shown by a shunt resistor to avoid oscillation through distributed capacities. Actually the voltage across each winding will be a double impulse (first positive and then negative) as will be shown later. The choice of a transformer is not critical but will in general be chosen with regard to the range of operating frequencies since much higher frequencies may be generated by vacuum tubes than by gas tubes.

A widely used form of saw tooth voltage generator is the circuit of Fig. 6. High vacuum tubes are employed and the circuit is fundamentally the same as the preceding one. The shorting tube, S, is made regenerative by means of a polarity reversing tube V instead of a transformer. When charging current flows through S, a negative voltage pulse across the plate resistor load is amplified as a positive voltage pulse by tube V and applied to the grid of S to increase its conductivity during the retrace interval. The direct connection of the plate of V to the grid of S is permissible since as in the preceeding figures the grid will be returned to a point on the battery to provide suitable bias.

The RC circuit which controls the trace part of the cycle is the condenser C and the plate-cathode resistance of the pentode R. The plate current of a pentode is constant for a wide range of plate voltage and may be set by its grid bias. Hence by substitution of the pentode for R we predetermine a constant current discharge of C during the trace part of the cycle. This means that the trace voltage across C will vary linearly with time. Substantially linear trace saw tooth voltage may be had by this method. The pentode may of course be used to replace R in the preceding circuits. To provide a balanced output a portion of saw tooth voltage across C may be taken from a condenser in series

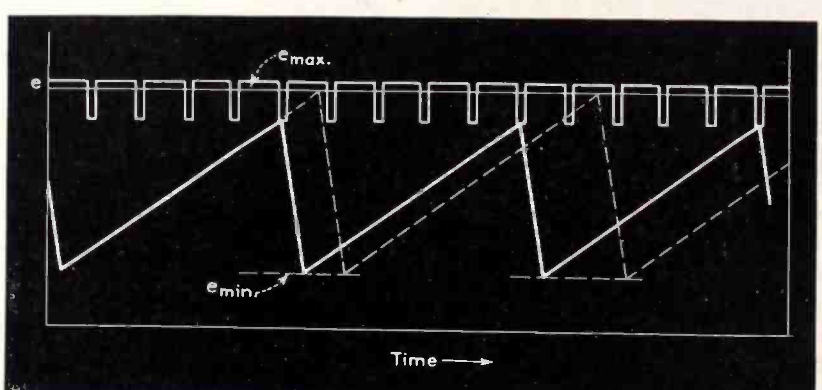
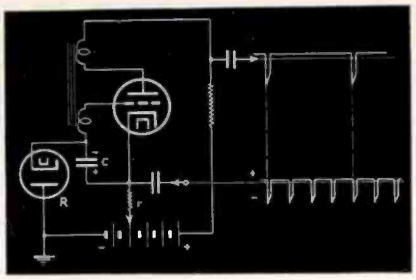


FIG. 10—Rectangular pulses of suitable amplitude and sign control frequency of relaxation oscillators by altering the breakdown voltage timing, as shown by solid saw tooth wave



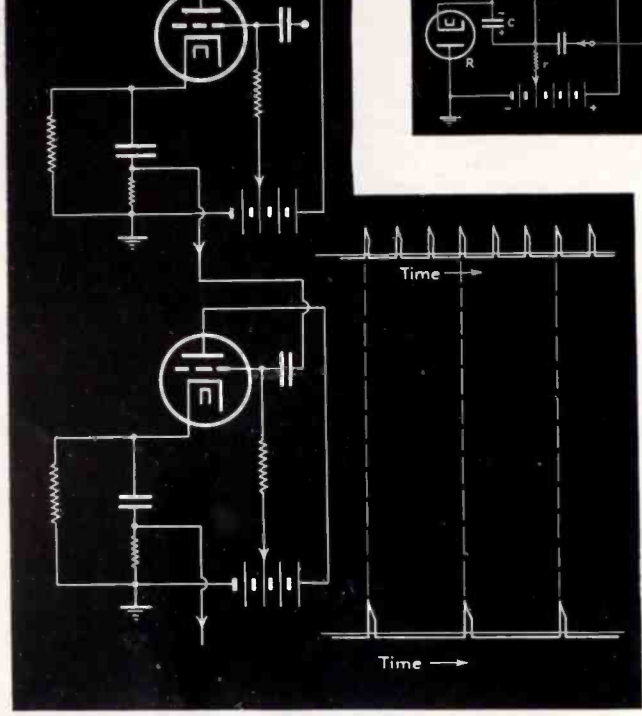


FIG. 11—(Left) Diagram illustrating method of synchronizing two relaxation oscillators through use of voltage pulses

FIG. 12—(Above) Synchronizing arrangement used in the counter type of frequency dividing circuits

with C to the grid of amplifier, V_2, with the gain of V_2 adjusted so that the saw tooth voltage output at O_2 is equal in amplitude and opposite in polarity to that at O_1.

Two of the earliest forms of relaxation oscillators, both of which are still widely used, are the "multivibrator" and the "blocking oscillator" shown respectively in Figs. 7 and 8. They are primarily useful as sources of impulse waveform.

The multivibrator in its original form is simply two resistance coupled stages; the output of the second stage being coupled back to the input of the first so that the arrangement is regenerative. For example the condenser C_1 will be charged when tube V_1 is conductive and the charge must leak off through R_1. When V_2 is conductive the condenser C_2 is charged. With equal CR time constants in the two coupling circuits the tubes V_1 and V_2 are alternately conductive for equal time intervals, that is the trace and retrace intervals of the wave are equal. Pulse voltages of opposite polarity are therefore available from the two coupling circuits. It is also possible for each condenser to be charged in the opposite sense by the flow of grid current which must leak off through the grid resistor so that when C_1 is being charged, C_2 is being discharged or charged in opposite sense and vice versa. With dissimilar coupling circuit constants the trace and retrace intervals will differ.

The blocking oscillator of Fig. 8 is a conventional (but untuned) feedback circuit arranged with a grid condenser and leak so that when the tube conducts, grid current flows to charge C negative. The tube is therefore shut off until the charge leaks off through R. In some arrangements of the circuit one of the windings is tuned by a condenser to a high frequency so that several cycles of oscillation occur before C is charged sufficiently to stop the flow of plate current. Voltage across one of the windings will be of double impulse form which may be used for a variety of purposes.

A very convenient form of saw-tooth voltage generator employing a single pentode tube is shown in Fig. 9. The action of the circuit is not simple and a variety of explanations have appeared in the literature. Basically the operation depends upon the suppressor grid which has the ordinary control characteristics of positive mutual conductance relative to the plate but which has opposite control or negative mutual conductance relative to the screen grid. This is evident since a negative potential on the suppressor turns electrons back to the screen grid. The inner elements of cathode, suppressor grid and screen grid (the screen grid being viewed as an anode), with the elements $R_1C_1R_2$ comprises a regenerative circuit. The elements $R_1C_1R_2$ determine the periodicity R_1 principally affecting the ratio of trace to retrace intervals. Narrow pulses of current flow to the plate to charge C which discharges slowly through R so that saw-tooth voltage is developed across C.

Synchronization and Counter Circuits

As has been shown the periodicity of an RC relaxation oscillator is controlled by its charging and discharging time constant circuits and by two levels of voltage. (See Eq. 1) Synchronization of the oscillator to conform with the periodicity of some other source is effected by controlling at least one of these voltage levels, generally that which terminates the trace part of the cycle. In Fig. 10 these levels for a saw-tooth voltage waveform are shown as e_{max} and e_{min} and the natural relaxation period is shown by the dotted saw-tooth line. If we modify the level e_{max} by superimposing upon it the pulse waveform as shown it will be clear that the trace part of the cycle may be interrupted by the lowering of this maximum level during a pulse peak. In the illustration it is not until the fifth peak occurs that the cycle is interrupted or tripped. It is evident from the diagram that relaxation oscillators may be accurately synchronized by this method at the same periodicity or at a submultiple of the synchronizing signal. This is fortunate since in using the saw-tooth wave as a time axis it is desirable to synchronize it at a submultiple of the signal periodicity thereby to show a succession of several cycles of the signal waveform on the oscilloscope screen.

Sharp pulses for synchronizing may be derived from all recurrent waveforms. While synchronization is not limited to the use of pulses they are to be preferred since the

(*Continued on page* 84)

GRAPHICAL ANALYSIS of SAW TOOTH WAVES

By ULRICH R. FURST
Chicago, Ill.

ALTHOUGH radio engineers are mainly concerned with sinusoidal waves and oscillations they frequently encounter periodic functions of other shapes. Many of these other waves consist of a slow rise of a current or voltage and a much faster decline back to its original value; this is repeated periodically. Waves of such shape are found in condenser input filters of rectifiers, deflection voltages and currents for cathode-ray tubes, multivibrator circuits, phase inverters etc. They are characterized by a relatively large content of higher harmonics.

In all applications of such waves or oscillations it is of importance to know the amplitudes of the higher harmonics. This information is desirable in the design of amplifiers to provide the desired amplification of the input waves without excessive volume distortion, or of filters which have the desired attenuation. Such data is also useful to select such a wave-shape, for frequency-multiplication in multivibrators, that the amplitude of any particular harmonic is zero or a maximum value.

For computing the curves of the diagram on the following page the simplifying assumption has been made that both the rise and the decline of the function have a constant rate of change or that the curve appears graphically as a combination of two straight lines as in Fig. 1. This assumption is permissible since it is a very good approximation in most cases and facilitates the computation of the amplitudes of the harmonics by a Fourier analysis.

By selecting the point P (Fig. 1.) as the origin of our coördinate system it can be seen, that the coefficients of all cosine expressions are zero and only those of the sine expressions must be computed from following the formula:

$$b_n = \frac{1}{\pi} \int f(x) \sin nx \, dx,$$

integrated over a full period of $f(x)$ from point P to point P' in Fig. 1.) where n is the order of the particular harmonic.

By making the greatest amplitude of our function $f(x)$ equal to 1 (or 100 per cent) the following expression for b_n is obtained:

$$b_n = \frac{2 \sin (n \pi x)}{\pi^2 n^2 x(1-x)}; \qquad 0 < x < 1$$

This becomes indefinite for values of $x = 0$ and $x = 1$ and after differentiation of numerator and denominator in the usual way we obtain $b_n = 2/n\pi$ for $x = 0$ or 1. Here x means that fraction of the total cycle during which our function rises from zero to its maximum value of Fig. 1.

In the diagram on the following page curves are plotted representing the amplitudes of the higher harmonics b_n as a function of the value x and of the order n of the harmonic. The amplitudes b_n are plotted in logarithmic scale to emphasize small values of b_n. As could not be otherwise expected the curves are symmetrical with the value $x = \frac{1}{2}$ (or 50 percent) as axis of symmetry, so that only one half of the diagram actually had to be plotted. The value $x = 30$ percent gives the same values of b_n as $x = 100 - 30$ percent or 70 percent. This accounts for the double scale on the abscissa axis.

The diagram can be used in the following manner: A. To find the harmonic content of a particular saw tooth wave express values of x and $1-x$ in terms of percentage of a complete cycle. For instance a wave characterized by the fact that the voltage rises during 9/10 and declines during the remaining 1/10 of the full cycle is represented by $x = 90$ percent. For this value of x we find the amplitude of the third harmonic to be 20 percent of the full saw tooth wave amplitude, of the seventh harmonic 3.7 percent and so on. If not more than 5 percent amplitude distortion can be permitted, in the saw tooth amplifier its frequency-characteristic must be such that all harmonics up to and including the sixth must have the same amplification.

B. To find the wave-shape which has a relatively high content of one particular harmonic (for instance for frequency-multiplication with multivibrators) select that value of x for which the desired harmonic has a high value of b_n. If for instance a high current of the sixth harmonic and at the same time a low content of the fifth harmonic is desired, the most favorable value of x is 40 percent (or 60 percent which amounts to the same waveform).

The diagram also shows, that the greatest content of harmonics can be achieved with $x = 0$ (or 100 percent and that all even harmonics are eliminated for $x = 50$ percent.

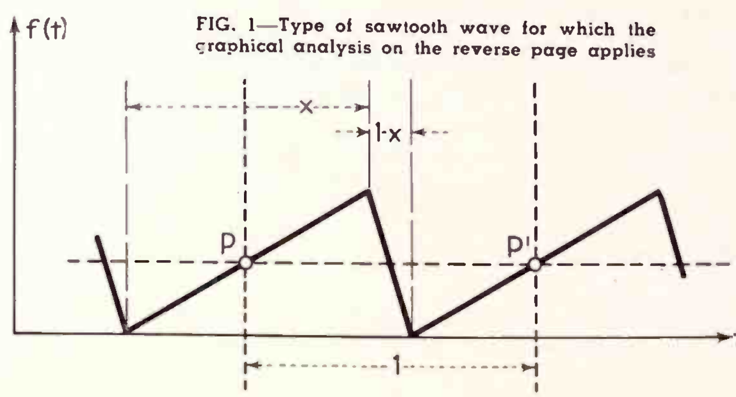
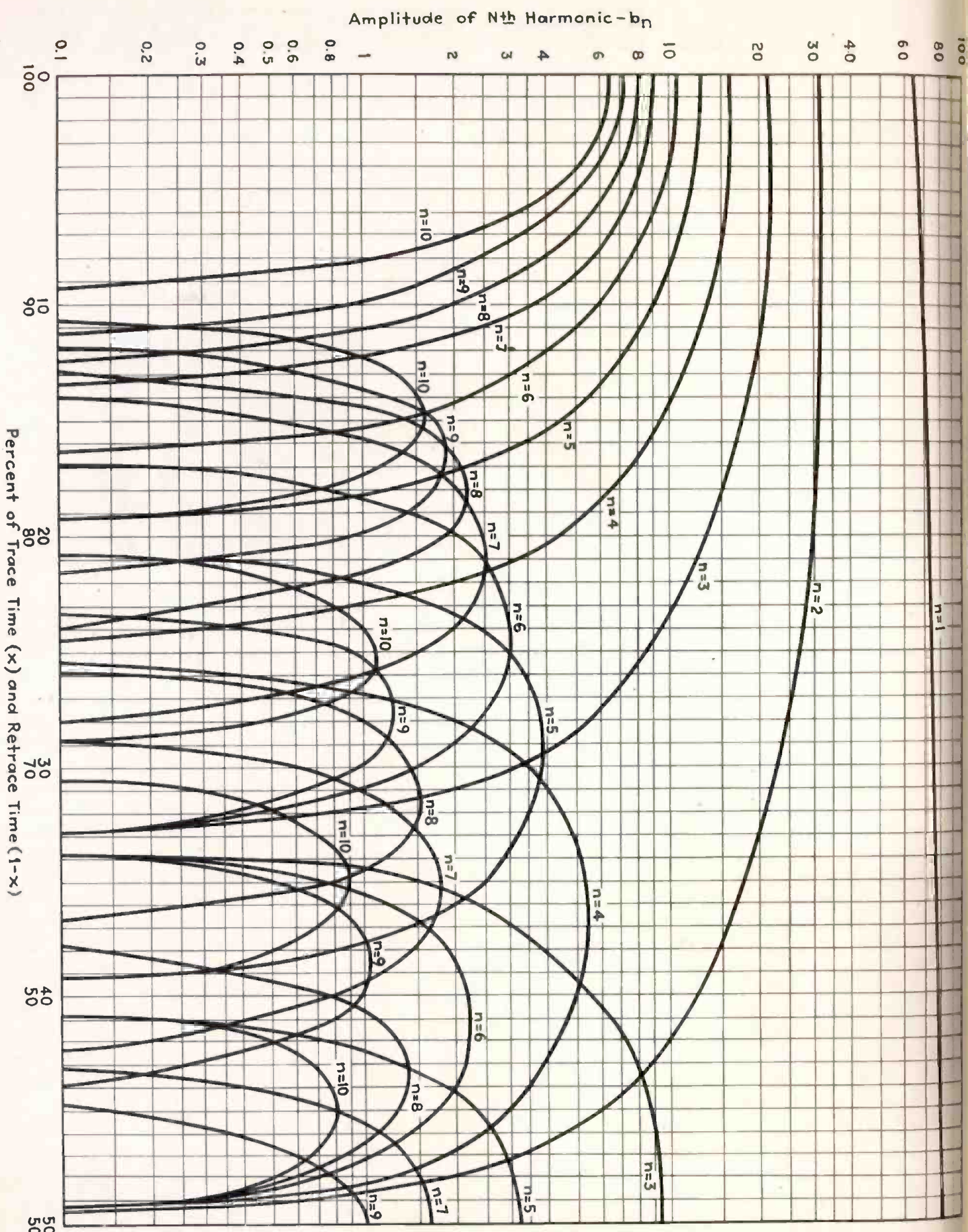


FIG. 1—Type of sawtooth wave for which the graphical analysis on the reverse page applies

Graphical Analysis of Saw Tooth Waves



Graph illustrating the amplitude of harmonic components, up to the tenth harmonic, of sine waves to produce saw tooth waves whose trace and retrace values are x and $(1-x)$ portions of a complete cycle

TUBES AT WORK

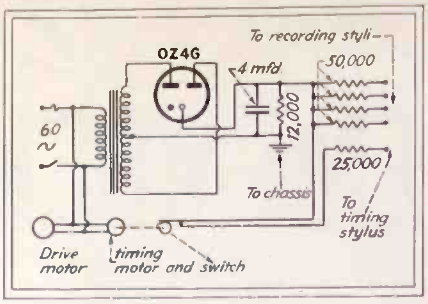


Fig. 3—Electrical circuit of versatile time-displacement recording device

Versatile Electro-Kymograph

By Charles Moore, B.S. and Harlan Bloomer, Ph.D

The electro-kymograph herein described may be adapted for use in various physical and physiological investigations in which data are gathered from time displacement curves. It records by means of an electric current passed through sensitized paper. Records are permanent.

The first machine of this type was constructed for the University of Michigan Speech Clinic, to be used chiefly in the study of respiratory and diadochokinetic movements. It was designed to provide the advantages of portability, convenience of operation, versatility of use and simplicity and cheapness of construction. Pictures are shown in Fig. 1 and Fig. 2.

Construction

The machine was constructed on an 8 by 16½ inch base and is housed in a "portable sewing machine type" cover (omitted from the illustrations) 9¾ inches high. The cover contains a drawer for accessories such as the pneumographs and tambours used in physiological studies. When fully equipped with all accessories, the entire unit weighs forty pounds.

The power supply, the synchronous motor driving the paper and the timing motor are located beneath the metal plate over which the recording paper passes.

The recording paper used was developed for radio facsimile reproduction. The entire roll is so mounted and placed that the feed is continuous. The paper is drawn across the metal plate at constant speeds by a set of rollers driven by the synchronous electric motor. External interchangeable gears make it possible to select speeds of approximately 3, 5, 10, 22, 48, 95 and 154

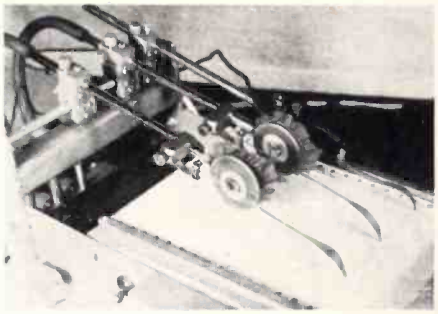


Fig. 2—Close-up showing two recording tambours and styli in foreground and magnetically operated time-marking stylus at rear. Special adjustable clamps at left permit unused styli to be raised from paper

inches per minute. The recording line is made by passage of approximately 200 volts d.c. from the point of the recording stylus through the paper to the grounded conducting plate beneath.

The stylus is a small lever to which a writing point of platinum (tungsten would also be suitable) has been affixed. Ordinary steel or brass tips disintegrate too rapidly to be satisfactory. A thin curved spring forms part of the stylus. The spring serves to maintain slight pressure between the paper and pointer. Since the recording mechanism does not remove a coating from the paper, the pressure of contact need be sufficient only to maintain contiguity, hence the element of friction is almost negligible. A fine black line is produced on a light background.

The electric circuit, shown in Fig. 3, is so constructed that all of the styli are wired in parallel. It is therefore necessary to isolate them from one another to prevent shorting out the other recording points. A series of 50,000 ohm resistors is provided for this purpose. The 12,000 ohm resistor loads the OZ4G cold-cathode gaseous rectifier tube sufficiently to insure proper operation. The capacitor removes objectionable power supply ripple. The 25,000 ohm resistor isolates the timing stylus.

Operation

The writing levers may be moved in a variety of ways. In the machine described they are attached to rubber-dam tambours which register changes in air pressure within a closed system. Rubber tubes connect the tambours to pneumographs (flexible rubber tubes for recording changes in circumference of the thorax and abdomen during breathing). Special valves have been constructed so that free movement of the subject can take place without disturbing the delicate adjustment of the recording point on the paper. In one position the valves permit adjustment of the pneumographs without injury to the tambours by providing an outlet by which air pressure changes can be minimized at will; in the other position the system is closed and the air flows freely between the two instruments.

The time marker employed is a small electro-magnetic signal marker operated by a small motor and switch which interrupts the current at suitable intervals.

All tambours and the timing stylus are held on a common mounting rod by specially designed clamps which allow the pointers to be raised or lowered, engaged or disengaged from contact with the paper. As many as four tambours and a timer can be easily mounted for recording on a strip of

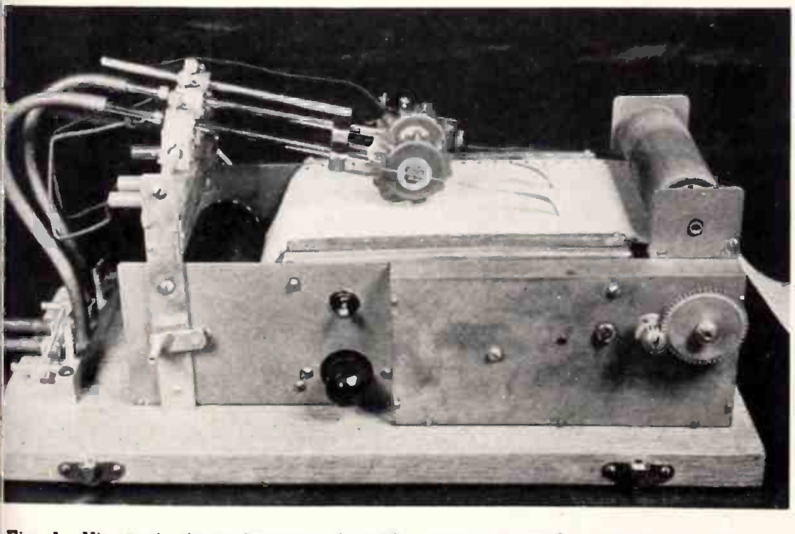


Fig. 1—View of electro-kymograph with cover removed. Direct current is passed through sensitized paper between the points of the styli and the grounded metal plate over which the paper slides. Other gears are readily substituted for those appearing at the right to change paper speed

Electronic Engineers,

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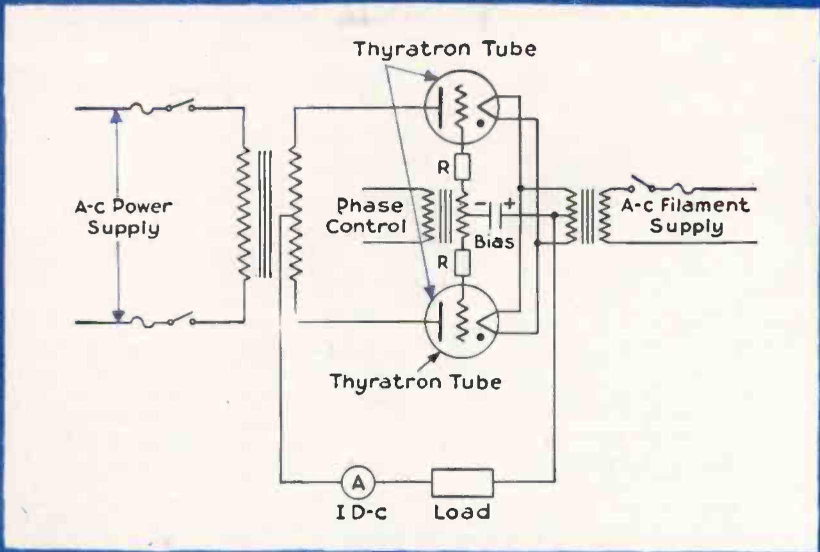
WITH THIS BASIC CIRCUIT YOU CAN DESIGN MANY CONTROL DEVICES



From this circuit can be built devices fundamentally the same, but which have myriad applications—such as controlling the speed of motors, maintaining the proper speed relations between two conveyors, and controlling and varying the intensity and color of light.

A thyratron is a… cathode, gas… charge tube in… one or more… trodes are empl… to control ele… statically the sta… of the unidirect… current flow.

THE electronic circuit is entering more and more into industrial work as an automatic hand, an automatic eye, a new means of generating heat—control methods are being revolutionized. Results are showing that electronic-tube control is more accurate, more dependable, and often less expensive than ordinary electrical or mechanical methods. Electronic tubes are producing results heretofore unattainable.

The thyratron fits into the electronic picture as the industrial workhorse. Applications range all the way from amplifiers of minute currents passed by a phototube, to the control of large spot welders. Thyratrons have inherent characteristics that make them ideal for the task of converting electric power from one form to another. In many applications the thyratron is the power teammate of the phototube, with the phototube giving the orders in the form of grid voltage. Sensitivity, quietness, high-speed operation, durability as rapid-duty contactors, and general adaptability to automatic operation give thyratrons an extremely wide range of usefulness.

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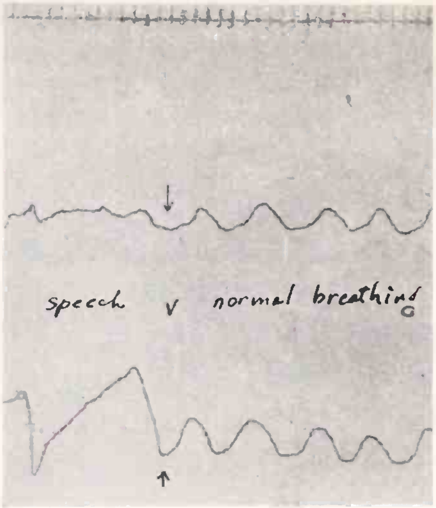

Fig. 4—Electro-kymographic record of breathing

paper 4¾ inches in width.

Typical Uses

Records of breathing made by the electro-kymograph are shown in Fig. 4. The upper line is the time line, indicating one second intervals. The middle line represents movements of the thorax at the level of the arm-pits. The lower line shows movements of the abdomen at the level of the umbilicus. The record is read from left to right. Downward direction of the line indicates inspiration. Drawn arrows indicate the point of transition from speech breathing to normal vegetative breathing. It can be seen from these tracings that rate, amplitude, direction and speed of displacement and other factors of interest to the student of respiratory movements may be easily determined.

In our uses of the machine we have not required frequencies of more than ten to fifteen cycles per second. We have not tested the upper limit of frequencies which can be recorded by this means, but there is reason to believe that several hundred cycles per second can be recorded and read satisfactorily. We have made tracings in which one hundred cycles per second were readily measurable.

• • •

More About Feedback Voltmeter

ANSWERING QUESTIONS about his "Sensitive Feedback Voltmeter With Rugged Milliameter Indicator" (ELECTRONICS, *April 1942, p. 88*) Lawrence Fleming writes: "A 1 ma meter can be substituted without making changes in the instrument. The sensitivity will be eight times greater but the stability of the zero reading will be eight times poorer. Inserting 5,000 to 10,000 ohms in series with the meter will bring both factors back to about what they are with the 8 ma instrument. Probably the best thing to do if a 1 ma instrument is available is to substitute a high mu triode for the 6J5 at V_4, adjust the total resistance in its cathode circuit so that the tube draws about 1 ma and change R_1, R_2 and P_2 so that the static potential of the junction of R_1 and R_2 is the same as that of the cathode of V_4.

"The reading of the instrument is proportional to the peak voltage of the input, whatever the waveform."

• • •

Airport Control Console

NOW IN ACTIVE SERVICE in the new tower at Miami, Florida's 36th Street airport, serving Pan American Airways and Eastern Air Lines, the traffic control console pictured embodies several interesting design ideas which simplify operation and facilitate maintenance.

The console is constructed around a welded steel frame. The desk top is made of cigarette-proof plastic. A central drawer, positioned just over the operator's knees, provides convenient space for charts. The lower edge of the console is protected by stainless-steel kick-plates. An electric clock, wind-direction indicator, wind-velocity indicator and a remote control indicating instrument may be seen on the middle sloping panel, illuminated by a fluorescent fixture equipped with a variable aperture which also lights the desk top.

Loudspeakers are mounted on sloping panels to the left and right of the instrument panel. On the sloping panel at the right, within easy reach of an operator seated at the desk, is a row of T-pad controls for adjusting receiver output levels. Five crystal-controlled, fixed-frequency receivers guard P.A.A., E.A.L., itinerant aircraft, scheduled airline and Army radio channels. These receivers are equipped with squelch circuits muting them until a carrier is received. A sixth fixed-frequency receiver monitors the MM range and receives weather broadcasts. A seventh receiver is tunable and is used for con tacting off-frequency aircraft and spe cial flights. All of these receivers ar mounted on vertical panels formin part of two racks which may be see at the left and right of the console be tween the floor and the desk top. Th racks are equipped with rollers. A pu on the handles at the bottom of eac rack rolls equipment forward withou disturbing wiring when it is necessar to replace tubes or make minor repairs

Fixed frequency receivers are read ily identified in the photograph as the are equipped with standard 3½ inc high etched panels. The tunable re ceiver may be seen at the top of th rack at the right. Space is available fo installation of three additional fixed frequency receivers, should these late prove necessary. Two would be mounte at the bottom of the rack at the righ and the third at the bottom of the rac at the left. The blank panel at th top of the rack at the left is eventuall to be used for mounting of telephon equipment.

The traffic control console was bui by the Communications Company, In of Coral Gables, Florida and incorpo ates a number of features suggested b Pan American Airways' Jimmie Wynn A 100-watt low frequency transmitte was part of the installation.

• • •

Electronic Surface Analyzer

A SURFACE ANALYZER designed by Th Brush Development Company of Cleve land makes rapid and permanent re ords of minute irregularities in the im mediate vicinity of manually selecte points on finely finished surfaces. Th record shows whether such irregu larities are above or below the surfac reference position and how much. I also indicates the number of irregular ities appearing along a relatively shor line passing through the selected tes

New radio traffic control console designed for Miami's 36th Street airport. Features include roll-out receiver racks facilitating maintenance

ALL the painstaking effort of the past quarter of a century is culminated in this supreme moment by dependability—at the "nerve center". CINCH is proud, not of one part, but many; sockets, connectors, terminal boards, lugs, tube holders, etc. All giving the best that's in them where "it will do the most good", keeping the air arm always within hearing, "Keeping them flying". Always CINCH has worked to perfect its parts to perform creditably. There is no greater reward than knowing where so much depends on the communicated signal, CINCH has a part.

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point. Sensitivity is such that surf irregularities of less than one mic inch may be recorded.

The operating principle of the a lyzer (see Fig. 1) involves the automa exploration or tracing of a short line the surface under test by means of fine point, magnification of any p pendicular motion of the point wi respect to the reference surface a recording of this motion on a movi paper chart. Three inter-connected un comprise the instrument; an analyz head, an amplifier and an oscillogra

Analyzer Head

The analyzer head consists of t component parts; a driving unit and

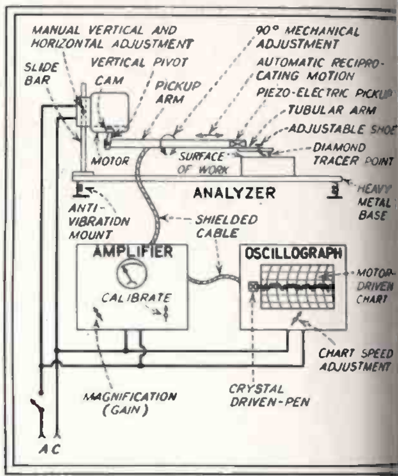

Fig. 1—Block diagram of surface analyz using piezo-electric crystal pickup an piezo-electric crystal oscillograph, ele tronic calibrating amplifier

pickup unit. The drive unit contains 110 v, 60 cps synchronous a-c mot which operates a cylindrical cam. T cam imparts a straight-line recipr cating motion to the pickup unit arm 0.060-inch long in each direction. Th motion is accomplished at a unifor velocity and one complete cycle require 10 seconds. Three mechanical adjus ments are provided. The unit may b raised or lowered in a vertical plan It may be swung in a horizontal plan And the pickup arm may be rotated u to 90 degrees about its longitudinal axi These adjustments permit the analyze head to be adapted to determination o surface irregularities in intricatel shaped parts.

The pickup arm is pivoted on conica bearings located at the drive unit, pe mitting free movement in a vertic plane. A calibrated four-ply piezo-elec tric crystal unit is mounted in the othe end of the arm. A diamond tracer poin is mechanically linked to the crystal b means of a tubular lever arm and i protected from mechanical damage by hardened steel finger which carries positioning shoe. The shoe rides over relatively large area of the surface un der test, establishing a reference leve for the tracer point and supporting th weight of the pickup arm. Scratch v

brations as low as 3 cps may be recorded.

The pickup and tracer point assembly furnished for the measurement of surface irregularities of ordinary production finishes has a sensitivity of 0.0012 volts output per micro-inch of vertical tracer point motion. Spherical radius of the tracer point is 0.0005 inch. Frequency response of the pickup unit is uniform within plus or minus 2 percent between 3 and 800 cps. (An additional pickup unit and tracer point is available for laboratory work. This assembly has a sensitivity rating of 0.0018 volts output per micro-inch of tracer point motion. Spherical radius of the tracer point is 0.0001 inch. Frequency response of the pickup unit is uniform within plus or minus 2 percent from 10 to 800 cps. Its use is recommended where anticipated scratch widths are 0.001-inch or less, as in very smooth surfaces.)

Amplifier

The amplifier is a two-stage device equipped with a calibrated step-type attenuator providing various degrees of overall surface irregularity magnification such as 40,000:1 (see Fig. 2), 4,000:1 and 400:1. A calibrating circuit is included which supplies test voltage

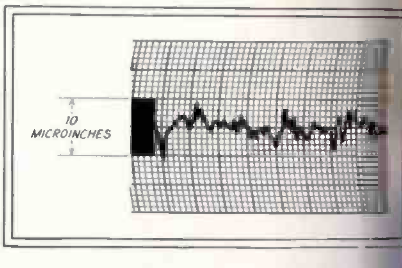

Fig. 2—Graph showing surface irregularities of honed surface. Vertical magnification is 40,000:1. Each small vertical square is 1 mm. indicating a 1 micro-inch movement of the tracer point. Chart speed was 25 mm per second, equivalent to 80:1 horizontal magnification

for adjusting the gain of the amplifier to provide any desired deflection on the associated oscillograph chart. At the most sensitive setting of the amplifier the deflection on the oscillograph chart may be as high as 1.5 millimeters per micro-inch of tracer point movement.

Frequency response of the amplifier is uniform within plus or minus 2 percent from 1 to 500 cps. Maximum voltage gain is 60,000. Maximum input voltage is 25 v peak. Maximum output voltage is 700. Input impedance is 10 megohms and output impedance 100,000 ohms.

Oscillograph

The oscillograph is of the direct-inking type with the pen actuated by a piezo-electric crystal. Thermostatic temperature control is included to insure stable crystal performance. The pen is designed for stiffness and low mass, enabling it to respond to fluctuations up to 60 cps. A maximum deflec-

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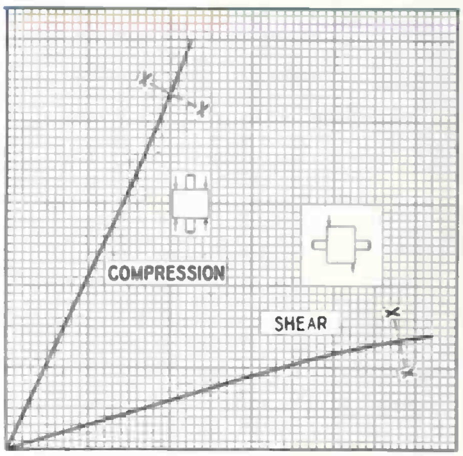
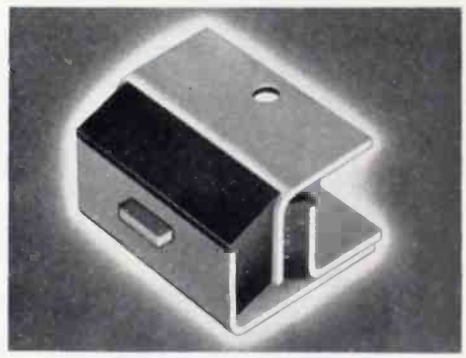
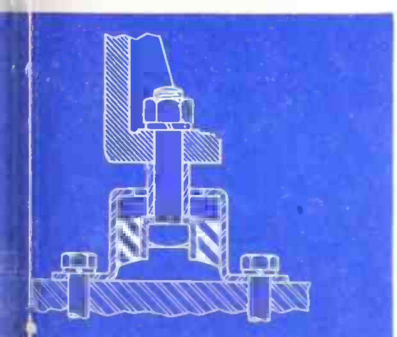
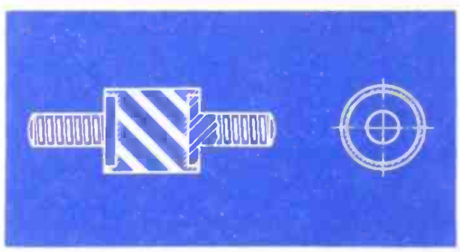
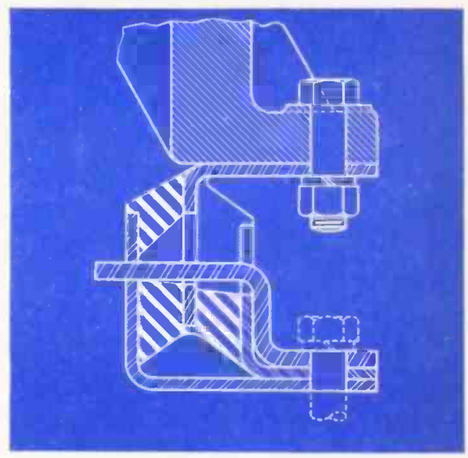


Load-Deflection Characteristics









y otecting the delicate instruments in aircraft, naval vessels, nk and other vehicles used by the Armed Forces, U. S. Royal outings are helping to maintain precision fighting efficiency.

Sh wn above are three of the standard types selected from the m rehensive line of mountings developed by the engineering aff of U. S. Rubber during many years of experience in the ia on, railway, automotive and marine fields.

If ou are faced with a problem of vibration, transmitted noise pact shock in connection with products used in the war o our engineering staff will gladly consult with you in the le on of standard mountings or in designing special mountings.

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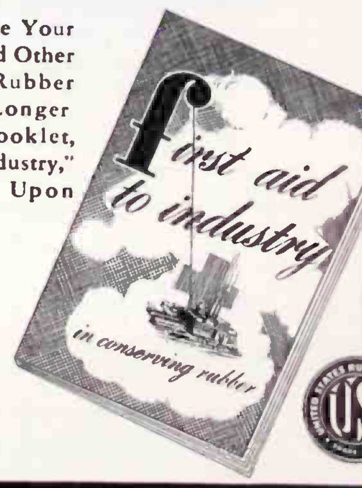

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TED STATES RUBBER COMPANY

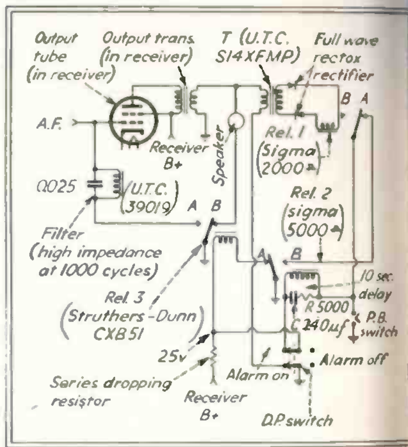
tion of 15 millimeters or about ⅝ inch each side of the zero axis is allowable.

The chart feed mechanism is driven by a 60 cps synchronous motor operating a gear train. Chart speed may be adjusted to 5 mm per second (horizontal magnification 16), 25 mm per second (magnification 80) or 125 mm per second (magnification 400). For most purposes a chart speed of 25 mm per second provides the most readily interpreted chart.

• • •

Automatic Air Raid Monitor

THE DIAGRAMMED DEVICE, designed by Lieutenant Arthur H. Vickerson and Sergeant Robert L. Gray, automatically warns Boston police transmitter operators when a local broadcast station transmits a 1000-cycle air raid warning tone. Operated by a receiver moni-



Automatic air raid monitor. The speaker is muted until a 1000-cycle warning tone sustained for 10 seconds or more is received. Announcements come through after the tone ceases

toring the broadcast station, the device keeps the receiver's loudspeaker muted during conventional programs, permitting it to operate only when the significant tone has been maintained for 10-seconds or more. Once the circuit is tripped by such a warning signal the loudspeaker continues to function, allowing subsequent aural announcements to come through until the device is manually re-set.

The circuit shows the device in the tripped condition. To place it in automatic service the push-button switch is momentarily depressed. Relay *2* is energized by d.c. flowing through its coil to ground, the armature pulling up to contact *B* and remaining in this position after the push-button is released due to the circuit established in parallel with the push-button through contact *A* of relay *1*. Opening of the circuit at contact *A* of relay *2* simultaneously breaks current flowing through the coil of relay *3* and the armature of relay *3* moves to contact *A*, disconnecting the

YOU will find these data most helpful in specifying the correct steatite ceramic insulation for your requirements. The chart eliminates guesswork and might save you many hours or days of laboratory tests.

You will also find from this chart that American Lava Corporation offers ceramic insulating materials with the widest range of physical characteristics available from any single source.

If you do not find the exact combination of physical characteristics you desire, our Research Division will be glad to work with you if you will detail your requirements. The skill of these engineers in developing special products for special purposes is favorably known to leading designers.

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CHATTANOOGA, TENNESSE[E]

loudspeaker and shunting the 10(cycle filter across the input of the ceiver's final audio stage.

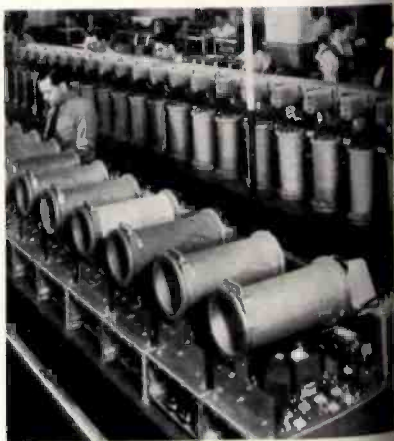
Incoming audio frequencies oth than the critical 1000-cycle warni tone are largely by-passed from t grid of the tube to ground as the filt presents a low impedance path. Th there is little audio output voltage a plied to the secondary of transform *T* when ordinary signals are receiv Between 1 and 3 volts d.c. develo across the coil of relay *1* when the d tant broadcast transmitter is normal modulated and this is insufficient cause relay *1* to pull up.

When a 1000-cycle tone is receiv the filter presents a high impedance a considerable voltage develops acr the input to the tube. D.c. potent across the coil of relay *1* rises to volts or more and causes the relay pull up. Movement of the armature relay *1* to contact *B* removes energizi current from the coil of relay *2*. Cu rent stored in capacitor *C* keeps rel *2* pulled up for 10-seconds while it le off through resistor *R* and the relay c but at the end of that delay period r lay *2* drops out. Dropping out of rel *2* energizes the coil of relay *3*. Th connects the speaker and removes t filter and the last 20-seconds of t standard 30-second warning tone heard. When the 1000-cycle tone ceas the armature of relay *1* returns to co tact *A*, restoring the alarm circuit the tripped condition shown in t diagram. This permits announcemen to come through until the push-butt is again depressed for resumption automatic operation.

The receiver may be used as a co ventional aural monitor, without t automatic muting feature, by placi the alarm switch in the "off" positi This energizes relay *3* and renders lays *1* and *2* inoperative, holding t speaker in the circuit with the inp filter removed.

• • •

ARMY EARS—OR EYES



Electronic equipment which shall be nameless rolls off the production line at a Western Electric plant in Shangri-La

PLASTICS in Electronics

(Continued from page 31)

A PHENOLIC MATERIALS (Continued)

Indur	Reilly Tar & Chemic Corp., Indianapolis, In
Insurok	Richardson Co., Melro Park, Ill.
Makalot	Makalot Corp., Bosto Mass.
Resinox	Monsanto Chemical Co., Springfield, Mass.
Templus	Bryant Electric Co., Bridg port, Conn.
Textolite	General Electric Co., Pitt field, Mass.
Michrock	Michigan Molded Plasti Inc., Dexter, Mich.
Neillite	Watertown Mfg. Co., W tertown, Conn.

B PHENOLIC MATERIALS

Durite	Durite Plastics, Phila., P

C PHENOLIC. CAST

Bakelite	Bakelite Corp., N. Y. C.
Catalin	Catalin Corp., N. Y.
Gemstone	A. Knoedler Co., Lancaste Pa.
Marblette	Marblette Corp., L. I. (N. Y.
Opalon	Monsanto Chemical Co., Springfield, Mass.
Prystal	Catalin Corp., N. Y.

D LAMINATED MATERIALS

Aqualite	National Vulcanized Fib Co., Wilmington, Del.
Cellanite	Continental Diamond Fib Co., Newark, Del.
Celeron	Continental Diamond Fib Co., Newark, Del.
Coffite	Formica Insulation C Cincinnati, Ohio
Dilecto	Continental Diamond Fib Co., Newark, Del.
Dilectene	Continental Diamond Fib Co., Newark, Del.
Duraloy	Detroit Paper Products C Detroit, Mich.
Formica	Formica Insulation C Cincinnati, Ohio
Insurok	Richardson Co., Melro Park, Ill.
Lamicoid	Mica Insulation Co., N.
Lamitex	Franklin Fibre - Lamite Corp., Wilmington, Del.
Micarta	Westinghouse Elec. & Mf Co.,
Panelyte	Panelyte Corp., N. Y.
Ohmoid	Wilmington Fibre Special Co., Wilmington, Del.
Phenolite	National Vulcanized Fib Co., Wilmington, Del.
Spauldite	Spaulding Fibre Co., Ton wanda, N. Y.
Synthane	Synthane Corp., Oak Penn.
Taylor	Taylor Fibre Co., Norri town, Penn.
Textolite	General Electric Co., Pitt field, Mass.
Ucinite	Ucinite Co., Newtonvill Mass.
Vulcoid	Continental Diamond Fib Co., Newark, Del.

(Continued on page 67)

PLASTICS in Electronics

(Continued from page 64)

: UREA

Bakelite	Bakelite Corp., N. Y.
Beetle	American Cyanamid Co., N. Y.
Cibanoid	Ciba Corp., N. Y.
Plaskon	Plaskon Co., Toledo, Ohio
Jformite	Resinous Products & Chemicals Co., Philadelphia, Pa.

CELLULOSE ACETATE BUTYRATE

Tenite II	Tennessee Eastman Corp., Kingsport, Tenn.

; POLYSTYRENE

Bakelite	Bakelite Corp., N. Y.
‚oalin	Catalin Corp., N. Y.
‚ustron	Monsanto Chemical Co., E. Springfield, Mass.
tyron	Dow Chemical Co., Midland, Mich.

CELLULOSE ACETATE

Bakelite	Bakelite Corp., N. Y.
ellulate	National Plastics Co., Detroit, Mich.
ibestos	Monsanto Chemical Co., E. Springfield, Mass.
emloid	Gemloid Corp., N. Y.
umarith	Celanese Celluloid Corp., N. Y.
lacite	Manufacturers Chemical Corp., Jersey City, N. J.
ixonite	Nixon Nitration Works, Nixon, N. J.
lastacele	E. I. du Pont de Nemours & Co., Arlington, N. J.
enite I	Tennessee Eastman Corp., Kingsport, Tenn.

ACRYLICS

rystalite	Rohm & Haas, Philadelphia, Pa.
ucite	E. I. du Pont de Nemours & Co., Arlington, N. J.
exiglas	Rohm & Haas, Philadelphia, Pa.

ETHYL CELLULOSE

hocel	Dow Chemical Co., Midland, Mich.
ercules	Hercules Powder Co., Wilmington, Del.

VINYLS

var	Shawinigan Prod. Corp., N. Y.
itacite	E. I. du Pont de Nemours & Co., Wilmington, Del.
tvar	Shawinigan Prod. Corp., N. Y.
rmvar	Shawinigan Prod. Corp., N. Y.
lva	Shawinigan Prod. Corp., N. Y.
roseal	B. F. Goodrich Co., Akron, Ohio
ylite	Carbide & Carbon Chemical Corp., N. Y.

VINYLIDENE CHLORIDE

Sran	Dow Chemical Co., Midland, Mich.

THE ELECTRON ART

Direct Reading Densitometer

ONE OF THE MOST ANNOYING (if not difficult) applications of the use of phototubes is in the measurement of density in photographic laboratories. The difficulty arises from the fact that density (like the decibel) is a logarithmic ratio of the quantities normally encountered, and for a relatively small density range, the ratio of light intensities which must be compared become quite appreciable. The difficulty of course, is that human responses are, to a first approximation at least, a logarithmic function of the stimulus, whereas the response of most measuring instruments is frequently linear and can be made logarithmic only with proper design and care.

A particularly simple, and apparently effective method of using a phototube to measure light intensities whose ratios vary over a range of 1,000 to 1 (giving a range of densities from 0 to 3) is described by Monroe H. Sweet in the February 1942 issue of the *Journal of the Society of Motion Picture Engineers*. Features of this instrument are the freedom of fatigue since all optical measurements are made by means of a phototube rather than by means of the human eye, the use of a logarithmic amplifier which, incidentally produces a linear density scale, and the large meter with direct reading dial calibrated directly in terms of density rather than in terms of light transmission ratios. The instrument is a-c operated through use of a type 80 rectifier, and requires only one 6F5 tube in addition to this rectifier (and its regulation tube) and the 929 phototube. The cost of the densitometer is relatively low, and tests indicate that when properly constructed and calibrated, high precision is attained over a long period of time.

The heart of the densitometer, and the cause for its success, is the logarithmic amplifier used in conjunction with the linear vacuum type phototube. The development of the amplifier circuit may be seen from Fig. 1, in which the cathode of the phototube is connected directly to the grid of a triode. Light falling on the phototube will create grid current and the potential of the grid will tend to become positive. This gives rise to an increase of plate current which is measured by the appropriate meter in the plate circuit of the triode. According to the author the following relationships apply:

1. Light on the phototube is a linear function of the light transmitted by the sample of film under measurement.
2. The phototube current is a linear function of the incident light.
3. The phototube current is equal to the grid current.
4. The grid potential is a logarithmic function of the grid current. The author does not show how this is arrived at, although this problem is analyzed by Tiedman in the March 1941 issue of ELECTRONICS, and by J. Russell, in the December 1937 issue of the *Review of Scientific Instruments*.
5. The plate current is a linear function of the grid voltage since the tube is operated as a Class A ampilfier; it is therefore a logarithmic function of the phototube current.

The phototube circuits of Fig. 1 operate in accordance with these principles. The top diagram produces an approximately logarithmic relation between density of the film and the plate current, but the relationship can be made more nearly linear, except for very small light intensities (corresponding to high film densities or very low values of plate current) by the modification shown in the center diagram. The improvements in the lower diagram permit a linear plate current response for a density range of from 0 to 3 when the grid resistor is properly selected. The use of this grid resistor straightens the response of the instrument at high densities or low values of grid current, by providing a current which opposes the phototube grid current. This bucking current is of the order of 10^{-8} ampere which is negligible compared with the phototube current of 20 microamperes for measuring 0 density. However, this current becomes an appreciable portion of the phototube grid current for densities above about 2.5 and therefore may be used to straighten the response at high densities.

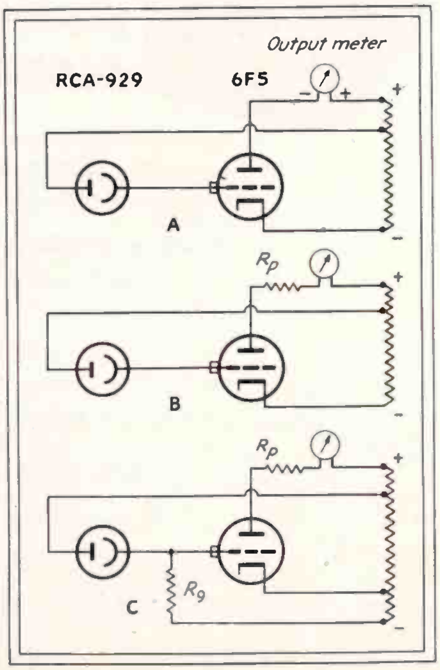


Fig. 1—Three circuits providing more or less logarithmic response to light. By adjustment of R_g, logarithmic response over ratio of 1000 to 1 is obtainable

The complete schematic wiring diagram of the direct-reading densitometer is shown in Fig. 2. Although no circuit constants are given, the proper operation of a triode merely necessitates that suitable voltages be applied to its elements. These are obtained from the transformer and rectifier-filter arrangement which is also provided with a voltage regulator tube. The only critical portion of the entire circuit, is the appropriate value of the grid resistor, which is probably in the neighborhood of several tens of megohms or more. The correct value must be determined either experimentally, or from the tube design data for low values of plate current.

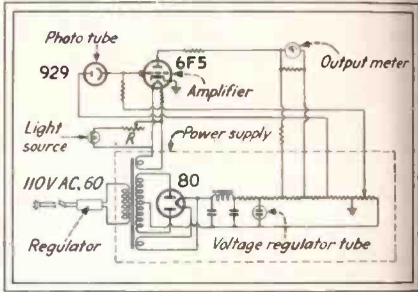
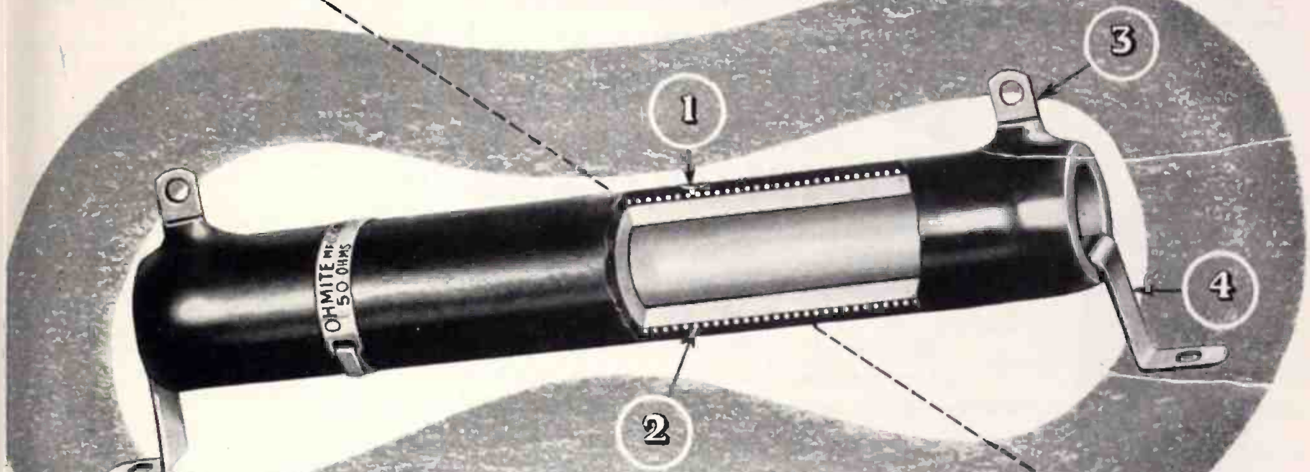


Fig. 2—Working circuit of linear densitometer using phototube to measure light

The phototube, grid resistor and triode, which should have an external cap for the grid, are mounted in a metal cylinder which serves as the measuring arm of the densitometer. These three units are mounted in close proximity to one another to reduce to a minimum the possibility of leakage. Although no mention is made of the difficulties of measuring small phototube currents, the usual precautions against leakage and the accumulation of dust or moisture on circuit parts connected to the grid circuit should be taken if trouble is to be kept to a satisfactory minimum.

Reproducibility, stability, drift, and other factors are shown by the author to have a negligible influence on the accuracy of the instrument, and the instrument of this design has been used in commercial testing of films for several months at the Agfa Ansco Research Laboratory in Binghamton, N. Y.

OHMITE RESISTORS
Engineered for Exacting Electronic Equipment

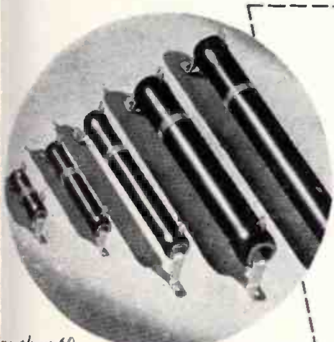


X-Ray Photo Shows Evenness of Winding

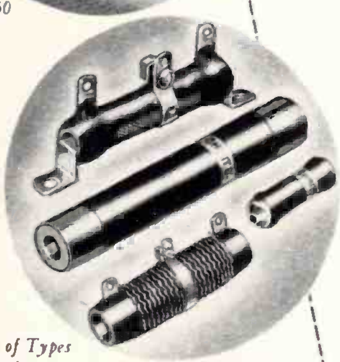
THE cut-away view shows several of the outstanding features of one of the most widely used Ohmite Resistors.

1. The resistance wire is wound on a ceramic core. Ohmite Vitreous Enamel holds the wire rigidly in place—insulates and protects the winding—dissipates heat rapidly—withstands humidity.
2. The evenness of the winding, shown in the x-ray photo, prevents "hot spots" and failures—and makes for long, reliable service on the job.
3. The resistance wire is both mechanically locked and brazed to copper terminal lugs, assuring perfect electrical connection between lugs and wire. The lugs are tin-dipped for ease in soldering the connecting wires.
4. The mounting brackets hold the resistor firmly yet resiliently in place. They are easy to mount—easy to remove.

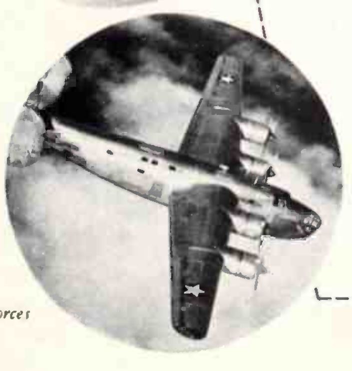
More than sixty different core sizes make possible an almost endless variety of regular or special resistors to meet every need. Core sizes range from 2½" diameter by 20" long to 5/16" diameter by 1" long. Wattages range from 1 to 1500 watts—Resistances, from a fraction of an ohm to 250,000 ohms. Available in fixed, adjustable, wire or flexible lead, tapped, ferrule, Edison base, bracket, cartridge, strip, precision, non-inductive and other types. Ohmite Engineers are glad to help you on any resistor problems in connection with Governmental or Industrial requirements.



...re than 60 ...Sizes



...le Range of Types ...Every Need



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Time Bases

MUCH HAS BEEN DONE in the design (time base generators for use with cath ode-ray tubes since the early days of th Abraham and Block's multivibrato O. S. Puckle surveys this field in a article in the December, 1941 journal o *The Institution of Electrical Engineer* (British publication). The article i called "Time Bases."

Of the many time base generator certain ones have unusual possibilitie Of these is one developed by the autho and shown in Fig. 1. This generator i

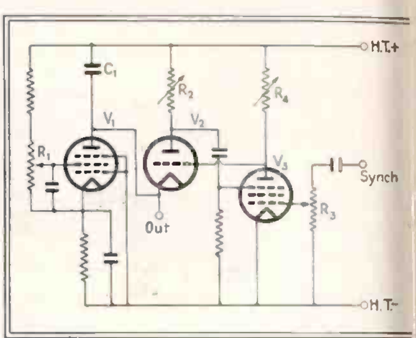


Fig. 1—Puckle's time base circuit

capable of generating a saw-toothe wave at frequencies up to one mega cycle. In this circuit, condenser C_1 in creases its charge until its potential i great enough to allow plate current t flow in triode V_2. The voltage drop no developed across the small variabl trigger resistance R_2 is impressed o the suppressor grid of V_3 which has it anode directly coupled back to the gri of V_2. In this way, the two tubes re

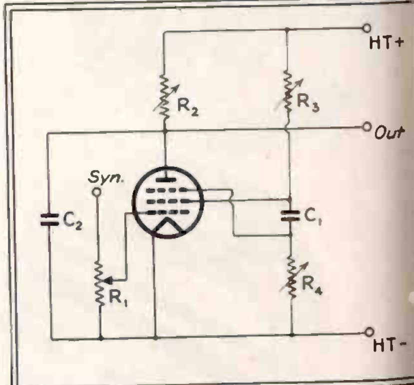


Fig. 2—Fleming-Williams time base circuit

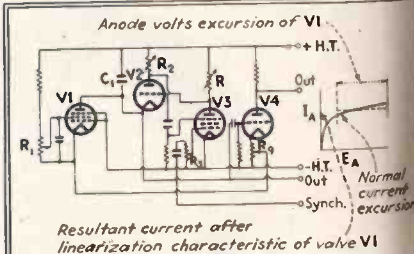


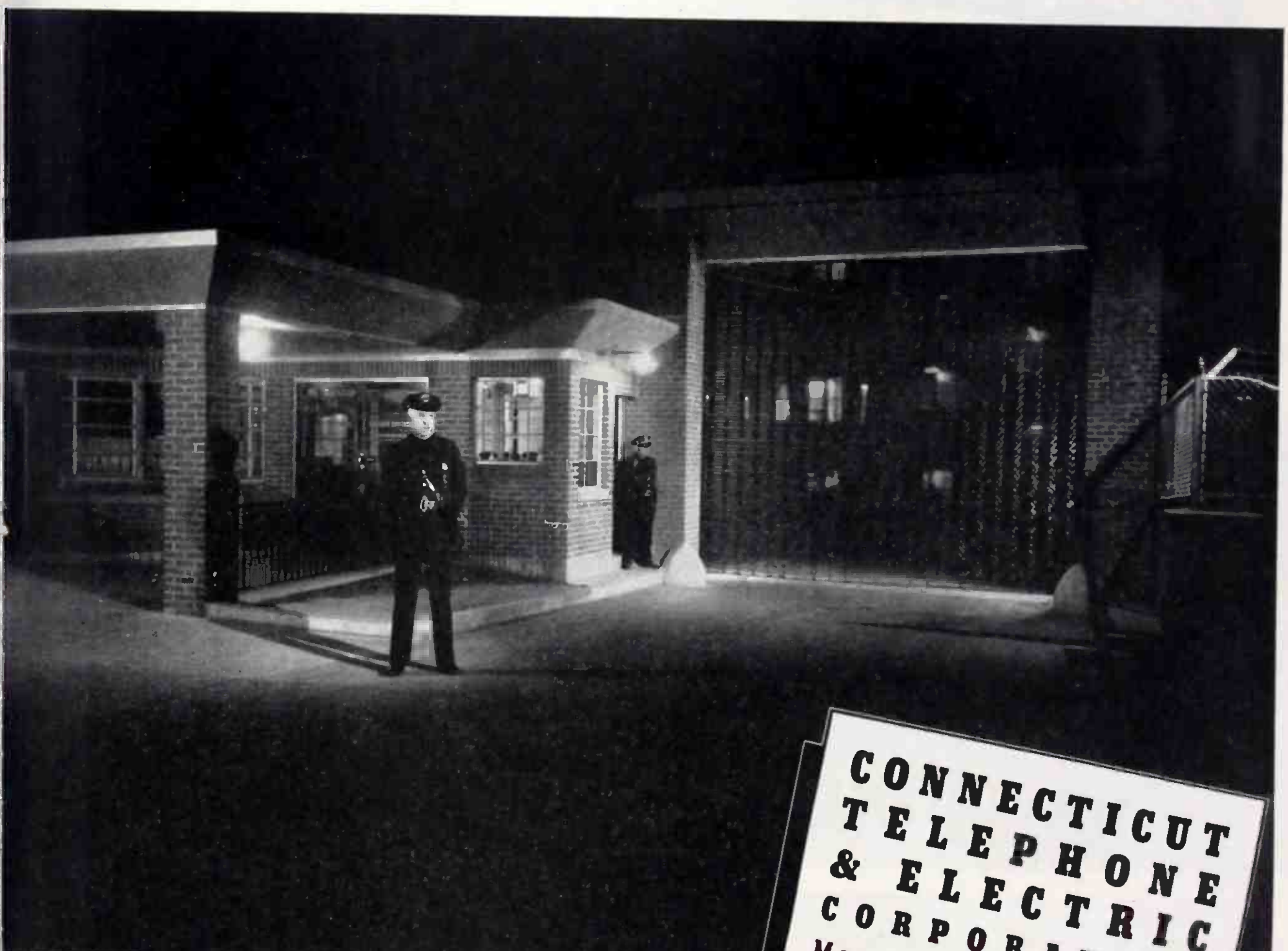
Fig. 3—Bedford's circuit for linear time base

The right to be remembered must be earned

These are times when everyone's highest privilege is to serve in every way he can. It is not pleasant to turn one's back on old friends, but this is not the day for half effort or equivocation.

We count ourselves fortunate that we have a substantial contribution to make. *Connecticut's* skill in precision electrical engineering and manufacturing has been developed since the early days of the telephone. Its experience in the manufacture of military materiel extends back through the first World War. Its engineers are seasoned in assisting Army and Navy experts. It is geared for mass production with laboratory precision, thus speeding our war effort by minimum waste of time and materials.

And so once more we find ourselves working behind forbidding barriers, surrounded by alert guards, thinking wholly in terms of all-out effort for victory. This does not mean that our peacetime customers have been forgotten. To the contrary, we feel that in giving everything we have to the largest job in American history, we can best earn the right to be remembered when peace is won.



CONNECTICUT TELEPHONE & ELECTRIC CORPORATION
Meriden Connecticut

Research, Engineering, Precision Manufacturing

produce the threshold effect of a g triode but haven't any of its disadva tages. The amplitude of the sweep c cuit voltage is controlled by the varia resistor R_4. It is of interest to note th approximately square waveform vo age pulses can be obtained from t drops across R_2 and R_4. A single tu time base circuit developed by Flemin Williams is shown in Fig. 2.

The Bedford circuit, shown in F 3, is one of the many circuits develop for improving the linearity of the sa toothed time base wave. This circ requires the use of the potentiomet R_0 which must be adjusted for best o eration of the generator. Another l ear time base generator is that of t Jenkin's circuit shown in Fig. 4. Th

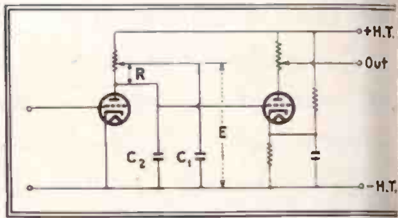


Fig. 4—Jenkin's method of linearizatio

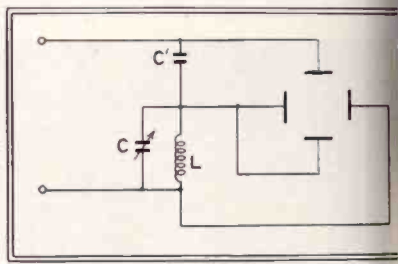


Fig. 5—Circular time base using a tune circuit

circuit requires a square wave im pressed voltage and the correct settin of resistance R. The condenser C_1 mu have sufficient capacity to hold t voltage across it constant. Time ba condenser C_2 is charged and discharg as the grid potential is decreased an increased respectively.

A circular time base has many use in particular when the potential to examined is connected in series with th d.c. potential to the final anode of th cathode-ray oscillograph. A useful ci cuit for generating a circular time ba when the source voltage is impure shown in Fig. 5. The parallel coil co denser combination is first set for reso

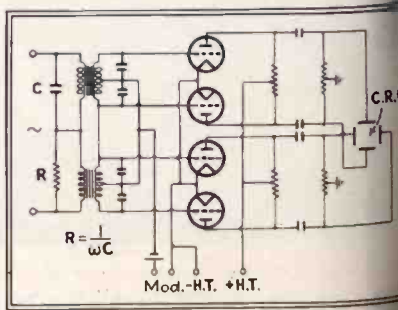


Fig. 6.—Circular time base

Another Eimac Achievement

Illustration shows typical application of electromagnet actuating coil to Vacuum Relay. In certain installations outside flash-overs are eliminated by use of ball type connectors.

Solves a Tough Electrical Problem

Handling 20,000 volts RF potential with this Eimac vacuum relay is as easy as turning on your living room lights.

Over two years ago Eimac engineers developed this strange looking vacuum tube which has been seeing service ever since. It is a single pole double throw relay used for many high voltage switching applications. Although the contact spacing is only .015", no arc-over is experienced inside the tube. Changes in air pressure and humidity, such as encountered in aviation, have no effect on the breakdown within the relay, because the contacts are in vacuum. Actually a flash-over will occur across the outside terminals before breaking down within. A tribute to the high degree of vacuum attained on Eimac pumps.

This development is a direct outcome of the far-reaching advancements made possible through the Eimac technique of vacuum tube construction. A typical example of why Eimac transmitting tubes are first choice of leading engineers throughout the world.

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Eimac
VACUUM RELAY

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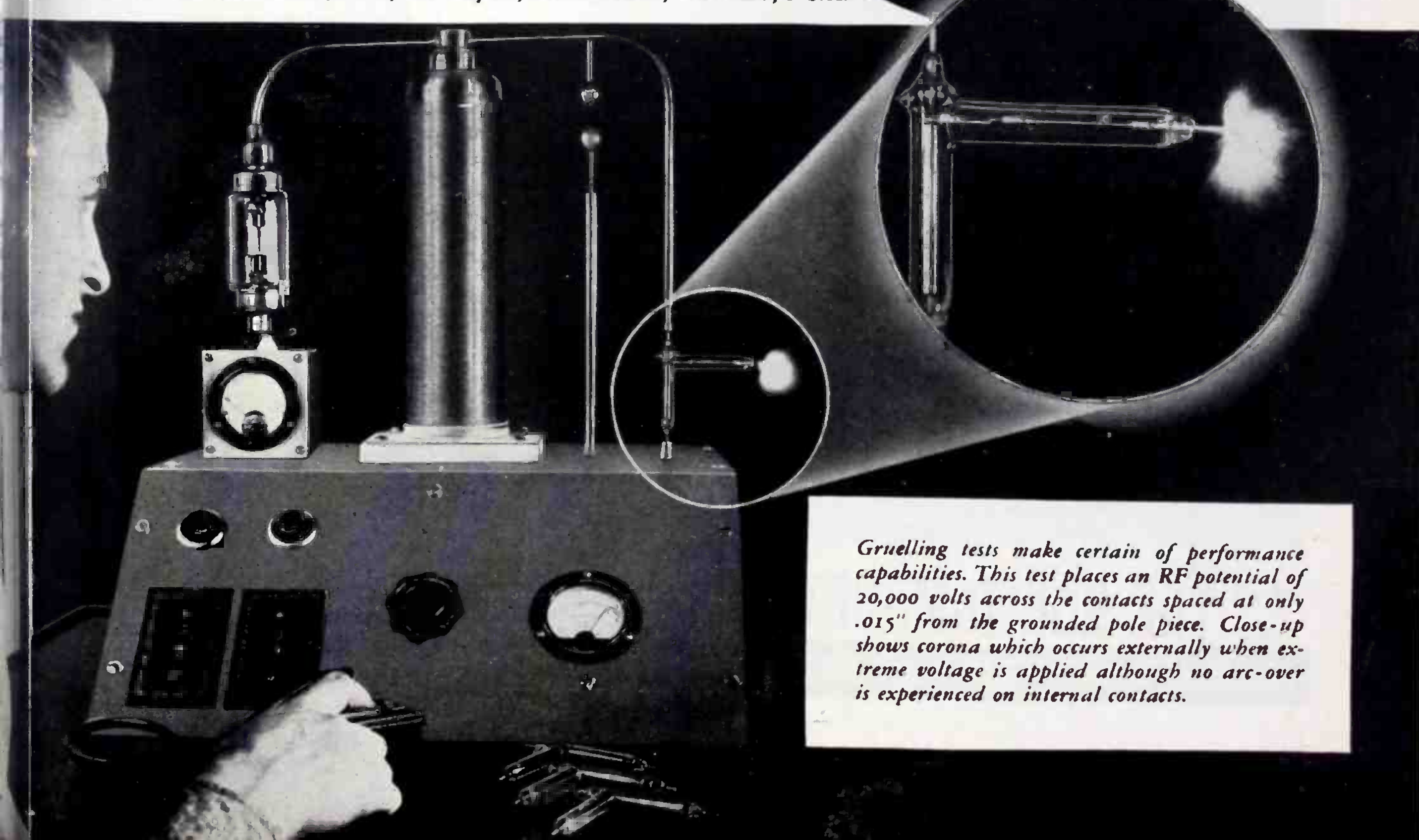
San Bruno, California, U. S. A.
xport Agents: FRAZAR & CO., LTD., 301 Clay St., San Francisco, California, U. S. A.



Gruelling tests make certain of performance capabilities. This test places an RF potential of 20,000 volts across the contacts spaced at only .015" from the grounded pole piece. Close-up shows corona which occurs externally when extreme voltage is applied although no arc-over is experienced on internal contacts.

ance and then C' is adjusted until circular pattern appears on the scre. A more involved circular time base ge erator is shown in Fig. 6. Here t potential to be examined is connect to the grids of the four tubes.

Mr. Puckle's I.E.E. paper deals w the development of various types time bases using both hard and s tubes, for both general and specific a plications. The purpose of the paper to elucidate the principles involved in wide variety of known time base c cuits rather than attempt to deal wi descriptions of actual instruments. a general survey article, this is qu a complete and comprehensive pap and contains a bibliography of twent two articles, mostly European.

High Speed Oscillography

A SHORTAGE OF electronic apparat for research in private industry exi because of the present war needs. Th can be overcome to some extent by designing outmoded equipment to co form to modern specifications. A design of an early model General El tric cathode-ray oscillograph of t cold-cathode type is described in a pap entitled "Developments in High Spe Oscillography." The article was writt by J. M. Bryant and M. Newman a appears in the *Engineering Exper mental Station Technical Paper No.* published by the University of Minn sota.

In redesigning this equipment, th following are some of the more impo tant changes and additions: A ne cathode-tube with a removable catho assembly to permit polishing and r

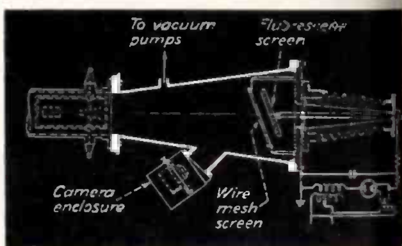
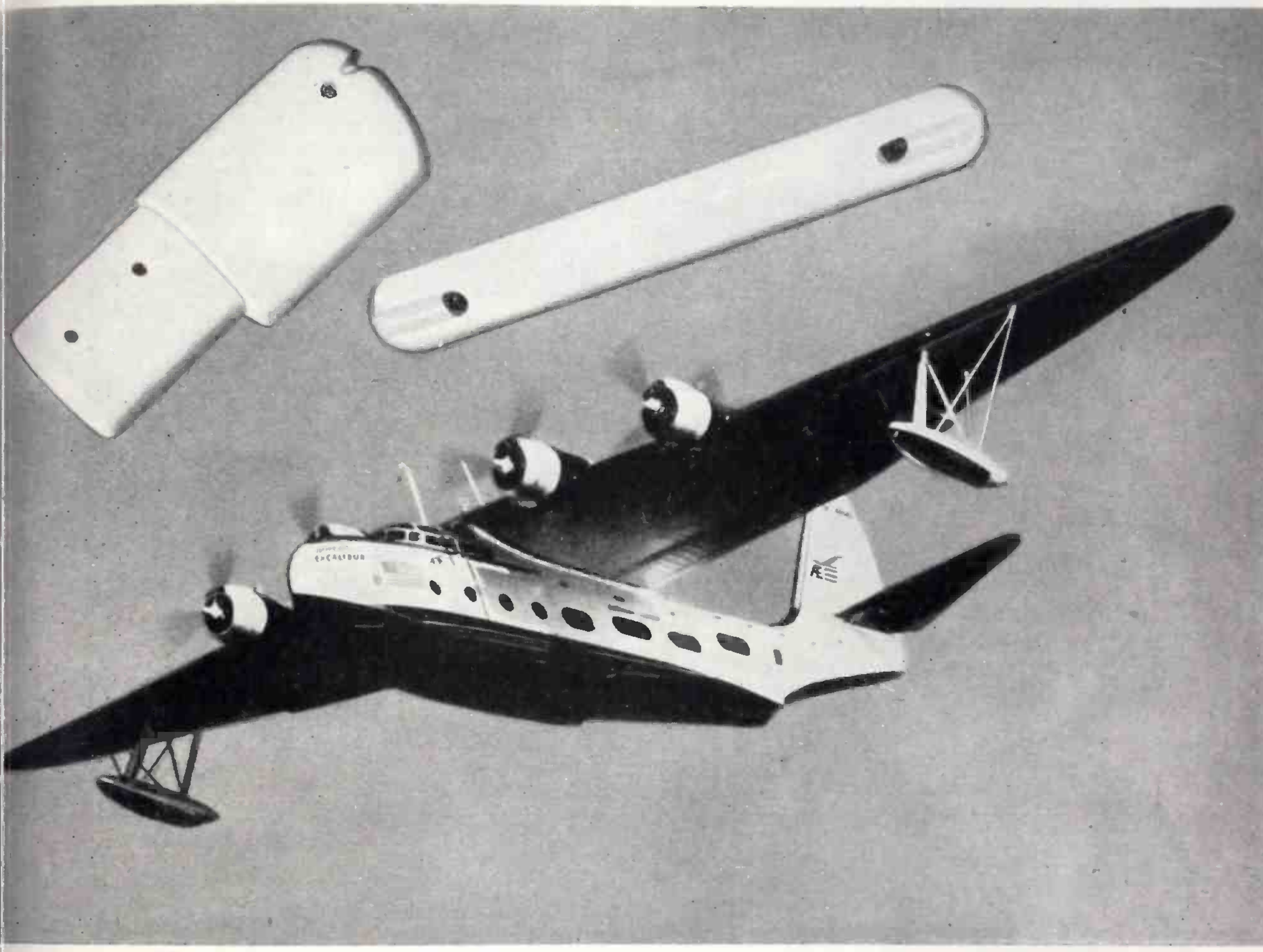


Fig. 1.—Connections for additional accelerating potential for high speed oscillograms

pairing; a differential vacuum syste which permits a higher vacuum in th discharge tube than in the deflectio and recording chambers; a larger de flection tube; a removable deflection an sweep circuit assembly; the use of bot a focusing and refocusing coil; an ad dition of an outside camera mounted s as to take pictures of phenomena de picted on the fluorescent screen; an faster sweep and time calibration cir cuits.

These features plus an additional ac celerating potential between the anod and the fluorescent plate as shown i Fig. 1 have increased the writing spee to one-fifth of that of light. It is pos sible to take oscillograms for a time in terval of less than one microsecond.



Rheotron or Induction Accelerator

IN FEBRUARY ELECTRONICS was pub-lished a brief description of a new elec-tronic tool originally developed by Dr. Donald W. Kerst at the University of Illinois and later further developed at the General Electric Research Laboratories. Further data on the device, which speeds electrons just as the cyclotron speeds positive particles, were published in the *Physical Review*, 6… 1941 and 60, 53, 1941. The following material is taken from the *Journal of Applied Physics*, January 1942, … 14. Dr. Kerst, incidentally, does not wish his electron accelerator to be known by the term "rheotron" but rather as a "betatron". At the University of Illinois, he states "an energetic group of graduate students is proceeding with experiments in nuclear physics" by means of the betatron installed in the … power plant there.

"A glass tube perhaps 5 cm across in the shape of a ring about 20 cm in diameter (i.e., shaped like an American doughnut) surrounds the closely spaced pole pieces of a laminated magnet excited by a 600-cycle current. Electrons liberated from a filament near the … wall of the evacuated tube are accelerated in gradually contracting orbits to a circle of predetermined ra… within the tube until they strike a target. The magnetic field between the magnet poles is not meant, at any instant, to be uniform. It must … radially in such a way that electrons which happen to be circling a little too far out or a little too far in are brought quickly back to the proper orbit. … find out how the ring of moving …

• • •

LEARNING THE HARD WAY

To prepare the students in Montreal, Canada, for their first flight across the Atlantic, students must attend school where they are taught to receive and send radio messages


Somewhere-Everywhere
Our fighting men are receiving combat orders and reporting progress via two-way radio. And the success of the operations and the lives of the men depend upon efficient coordination between services.
JEFFERSON-TRAVIS is justly proud of the record for dependability that our field units are establishing. Two-way radio communication equipment must not fail.
BUY WAR BONDS AND STAMPS!
Our officers and employees have ALL subscribed to the Treasury Department Pay-Roll Savings Plan. Here too, our effort is 100%.
JEFFERSON-TRAVIS RADIO MFG. CORP.
NEW YORK, N. Y.
Manufacturers of Aircraft, Marine and Mobile Radio Communication Equipment

trons is finally made to deviate from its circular path to strike get, the reader must turn to the paper. We can merely indicate is accomplished by having certai of the poles reach saturation others. The design of the magn trols the success or failure of strument.

During each revolution the el are accelerated by an amount e the instantaneous emf which wo induced in a wire placed at the p of the orbit. The acceleration i pleted during the first quarte while the field is increasing, b electron speeds are so high tha haps 100,000 revolutions are p in this time, before the electrons the target. During the third qu cycle, acceleration of the electron ceeds in the reverse direction, s the target, bombarded from both will emit x-rays intermittently times per second, but with a n spatial asymmetry. Currents t target in the Illinois instrumen about one-thirtieth microampere Mev (million electron volts). T duction accelerator is a pron source of high energy photons when some mechanical difficulties been overcome, the electron bean be brought out of the accele chamber to provide a strong sou electrons for nuclear investiga and it may soon be possible to cate some low energy cosmic-ray nomena under controlled conditio the laboratory."

• • •

RADIO DIRECTS RAI TRAFFIC AT ARMS PLA

C. K. Tummel is shown using one of FM radio telephones that have been stalled in the eight locomotives of Elwood Ordnance Plant's private railro system. By means of radio the loco tives are kept in constant communicati with the dispatcher's tower, increasi efficiency and reducing the possibility accidents

Television in National Defense

TELEVISION HAS BEEN applied t successful training of the 200,00 unteer workers in the City of York. The April 1942 *Radio A* scribes the method of presentati an article entitled "Raid Traini Television."

Faced with the necessity of tr an army of volunteer air raid wa the New York City Police Depar accepted NBC's suggestion that utilize television. Now volunteer dens in New York City, New J Connecticut, Philadelphia and Schenectady receive their tra simultaneously over the air wave

After a convincing test broa officials accepted the offers of the Mfg. Co., General Electric, and DuMont Laboratories to deliver, of charge, receiving sets from stock on hand. These sets have installed in police precinct st houses all over New York City. program originates over W NBC's pioneer television station, a received direct in New York City, Jersey and Connecticut, by relay b casts over WPTZ in Philadelphia over a television transmitter in nectady, six times daily on the three days of the week.

The course consists of six lesson cluding a formal lecture, a staged formance of an air raid warden ticing his duties in directing p trians to shelter and stopping t during an imaginary raid, and a monstration of correct procedure ing a bombing. Television per standardized training and elimi all chance of confusion from two interpretations. Dramatization diagrams, accompanying the lect clarify all problems and make definite impressions. It also result greater economy, since only one structor is needed for all.

Air raid warden courses, howe are just the beginning. Special courses for fire watchers, nurses, d ers and other defense workers follow.

• • •

SWISS ARMY

Swiss anti-aircraft battery in action wi telephone operator receiving and fo warding orders and sound detectors operation

Metal-Coated Mica Condens

AN INTERESTING ARTICLE on the meth of depositing metallic films for met coated mica condensers and their pacitance stabilities appears in March, 1942 issue of the British pe odical, *Journal of Scientific Instrume* It is "Notes on the Preparation Properties of Metal-Coated Mica C densers" by J. D. Craggs.

The author discusses the cath sputtering and the condensation vacuum methods of metallic film positing. He found that mica conden of this type give capacitance stabil of better than one part in a thous

With the increased demands on quality of component parts, as a re of wartime requirements, any me to increase the stability is worth ing. This article is particularly in esting since certain phases of technique of construction is given this article.

Solder Fluxes

IN THE MARCH 1942 pamphlet of *and its Uses*, a review issued by Tin Research Institute, H. C. Watk reports on "Improved Solder Flux" as follows:

A satisfactory lactic acid flux wh only leaves a trace of residue afte soldering operation, and is non-c rosive on copper and copper alloys has only a slight effect on steel and t plate contains:

Lactic acid	15%	(by volume
Casolene oil	0.2%	"
Water	84.8%	"

A resin + aniline hydrochloride f which may be used both in hand dip-soldering operations and leaves corrosion in the soldering of copp copper-base alloys and tin plate but not recommended for use in sealed instruments having steel parts si the residual chloride vaporizes su ciently to produce a slight trace of r contains:

Resin	20%	by weig
Aniline hydrochloride	1%	"
Methylated spirit	79%	"

Care must be taken to avoid inhali the vapor as it is poisonous.

A non-corrosive flux leaving a n greasy residue for use in soldering t plate contains:

Resin	20%	by weig
Lactic acid	5%	"
Methylated spirit	75%	"

Another improved solder flux th may be produced in a syrup like form heating the resin and mannitol wi lactic acid dissolved in methyla spirit and allowing the product to c contains:

Resin	48%	by weig
Mannitol	12%	"
Lactic acid	10%	"
Methylated spirts	30%	"

PERIODIC WAVE FORM ANALYSIS

(*Continued from page* 48)

timing is then more precise. The important point is that the leading edge of the pulse (the left edge which occurs earlier in time) should be as steep as possible where it intersects the saw-tooth trace. In the preceding figures, positive poled pulses will generally be coupled to a grid to effect synchronization as indicated on the drawings of Figs. 8 and 9.

As shown in Fig. 3 the current through a condenser is of impulse form if the voltage across it is a saw-tooth. Hence a small resistor in series with the charging condenser in any of the relaxation circuits shown will be a source of pulse voltage. Thus in Fig. 11, two oscillators of the form shown in Fig. 4 are synchronized by this method so that the lower oscillator operates at a submultiple of the frequency of the upper one. The illustration is for a 3 : 1 division. The time constant of the lower oscillator will be chosen so that its natural periodicity is slightly lower than the desired frequency, whereby the upper oscillator may pull it into sync. Where a large ratio division of frequency is desired it is preferable to divide in steps of small ratio and thus avoid errors due to power supply fluctuations. Thus a series of synchronized relaxation oscillators known as a dividing chain is frequently employed in television, for example in television transmitters to fix the relation between the line and field scanning frequencies.

A related type of synchronizing is employed in the counter type of dividing circuit of which Fig. 12 is an example. Inspection will show that the circuit employs the elements of Fig. 8 above. However, the *RC* circuit is in the ground side of the grid circuit and *R* is a diode which is biased by the battery so that normally it will not pass current. Assuming a point in the cycle where the tube has just ceased to pass current, we note that the condenser *C* is charged with the polarity indicated but that the charge cannot leak off since the only discharge path is through the diode which is opposed by the battery bias. Now we apply a signal of negative pu[ls]es across the small resistor *r*, as sho[wn], we shall have an increment of [dis]charge of *C* during the occurre[nce] of each pulse until the grid volt[age] level permits the circuit to relax [an]d recharge *C*. The choice of cir[cuit] constants will of course determ[ine] the number of pulses required [to] discharge *C*. Here the timing of [the] synchronizing pulses is immater[ial]. But the amplitude and duration [of] each pulse does affect the amo[unt] of each increment of discharge. [F]or similar synchronizing pul[ses] each increment of discharge will [be] slightly less than the preceding [one] so that the voltage across *C* will [ap]pear as an exponential series [of] voltage steps. A somewhat hig[her] order of division may be achie[ved] with a carefully designed coun[ter] circuit.

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TRAINING FOR A HERO

Sgt. Joseph Lockhard (left), who gave a[n] unheeded air raid warning at Pearl Ha[r]bor on Dec. 7th is shown en route to Fo[rt] Monmouth, N. J. where he will attend th[e] officers' training school

Industrial Tubes

Type WL-608

Westinghouse

KENOTRON; high-vacuum, half-wave rectifier; glass envelope; oil cooled; overall height 14¾ inches (max); diameter 5⅛ inches (max).

E_f = 10 v
I_f = 10 amp
Peak Inverse Anode Voltage
= 60,000 v (max)
Peak Anode Current
= 0.20 amp
Avg Anode Current = 0.06 amp

Type WL-612

Westinghouse

KENOTRON; high-vacuum, half-wave rectifier; glass envelope; air cooled; overall height 25$\frac{3}{32}$ inches (max); diameter 6⅛ inches (max).

E_f = 10 v
I_f = 50 amp
Peak Inverse Anode Voltage
= 150,000 v (max)
Peak Anode Current
= 0.75 amp
Avg Anode Current = 0.24 amp

Type WL-613

Westinghouse

KENOTRON; high-vacuum, half-wave rectifier; glass envelope; air cooled; overall height 19 inches (max); diameter 5⅛ inches (max).

E_f = 11 v
I_f = 10 amp
Peak Anode Current
= 0.20 amp
Avg Anode Current = 0.06 amp

Type WL-456

Westinghouse

KENOTRON; high-vacuum, half-wave rectifier; glass envelope; air cooled; overall height 18¾ inches (max); diameter 5⅛ inches (max); flexible leads.

E_f = 11 v
I_f = 20 amp
Peak Inverse Anode Voltage
= 140,000 v (max)
Peak Anode Current
= 0.20 amp
Avg Anode Current = 0.06 amp

Type WL-660

Westinghouse

KENOTRON; high-vacuum, half-wave rectifier; glass envelope; air cooled; overall height 32⅞ inches (max); diameter 6⅛ inches (max).

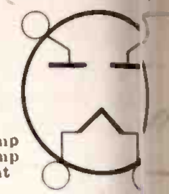
E_f = 10 v
I_f = 10 amp
Peak Inverse Anode Voltage
= 230,000 v (max)
Peak Anode Current
= 0.10 amp
Avg Anode Current = 0.30 amp

Type WL-669

Westinghouse

PHANOTRON; mercury-vapor, full-wa[ve] rectifier; glass envelope; overall he[ight] 6 inches (max); diameter 2⅛ inc[hes]; 4-pin base.

E_f = 2.5 v
I_f = 12 amp
Tube Voltage Drop
= 9 v (approx)
Peak Inverse Anode Voltage
= 1000 v (max)
Peak Anode Current = 3.1 amp
Avg Anode Current = 2.0 amp
Temperature Range, Ambient
= 20—55° C



WL-669
WL-670

Type WL-670

Westinghouse

PHANOTRON; mercury-vapor, full-wa[ve] rectifier; glass envelope; air coo[led]; overall height 7½ inches (max); di[am]eter 3⅛ inches; 4-pin base.

E_f = 2.5 v
I_f = 24.0 amp
Tube Voltage Drop
= 11 v (approx)
Peak Inverse Anode Voltage
= 1000 v (max)
Peak Anode Current
= 9.5 amp (max)
Avg Anode Current = 6.0 amp
Temp Range, Ambient
= 20—55° C

WL-669
WL-670

Type WL-786

Westinghouse

PHANOTRON; mercury-vapor, half-[wave] rectifier; metal envelope; overall h[eight] 19½ inches (max); diameter 4⅛ in[ches] (max); flexible leads.

E_f = 2.5 v
I_f = 100 amp
Tube Voltage Drop (approx)
= 10 v
Peak Inverse Anode Voltage
= 1500 v (max)
Peak Anode Current
= 150 amp
Avg Anode Current
30 amp (max)
Temp Range, Condensed Mercury = 20—70° C

Type WL-679

Westinghouse

IGNITRON; high-peak-current, pool-[cath]ode tube; water cooled; for rec[tifier] service; metal envelope; overall h[eight] 19 inches (max); diameter 4¼ i[nches] (max).

Nominal D-C Voltage Output
= 600 v
Peak Forward and Inverse
Voltage = 2100 v
Avg Anode Current = 100 amp
Peak Anode Current
= 600 amp
Ignitor Voltage (typical)
= 150 v
Ignitor Current (typical)
= 40 amp (max)

Type WL-651

Westinghouse

IGNITRON; high-peak-current, pool-cath- ode tube; water cooled; for welding service; metal envelope; overall height 18 inches (max); diameter 4¾ inches (max).

Supply Voltage (rms) = 400—500 v
Peak Inverse Voltage = 720 v (max)
Demand = 1200 kva
Avg Anode Current = 14.0 amp (max)
Peak Current at Max Avg Anode Current = 1130 amp (max)
Peak Anode Current = 3400 amp
Avg Current at Max Peak = 75.6 amp
Averaging Time = 7.1 sec (max)
Ignitor Voltage (typical) = 200 v
Ignitor Current (typical) = 25 amp

Type WL-652

Westinghouse

IGNITRON; high-peak-current, pool-cath- ode tube; water cooled; for welding service; metal envelope; overall height 17 inches (max); diameter 2¾ inches (max).

Supply Voltage (rms) = 400—500 v
Peak Inverse Voltage = 720 v (max)
Demand = 600 kva
Avg Anode Current = 56.0 amp (max)
Peak Current at Max Avg Anode Current = 565 amp (max)
Peak Anode Current = 1700 amp (max)
Avg Current at Max Peak = 30.2 amp
Averaging Time = 9.0 sec (max)
Ignitor Voltage (typical) = 200 v
Ignitor Current (typical) = 25 amp

Type WL-655

Westinghouse

IGNITRON; high-peak-current, pool-cath- ode tube; water cooled; for welding service; metal envelope; overall height 23 inches (max); diameter 5⅝ inches (max).

Supply Voltage (rms) = 400—500 v
Peak Inverse Voltage = 720 v (max)
Demand = 2400 kva (max)
Avg. Anode Current 35.5 amp (max)
Peak Current at Max Avg Anode Current = 2260 amp (max)
Peak Anode Current = 6800 amp
Avg Current at Max Peak = 192.0 amp
Averaging Time = 5.6 sec (max)
Ignitor Voltage (typical) = 200 v
Ignitor Current (typical) = 25 amp

ype WL-656

estinghouse

'NITRON; high-peak-current, pool-cath-ıe tube; water cooled; for welding ırvice; metal envelope; overall height inches (max); diameter 4¾ inches ıax).

ıpply Voltage (rms) = 200—250 v
ık Inverse Voltage = 360 v (max)
)mand = 1200 kva (max)
g Anode Current = 14.0 amp (max)
ık Current at Max Avg ınode Current = 2260 amp (max)
ık Anode Current = 6800 amp (max)
ıg Current at Max Peak = 75.6 amp
ıraging Time = 14.0 sec (max)
ıitor Voltage (typical) = 100 v
ıitor Current (typical) = 25 amp

'ype WL-753-A

lestinghouse

NITRON; high-peak-current, pool-cath-e tube; water cooled; for rectifier ·vice; metal envelope; overall height inches (max); diameter 5⅝ inches ıax).

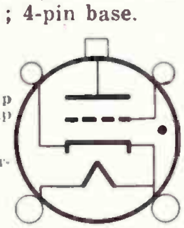
ninal D-C Voltage Output = 600 v
'k Forward and Inverse Voltage = 2100 v
Anode Current = 225 amp
k Anode Current = 1200 amp
itor Voltage (typical) = 150 v
itor Current (typical) = 40 amp (max)

'ype WL-631

'estinghouse

YRATRON; grid-controlled gaseous-charge rectifier; glass envelope; erall height 7¾ inches (max); diameter $3\frac{1}{16}$ inches (max); 4-pin base.

= 5.0 v
= 4.5 amp
Pk Anode Voltage = 1000 v
Pk Anode Current = 15.0 amp
Anode Current = 2.5 amp
Voltage for Starting—egative
p Range. Condensed Mercury = 40—80° C



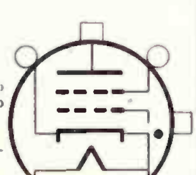
WL-631

'ype WL-632

'estinghouse

YRATRON; grid-controlled gaseous-dcharge rectifier; glass envelope; orall height $7\frac{15}{16}$ inches (max); di-aeter 3 inches (max) plus one-half ih for grid cap side of envelope; 4-p base.

E = 5.0 v
I = 4.5 amp
Pk Anode Voltage = 1000 v
Pk Anode Current = 15.0 amp
A Anode Current = 2.5 amp
G Voltage for Starting—Negative
Tmp. Range. Condensed Mercury = 40—80° C

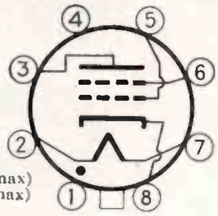


WL-632

Type 2050

THYRATRON; grid-controlled gaseous-discharge rectifier; glass envelope; overall height $4\frac{1}{8}$ inches (max); diameter $1\frac{9}{16}$ inches (max); 8-pin octal base.

E_f = 6.3 v
I_f = 0.6 amp
Tube Voltage Drop
= 8 v (approx)
Peak Anode Voltage
Inverse = 1300 v (max
Forward = 650 v (max)
Shield-Grid Voltage = 0 v
Anode Current
Instantaneous
= 500 ma (max)
Average = 100 ma (max)

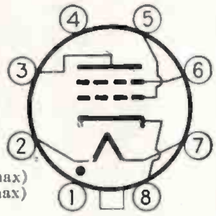


2050
2051

Type 2051

THYRATRON; grid-controlled gaseous-discharge rectifier; glass envelope; overall height $4\frac{1}{8}$ inches (max); diameter $1\frac{9}{16}$ inch (max); 8-pin octal base.

E_f = 6.3 v
I_f = 0.6 amp
Tube Voltage Drop
= 14 v (approx)
Peak Anode Voltage
Inverse = 700 v (max)
Forward = 350 v (max)
Shield Grid Voltage = 0 v
Anode Current
Instantaneous
= 375 ma (max)
Average = 75 ma (max)



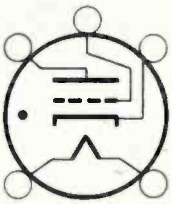
2050
2051

Type WL-629

Westinghouse

THYRATRON; grid-controlled gaseous-discharge rectifier; inert-gas filled; glass envelope; overall height $4\frac{1}{2}$ inches (max); diameter $1\frac{9}{16}$ inches; 5-pin base.

E_f = 2.5 v
I_f = 2.6 amp
Peak Anode Voltage = 350 v
Peak Anode Current = 0.2 amp
Avg Anode Current = 0.04 amp
Grid Voltage for Starting—
Negative
Temp Range, Ambient
= − 20— +70° C

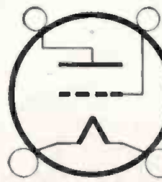

WL-629

Type PJ-8

General Electric

PLIOTRON; grid-controlled high-vacuum triode; glass envelope; overall height $5\frac{5}{8}$ inches (max); diameter $2\frac{3}{16}$ inches (max); 4-pin base.

E_f = 4.5 v
I_f = 1.1 amp
E_b = 350 v (max)
E_c = − 20 v
I_b = 19 ma
μ = 8.5
g_m = 1330 μmhos
Dissipation = 10 watts (max)


PJ-7 PJ-8
PJ-21

Flexible Amplifier

(*Continued from page* 41)

‹e should desire to write a comœhensive relation. Actually, there a› two feedback loops in the amplifı of Fig. 2. Only the major one,]IX, QNY, is considered in the fregoing equations. Due to the unbassed 2,000-ohm cathode resistors i the second stage there exists a fdback loop within that stage itsf. This produces no additional cısiderations for the mathematics irolving equalization of the type C al D networks, but in the A and B nworks we are operating upon that sne cathode circuit to produce ealization. Since the cathode resitors of this stage are the receivii loads for both of these feedback lcps, application of the A and B sitions will affect the performance o both loops.

A summation of the various types o controls and equalizations possile with this amplifier will reveal tht for a unit flexible to the maxinm extent here indicated a total of alut twelve front-of-panel controls wld be required. Fortunately, for ai given application where certain fictions need never be performed th number would probably not be nessary. Obviously the application inlving the largest number of contr's is the equalization of loaded tephone lines. One type D, one te B, and two type A sections are th minimum requirement for this. Eh type A section should have a venier frequency-resonance-adjustnt as indicated in Fig. 2 in additi to the resistor tap switch calited in volume units. Furtherme, one of the A sections might we be equipped with a main resonat frequency control with a spread fn perhaps 2000 to 8000 cps togeier with a double-gang potentionter for tapping down on the 7F7 caode resistors as previously mentied. Certainly many applications of this equalizing amplifier would nt require the power level of ten wts for which this unit is designed. In such circumstances, use of a smller beam type tube (6V6) could be employed.

NEW BOOKS

An Introduction to the Operational Calculus

By WALTER J. SEELEY, *Professor of Electrical Engineering, Duke University. (167 pages. Price, $2.00. International Textbook Co., Scranton, Pa.)*

AS THE COMPLEXITY OF THE physical phenomena with which engineers and physicists deal continually increases, more compact, more rigorous, and more powerful methods of analysis are required if the physical phenomena taking place are to be accurately specified in analytical language. Undoubtedly that branch of mathematics known as differential equations is the most rigorous and powerful method of mathematical analysis in common use by the nonprofesional mathematician, but even here more compact methods are a decided advantage. "The operational calculus as developed in this book is merely a shorthand method of solving certain types of differential equations and as such makes its contribution to mathematical analysis. The purpose of this handy little volume is to develop certain of the methods of operational calculus for the use of undergraduates in engineering schools whose mathematical background is limited, and for engineers who may have lost the facility of manipulating mathematics through disuse.

The first portion of the book reviews the classical methods of solving linear differential equations, but differs from most treatments in that the nomenclature of operational calculus is employed. Accordingly, there is no well marked division from the classical methods of manipulating differential equations to the operational calculus method. The student is therefore gradually and unknowingly making use of operational calculus before he has had an opportunity to build up resentment for the "theoretical" studies of his college course. The gradual and painless manner in which Prof. Seeley makes use of operational methods, and the practical use he makes of the methods developed in his text is an important pedagogical contribution.

It is the reviewer's experience that it takes an advanced and mature mind to overcome the strong desire for "practical" knowledge which is so frequently considered to be the antithesis of "theoretical" learning. Often there is complete failure to recognize that both are merely different points of view of the same thing and that the main difference between the two is merely the degree to which they have been publicized. Both are necessary if any appreciable progress is to be achieved, and often the theoretical learning of one generation is absorbed by the next as its practical working tools. The free and easy style which Prof. Seeley has, and the application of operational methods immediately and directly to problems of electric circuits, should do much to develop in the student using this little volume a maturity of mind which is frequently lacking because the interrelationships between mathematics and physical principles are not sufficiently clearly defined. Theory and practice are, at worst, first cousins in this volume.

While the volume should be useful to anyone desiring a knowledge of operational methods, it will be particularly suitable to electrical engineers since the practical problems have been selected from the field of electric circuit analysis.—B.D.

Electron-Inertia Effects

By F. B. LLEWELLYN, *Published by the Cambridge University Press (Macmillan Co., 60 Fifth Avenue, New York). 102 pages, 13 figures. Index, 2 pages. Size, 8½ x 5½ inches. Price, $1.75.*

THE BEHAVIOR OF VACUUM tubes at high frequencies has been a subject of intensive study for more than a decade. The author of this monograph has taken a very active part in the study, and it is no exaggeration to say that the present satisfactory state of our knowledge of a considerable portion of this subject is attributable to his work. In this monograph he presents a clear and authoritative account of the bearing of electron-inertia effects on the small-signal, high-frequency theory of vacuum tubes.

The monograph is divided into eight chapters. The first contains a brief sketch of the classical treatment of effects of electron inertia in problems which pertain to the passage of electromagnetic waves through ponderable matter. The object of this introductory chapter is to emphasize the fact that although electron-inertia effects have been encountered before in problems of physics, the assumptions which form the basis of treatments of these problems are not valid for an analysis of the behavior of vacuum tubes at high frequencies. In the next two chapters the differential equations which are fundamental to an analysis of the passage of electrons from one to another of two infinite parallel planes are set up; series-order solutions of these equations, useful mainly for small-signal operation such as takes place in receiving tubes, are developed; and the zero-order solutions utilized to exhibit the d-c relations in planar diodes and negative-grid triodes. The following three chapters are devoted to an exposition of the first-order solutions and application of these results to planar diodes and negative-grid triodes, the latter being considered as two cascaded diodes. The physical significance of the mathematics is illustrated by discussions of such practical matters as equivalent first-order circuits, the dependence of the tube parameters on frequency, the increased cathode emission required for space-charge-limited operation at high frequencies, and the utilization of the diode as an oscillator at high frequencies. The final two chapters contain an application of the second-order solutions to the calculation of small-signal rectification in a planar diode; a concise exposition of the behavior of vacuum-tube voltmeters at high frequencies, based on an analysis of the space-charge-free situation; a brief qualitative discussion of the modifications introduced by departure from the parallel-plane electrode configuration; and a short treatment of the Barkhausen-Kurz and Magnetron oscillators.

By way of conclusion the author calls attention to the urgent need for solutions of such problems as the multi-valued electron-velocity situation which is characteristic of retarding field tubes, and the large-signal, high-frequency theory of vacuum tubes. It is a striking commentary on the speed with which technical advances are occasionally made that these problems have been solved since the book was printed.

The monograph is paper-covered, but the printing and 13 figures are excellent. Like other Cambridge Physical Tracts, it is a thoroughly good job on the part of both author and publisher.—B.S.

Electric Motors in Industry

By D. R. SHOULTS and C. J. RIFE, *General Electric Co. Edited by T. C. Johnson, General Electric Co. John Wiley and Sons, Inc., New York, 1942, 389 pages. Price, $4.00.*

THE MAJOR PORTION of electrical power used by industrial organizations in this country is used to obtain some sort of mechanical motion in machinery through the use of electric motors. In general, it has not been necessary for the electrical engineer specializing in electronics to have much more than a speaking acquaintance with motors while performing his everyday job. But to have a well rounded knowledge of electrical engineering he should be more than a little familiar with the principles of operation of motors, and their application and control. "Electric Motors in Industry" is well suited to the purpose of learning the fundamentals of motor operation. It deals with the basic principles which are readily understood, and which at the same time form the basis for proper application of the motor. In addition to characteristics of motors, the application of motors to specific uses is discussed as well as various control methods and coordinated drive systems. It is very interesting that in this book, which has grown out of a course in industrial engineering given by the General Electric Co. for engineers to be assigned to various departments throughout the company, there are two chapters dealing with electronic devices and their application to industry. In the small space allotted to electronics an excellent discussion of the principles of operation and application is presented.—C.W.

'elevision, Today nd Tomorrow

y LEE DEFOREST. *360 pages, 1942, 'rice $3.75. The Dial Press.*

R. DEFOREST HAS written a book for ıe lay reader in which he explains hat makes television possible, what its ɔnomic problems are, where it may go fter the end of the war has removed ıe blight now upon it. The first chap- ırs deal with the historic attempts to ınd pictures to distant parts, through ıe work of May (selenium), Nipkow, ampbell Swinton, Jenkins, Baird, and lexanderson and down to the more cent men like Farnsworth and worykin. While most of the book deals ith the techniques, the author writes mply and a great deal of the book n be understood by the non-technical ader.

Therefore the lay reader, interested t in the high-powered techniques ıich make sending moving pictures to distance possible, but in the interest- g non-scientific aspects of a new dium will find Dr. DeForest's book a od source.

Chapter headings indicate what the ok holds:—Cathode-ray systems, stu- technique, antennas for receiving, eep circuits, television and frequency ɔdulation, the DuMont System, pro- tion systems, etc.

The engineer without previous ex- rience in television and the non- chnical man will find Dr. DeForest's ok an interesting and easy-to-read mmary of the technique of sending ving pictures to distances through ace.—K.H.

asic Radio

J. BARTON HOAG, *Head of the De- rtment of Science, United States ast Guard Academy. D. Van Nos- ınd Co., New York. 380 pages, 1942. ice $3.25.*

. HOAG HAS WRITTEN this elementary ok on radio principles for students ıose background in physics and math- ıatics is limited. Most of the chapter adings follow the conventional pat- n of other radio texts, but others do . The author has made a modern ok, including as chapter headings ch subjects as the operation of oscil- scopes, photoelectric cells, direct-cur- nt amplifiers, frequency modulation, ıg and short lines and microwaves. ultivibrators, pulse amplifiers, and age dissector tubes, are treated; us this book would be a good e for many men who have been t of the radio industry for some time d who wish a quick refresher to ing them up to date. There is prac- ally no mathematics, and although a dent with no background in radio perience or terminology might find difficult going without an instructor, would find this a useful book for ssroom work.—K.H.

NEWS OF THE INDUSTRY

Requirements for radio equipment for use in lifeboats. MacDonald and Grimditch of Hazeltine are elevated in rank in company. Other industry news

SSSS Lifeboat

PLANS ARE IN PROGRESS for the large-scale production of portable radio transmitters for use in lifeboats (ELECTRONICS, March 1942, p. 25) to insure protection and rescue of American seamen from torpedoes, bombed or shelled ships. Four manufacturers are known to be completing suitable designs and there are undoubtedly many more working on the problem.

Lifeboat transmitters are no longer optional extras. On April 16 the United States Coast Guard wrote the following provision into Section 153.23, p. 2909 of the Federal Registry: "There shall be available on board mechanically propelled ocean and coastwise vessels of over 1,000 gross tons for use in lifeboats at least one portable radio instrument which complies with regulations of the Federal Communications Commission." On May 8 the FCC released the regulations referred to, adding Section 8.209 and 8.210 to its rules governing ship service and modifying Section 2.77.

Highlights of the FCC specifications for lifeboat transmitters are as follows: *Frequency:* 500 Kc., tolerance 0.5 per cent, pretuned, frequency control not available to the operator. *Power Output:* Not less than 5 watts into an artificial antenna with 100 μμf effective capacity and 10 ohms effective resistance at 500 Kc., such artificial antenna to be furnished with the equipment, product of antenna current in amperes and maximum height of the antenna in meters above the water to be not less than 5. *Type of Emission:* A-2 (modulated telegraphy) amplitude modulation only, or B (damped wave telegraphy), modulation frequency to be between 450 and 1,250 cps. *Keying:* Must incorporate both manual and automatic means for transmitting distress signals in groups of three, interspersed at frequent intervals (for direction-finding) with dashes not exceeding four seconds in length, automatic code speed to be not more than 16 wpm. *Power Supply:* Manually operated generator with built-in voltage regulator, requiring not more than 60 rpm. and not more than 0.134 hp. at crank-handles or levers. Or storage battery with non-spillable casing, capable of running the transmitter at the required minimum output for 1½ hours or more. (Where a storage battery constitutes the power supply a spare must be provided, with provision for charging aboard the ship while at sea.) Not more than one manual switch for placing the equipment in operation, the switch to be self-releasing after not more than a three minute operating cycle where the transmitter is storage battery powered. *Antenna:* At least 40 ft. of flexible stranded copper wire, insulators, at least 20 ft. of flexible stranded wire or braid weighted at one end for immersion in the sea or for attachment to a prepared ground such as the hull of a metal lifeboat. A mast capable of supporting the antenna at a height not less than the length of the lifeboat and in no instance less than 26 ft. above the water, guys to be non-metallic. (Masts may be those provided for other purposes, such as sails.) Masts provided specifically for supporting antennas, or forming part of such antennas, may be metal. Complete antenna equipment as described above must be furnished with the transmitter and each lifeboat, up to a maximum of four per vessel, must have duplicating antenna equipment and supports. *Antenna Tuning:* Not more than two controls, suitable for obtaining resonance where the antenna capacitance is between 60 and 250 μμf, plus a visual antenna resonance indicator. *Case:* Transmitter, automatic keying device and power supply must be housed in one container equipped with handles or grips and 40 ft. of manila rope must be attached to the container. Weight of the entire equipment, including antenna wire, insulators and dummy antenna capacitor but excluding masts, must not exceed 65 lbs. The container housing the equipment must be watertight, buoyant and rugged and these conditions will be considered met if the equipment operates satisfactorily without repair or adjustment other than antenna tuning after it is dropped 12 ft. into sea water, will not leak after two hours submersion. *Instructions:* Instructions approved by the FCC covering installation and operation must be affixed to the transmitter in some durable, waterproof manner. A nameplate must state type and model number, manufacturer's name, rated output power and month and year of manufacture. An approved maintenance manual must be supplied with each transmitter. One spare tube (where equipment employs tubes) of each type used must be supplied. *Licensing:* Each lifeboat transmitter must be licensed.

Modification of the Commission's ship service regulations Section 2.77 confines type B (damped wave telegraphy) exclusively to emergency lifeboat service, prohibiting use of this type of emission for other purposes. Radio equipmer specifications previously on the bool in Section 8.201 through 8.208, appl ing to radio equipment for motorize lifeboats, continues to apply withou modification, the new regulations cove ing non-motorized lifeboats.

Transmitters in service or contracte for prior to July 1 are authorized fo continued use even though not in exa compliance with the new specification upon delivery of proof to the FCC tha such transmitters meet certain min mum requirements outlined in the Com mission's order. For example: A- (telephone) emission may be tempo arily accepted in lieu of automatic cod transmission and complete equipmen weight may be as much as 75 lbs. Mino power supply, casing and antenna sup port design differences may be waive There will not, however, be any com promise on such things as operatin frequency, availability of A-2 (modu dated telegraphy) emission, minimu power output and antenna resonanc indication.

The Industry

TWO WELL KNOWN NAMES in the radi field flared into prominence again re cently when the board of directors o the Hazeltine Service Corporation an nounced the election of William A. Mac

WGY'S BIRTHDAY PARTY

Dr. Katharine Blodgett, famed woman scientist, is shown giving the plaque to Kolin Hager, WGY manager. WGY recently celebrated its 20th birthday and Mr. Hager was an announcer on the original staff. WGY was one of the original network stations, produced the first radio drama, pioneered sound effects and numerous technical developments

[Don]ald as president and William H. [Gri]mditch as executive vice president [o]f that organization. Mr. Edgar A. [Ric]kard, formerly president, will con[tin]ue as chairman of the board of di[re]ctors. Mr. MacDonald has been with [th]e Hazeltine Service Corporation [sin]ce its incorporation seventeen years [ago] and until his recent elevation was [vic]e president in charge of engineering. M[r.] Grimditch has for many years been a[ss]ociated with the Philco Radio Cor[po]ration where he was director and vi[ce] president in charge of engineering.

[M]essrs. MacDonald (top) and Grimditch, Hazeltine's new executives

[Th]e entire staff of the Hazeltine Serv[ice] Corporation, in its laboratories in N[ew] York City, Long Island and Chi[cago] is engaged in research and design [in th]e field of radio, electronics and [gen]eral scientific research. Where so [muc]h talent goes these days with the [p]roduction of broadcast facilities at a [st]andstill, is anybody's guess.

[W]ALTER C. EVANS, general manager of [t]he Radio, X-Ray and Broadcasting [Div]isions of the Westinghouse Electric [& M]anufacturing Company announces the appointment of Gerald Z. Wo as works manager of the new war duction plant in Pennsylvania. Wollam, formerly assistant manag the Radio Division will supervise conversion of this plant to manufac of communication equipment for Government.

THE APPOINTMENT OF R. P. Alm manager of renewal radio tube was announced recently by C. W. S of the Hygrade Sylvania Corpora At the same time it was announced A. R. Oliver was appointed field manager of the renewal tube sales vision.

ROY HANNAN, formerly material pediter with the North American A tion Corporation has joined the chasing staff of Universal Microp Company of Inglewood, Calif. in a ilar capacity. This concern is emp ing many of its own products in construction of devices for preven sabotage and intrusion. Tiny acou pick-ups and concealed microphones used around the plant, with lines ning to central points, as well as to inside public address system. Thro this effective means the work of guards is made more adequate du periods of total darkness.

THE WAUGH LABORATORIES, 420 Lexi ton Avenue, New York City, annou the availability of its engineering service and testing laboratory facili for stress determination and analy Engineering consultants of the Wa Laboratories include Alfred v. de F est and Arthur C. Ruge, both of Massachusetts Institute of Technol Rudolf K. Bernhard, Pennsylva State College and Donald S. Clark, C fornia Institute of Technology. Laboratories are under the direction N. H. Roy, formerly of the Univers of Illinois.

Although the Waugh Laborato are primarily concerned with st which may be regarded as in the f of mechanical engineering, it would very strange indeed if applications electron tubes were not an impor part of the services which the Lab atories render.

UNION ACTIVITIES also come in for th share of comment in this month's view of the news. A contract betw the United Electrical, Radio and M chine Workers Union, negotiated w the Empire Ordnance Corporation, manded that the latter concern prov two vitamin pills per day per employ

FROM CHATTANOOGA comes the rep that several engineers of a large co tractor on the government's $35,000, TNT plant, had signed a petiti threatening to resign unless th wages were increased to "nearly parity" with that of union workm

It was claimed that many graduate civil engineers receive less salary than semi-skilled workmen. It was also claimed that the salaries of engineering employees average less than that of union workmen under them.

THE PRECISION APPARATUS COMPANY, formerly of 607 Kent Avenue, has moved to 92-27 Horace Harding Boulevard, Elmhurst, L. I., N. Y., more than tripling the size of the previously occupied plant.

ANOTHER EXAMPLE of the way in which the electronic industry is aiding the war effort recently came to this desk. An outdoor paging and announcing system has recently been installed at Eastern shipyards to provide instant communication throughout the dock and ships which are now under construction. The time saved by using the sound system for paging personnel and communicating with all employees simultaneously for general announcements has resulted in greater efficiency in all parts of the yard, according to George Ewald, commercial sound division manager of RCA Manufacturing Company, who made the installation. In one month, RCA sound systems were installed at 29 industrial plants, 16 government projects, 6 hospitals and institutions and one airport.

ENOUGH SCRAP METAL to build a mine layer has been salvaged from the Camden plant of the RCA Manufacturing Company in the first quarter of 1942, according to the Industrial Salvage Section of the Manufacturer's Committee of Camden County. Metal salvage included steel, aluminum, brass, bronze, copper, lead, nickel, tin, zinc, mica and other materials from the huge factory which is now given over to war production. A ton of rubber was also reclaimed from the plant the first day the War Production Board sent out a call for this strategic material.

Technical Personnel

AIDING IN THE NECESSARY program for operation and maintenance of the many highly technical pieces of equipment which it manufactures, the General Electric Company has expanded its training program to teach military men and its own employees how to maintain this equipment in the field. In explaining the operation of this program, Roy C. Muir, chairman of GEC's Education Committee said: "This is a war of science. A new type of engineering is required. Electrical machines and circuits must be coordinated with highly complex mechanical mechanisms, optical systems and radio. Some entirely new things have been developed.

"All that has been learned in the last 20 years about electronics, frequency modulation, television and high-frequency phenomena is now being applied to the airplane and warship. Lightweight instruments, generators, motors,

complicated control systems, armament, and ignition systems have been designed to withstand vibration and to operate in planes from sea level to high altitudes under widely varying humidity and temperature conditions."

A separate building is planned at one plant to house laboratories and classrooms for a new course in high frequency phenomena to be conducted by the G-E radio department. This will accommodate 100 engineers at a time who will attend classes and laboratory sessions 54 hours a week and will also prepare outside work.

ALTHOUGH THE FORMAL opening of the camp was not scheduled until June 6, more than 100 enlisted men were receiving initial instruction in aircraft warning at the Signal Corps School at Camp Murphy near West Palm Beach, Fla., weeks ahead of schedule.

INCREASED WARTIME NEEDS will speed production of thousands of new radio transmitting tubes in 1942 to help reinforce the nation's military signal communications and enlarge shortwave broadcasting facilities, according to an announcement by Westinghouse Electric & Manufacturing Company. For shortwave broadcasting stations fighting the Axis nations in a war of air waves, Westinghouse is now producing the largest air-cooled transmitting tubes in existence. This is the 25-kilowatt tube which, because of its air cooling, completely eliminates the need for the water cooling system previously employed for tubes of this size.

Publications

PARTICULARLY APPROPRIATE at the present time when so many specifications are being written comes the announcement of the new American Standard Definitions of Electrical Terms (C42-1942). Among the 70 groups into which definitions are divided is included a group on electrocommunication, and another on electronics. The project which has been in preparation for many years gives the definitions of technical terms used in electrical engineering, including correlation of definitions and terms in existing standards. Copies of this standard, in a 300-page book, 8x11 inches, may be obtained in Fabrikoid binding at $1 per copy from the American Standards Association, 33 West 39th Street, New York City.

ADDITION TO AN ALREADY imposing list of mathematical tables has recently been announced by National Bureau of Standards from whom the tables are available. Recently completed tables announced during May include Volumes 3 and 4 of the Table of Natural Logarithms and Tables of the Moments of Inertia of Ordinary Angles and Channels. The Natural Logarithms are given to 16 places of decimals from 0.0001 to 5.0000 in Volume 3 and to an equal number of decimal places from

5, 10 in Volume 4. Both are priced at $each, and are available from the Information Section, National Bureau of Standards, Washington, D. C.

FCC Activities

THE FCC RECENTLY amended its rules to permit licensees of commercial television stations to broadcast but four hours of program service per week instead of the fifteen hours weekly, required heretofore. The step was taken to prevent recession of this new art to a purely experimental or laboratory stage and to keep it alive, ready to flourish as a public service after the war emergency. This relaxation, consistent with similar measures, previously announced for relief of standard broadcast stations, will permit licensees to conserve the life of their equipment, particularly tubes, and will permit television stations to operate under conditions of greatly reduced personnel. Licensees serving the same geographical area are free to arrange and alternate their program schedules so as to increase the number of programs available to the public in their communities.

NATIONAL BROADCASTING COMPANY announced a revised television program schedule under which Station WNBT will be curtailed for the duration of the war. The new schedule will be reduced to four hours a week, in conformity with recently amended operating rules of the FCC.

F[illegible]

PERHAPS NO INDUSTRY has been more affected by war conditions than FM radio. Just at the time a promising audience was assured, the ban on manufacturing of receivers and a shortage of transmission parts froze the FM picture" states Zenith Radio in announcing the outcome of their survey "What about FM Radio?" Returns to the questionnaire were gratifying. No lack of interest was displayed by those who are definitely in the FM picture. They were decidedly optimistic about the future of FM broadcasting. But others who have not as yet been in the FM swim did not match the optimism of those already on the air. The survey says the average FM stations today is on the air 11¼ hours per day, and while it is licensed to use 13,190 watts output it is utilizing only about 5,950 watts because of incomplete equipment. A few stations now under construction have definite plans for going on the air despite curtailments, and August, September and November will each see an FM debut. The survey is summarized with an optimistic note, with the words "The prominence of FM in the military picture promises much advancement and general spreading of knowledge of high frequency radio among communications men."

FM's AUDIENCE WILL BE increased w that college radio stations, opera as members of the Intercollegi Broadcasting System will carry reg FM broadcasts. Arrangements are ing made to coordinate the IBC an actual "network" by using the chain. Programs originating from York can be carried to every FM tion of the existing chain, and broadcast to the students of the member stations located in the England and Middle Atlantic Sta By affording colleges the first ac network to be established, FM tr mission of college programs pres good commercial opportunities to tional advertisers interested in college market.

Replacement Parts System

THE DEFENSE COMMUNICATIONS Bo announced that it had recommende the War Production Board appr of a plan initiating a cooperative of replacement equipment for broadcast industry. The DCB furt recommended that the FCC be delega authority to administer those porti of the plan calling for centralized ministration by the Government. S a plan could operate only with the cooperation of the broadcasters and cooperation is assured since the p was prepared and submitted to DCB by the Domestic Broadcast Committee of the Board. The operat of the plan ought to go a long way relieve the priorities problem now c fronting the 900-odd broadcasting s tions in repair and maintenance ma rials.

Mathematicians and Engineers

HIGHER MATHEMATICS, applied by few scholars in the nation's industr laboratories, are making an importa addition to the total of America's dustrial might, according to Dr. T. Fry, director of mathematical resea of the Bell Laboratories. An outsta ing example of the value of mat matics to the national defense effort its use in aeronautics. About 100,0 hours of mathematical study go ir the design of modern four-motor tra port planes—about one hour out every six spent on the job.

Research mathematicians are al busy helping engineers discover n oil fields, make telephone lines car more conversations and "talk bette and build better and more efficient m chinery of many kinds. There a many situations, Dr. Fry said, wh the mathematician and engineer wor ing hand in hand can design a bett machine, or build it quicker and cheap than the engineer can do it alone. T single sideband telephone system volves only a single trigonomet equation, he observed.

Civilian Defense Communications

THE FEDERAL COMMUNICATIONS Commission, working closely with the Office of Civilian Defense, has drafted and placed in effect a War Emergency Radio Service Plan under which amateur and other available gear as well as operating manpower idle since December 7 may be utilized for emergency communications. Applications for the required special station and operator licenses will be accepted by the FCC only from properly accredited defense organizations.

Defense stations are to operate exclusively in the u-h-f bands, namely 112–116 Mc, 224–230 Mc and 400–401 Mc. Required transmitter stability ranges from 0.1 to 0.3 of one percent. Emission may be type A-0, A-1, A-2, A-3 or frequency modulation with 100 kc maximum swing. Power is limited to 25 watts input. Once licensed, equipment may not be altered without approval. Station licenses, blanketing portable and mobile as well as fixed units, will be good for one year.

Volunteers to whom defense organizations recommend issuance of special operator's licenses must already hold some form of license. Any class of license except restricted radiotelephone will be considered satisfactory. Special operator's licenses will be good for the duration and six months thereafter.

There will be two classes of defense stations, those operated under the authority of cities, towns and counties and called "Civilian Defense Stations" and those operated under the wing of states, U. S. territories or possessions and called "State Guard Stations." Civilian Defense Stations, which may by mutual agreement serve several communities, will be permitted to handle essential communications relating to civilian defense during and immediately following actual air-raids, impending air-raids and other enemy military operations or acts of sabotage. Drills will be permitted during practice alerts, blackouts and mobilizations staged by local defense or military authorities. Testing will be permitted during a designated two-hour period on Sundays until November 1 and on Wednesdays and Sundays thereafter. State Guard Stations may be operated during emergencies endangering life, public safety or important property or for essential communications related to state guard activities where other facilities do not exist or are inadequate. Networks may include police, forestry, special emergency and marine fire stations. Four hours of testing is permitted weekly.

Station and operator license applications have been prepared by the FCC, as well as booklet 60726 stating rules and regulations governing the new emergency radio service. This material is available to potential operators of emergency stations but it is recommended that such operators consult local defense officials before applying for it as defense groups, in any event, must file the actual applications for licenses.

NEW PRODUCTS

Month after month, manufacturers develop new materials, new components, new measuring equipment; issue new technical bulletins, new catalogs. Each month descriptions of these new items will be found here

Intrusion Protection System

A NEW ADDITION to a line of photoelectric protective systems is Type A28L Control for outdoor and indoor use over very long ranges. The light source projects a light beam for distances of 350 to 700 feet and it is possible to completely surround power plants, defense factories, and other vital areas. If the light beam is broken by intruders or

saboteurs, the photoelectric control contacts close causing several things to happen such as sounding alarms, operating a central station system, turning on flood lights, closing gates, etc.

The control is provided with a latching unit including a push-button station which may be located in the gate house, office, or other convenient point. This serves to latch the alarm in operation, once the light beam has been momentarily broken, until the reset button is operated. The unit is unaffected by changes in local light and will operate twenty-four hours a day. The relay contacts are pure silver and will handle 15 amps a.c., and 8 amps d.c. The control operates from 115 volts a.c.

Photoswitch Inc., 21 Chestnut Street, Cambridge, Mass.

Portable Vacuum-Tube Voltmeter

TYPE 727-A IS A NEW general purpose vacuum-tube voltmeter which is battery-operated, portable, and is designed particularly for use in the field. It is similar in appearance and general construction to Type 729-A Megohmmeter described in G-R's *Experimenter*, July 1940. Types 727-A and 726-A operate from the lowest audio frequencies up through the moderately high radio frequencies beyond 100 Mc. Both are intended to cover as wide a voltage range as is reasonably practicable over such a wide frequency band.

In the new instrument the stability of the battery power supply makes it possible to increase the sensitivity substantially without fluctuations or zero drift becoming bothersome. The most sensitive range gives full scale deflection on 300 millivolts, with 50 millivolts easily readable. On Type 726-A meter the most sensitive range is 1.5 volts full scale, and 0.1 volt is the lowest calibrated point. The new instrument is particularly convenient where readings of the order of a few tenths of a volt are to be made.

The high voltage range of the new instrument extends to 300 volts without the use of an external multiplier, in place of the previous 150-volt limit. This two-to-one increase is obtaine with a possible slight loss in accurac on the higher ranges, because a high resistance voltage divider is employe in the d-c output circuit of the diod rectifier. On the 0.3, 1, 3 and 10-vol ranges the sensitivity is largely deter mined by wire-wound resistances o relatively low value. The high-resis tance divider is used on the 30, 100, an 300-volt ranges only. The limits of ac curacy of these upper three ranges ar rated at 5% of the full scale instead o an approximate rating of 2% limit fo the 1, 3, and 10-volt ranges, to allow for possible slow or seasonal drift in

the divider ratio. The maximum accuracy (to within 2%) can be realized also on the high ranges if the setting of the internal calibration adjustments for these ranges can be checked occasionally.

More detailed description and a comparison with Type 726-A meter is con-

FIELD X-RAY FOR THE ARMY

The Picker X-ray field unit is shown dismantled and ready for packing. All the parts shown can be placed in the standard U. S. medical chest in less than seven minutes. The packing is designed to protect the equipment from injury even in cross-country travel ined in *The General Radio Experi-nter*, Volume XVI, No. 12. Included the booklet are frequency character-ic charts for both meters, as well as schematic circuit diagram of Type 7-A voltmeter.

General Radio Company, 30 State reet, Cambridge A, Mass.

nsulating Enamel

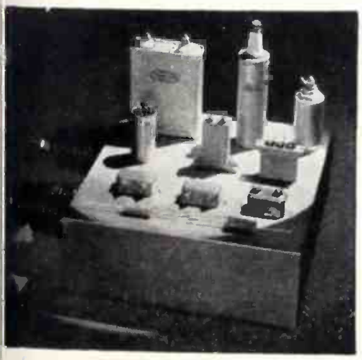
NTHITE No. 10 RED INSULATOR is an drying insulating enamel which will otect control or selonoid coils and her products from attacks of acid and ali. A single application provides a ugh, bright red, glossy, oil and water-oof film which offers maximum resis-nce to the attack of corrosives. The nufacturer tells of a test which was de in their laboratory recently. One at of enamel was applied to a glass be which was baked and immersed in 3% caustic solution for 24 hours. ere were no signs of deterioration d the insulator adhered tightly to e glass tube, retaining its high gloss.

The enamel may be used as inside or side protective coating for motor ndings, commutator end bars or for y application where a tough, high ss, bright red finish is desired. The terial provides a build up of 5 mils r coat, with a dielectric strength of r 850 volts per mil.

A specification sheet and a descrip-e folder is available from John C. lph Co., 168 Emmett St., Newark, J.

gh Voltage Filter pacitors

PE XJ CAPACITORS provide a wide ge of capacities in d-c voltage rat-s from 6000 to 25000. The contain-e are of heavy gage steel, welded oil ht and hot tinned. Wet process in-ators are proportioned to withstand entials in excess of the rated volt-of the capacitors. The case and



minals are bonded together by gasket erial treated to insure an oil tight jt under extreme temperature con-ons. After the completed stack is manently assembled in the case, a long vacuum drying and impregnating process is performed to eliminate the possibility of short life caused by the breakdown of air trapped in the windings. Vacuum mineral oil impregnation aids in obtaining low leakage current and negligible capacity change over a wide range of operating temperatures. The capacitors are available in 600 volts d-c operating in capacities from 2 to 10 μf, and in 25000 volts operating in capacities of from 0.1 to 1.0 μf.

Solar Manufacturing Corp., Bayonne, N. J.

Non-Magnetic Precision Bearings

THESE BEARINGS MAY be used in places where a magnetic bearing would introduce instrument variations. Designated as types NM4, NM5, and NM3P (corresponding to the manufacturers No. 4 and No. 5 radial bearings, and No. 3

pivot bearings) this non-magnetic series has races and balls manufactured of Berylco No. 25, a patented Beryllium copper alloy which is hardened after machining by heat treatment to approximately 40 Rockwell. All dimensions, tolerances and prices are similar to SAE 52100 chrome steel bearings and are more thoroughly described in Catalog No. 41 available from the manufacturer, Miniature Precision Bearings, Keene, N. H.

Ceramic Coil Forms

"CROLITE" COIL FORMS ARE made to specifications, in any diameter up to 3½ inches, in lengths up to 6 inches, if necessary, and in wall thicknesses of from ⅛ to more than ¼ inch. These coil forms may be had plain for holding insulated wire, or grooved to take so many turns of a given size of wire per running inch. The helical groove is available in single, double and triple (grooves within groove for multiple windings) grooves. Mountings can be made either integral with the coil forms or as separate pieces. Spool shapes can be made, particularly multiple spool forms or forms with a number of sections for separate adjacent windings. The coil forms can be extruded to tolerances of 1% or 0.005 inch. Two types of bodies are available in either Crolite 29 which is an all-round severe-service ceramic used for coil forms because of its good electrical properties, particularly low dielectric loss, with high mechanical strength, and Crolite 7 (which can be extruded only) which is suggested for use where the coil forms are subject to severe heat shock such as in soldering-iron or heating-element applications. Crolite has a smooth, clean finish and is usually used without glazing for most coil forms, although it can be glazed in standard white, if desired.

Henry L. Crowley & Company, West Orange, N. J.

Four-Pole Aircraft Relay

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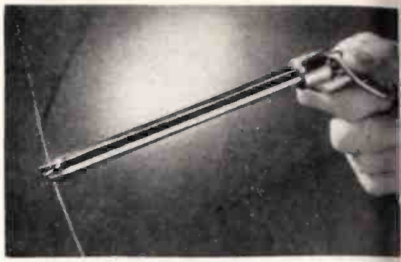

hard-to-get-at place, the trigger broug[illegible] downward and the cutters pick up t[illegible] missing part.

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Literature

Bibliography. "Bibliography on Circu[illegible] Interrupting Devices, 1928–1940" is [illegible] special publication sponsored by Ame[illegible] can Institute of Electrical Enginee[illegible] Committee on protective devices. It i[illegible] cludes, for the period 1928–1940 inc[illegible] sive, practically all material on the su[illegible] ject published in the American trade a[illegible] technical press, and the principal a[illegible] ticles published in other countries. T[illegible] content of the bibliography includ[illegible] separate sections on air circuit brea[illegible] ers, oil circuit breakers, water circu[illegible] breakers, rapid reclosing circuit brea[illegible] ers, recovery voltages circuit breaker[illegible] general and miscellaneous circu[illegible] breakers, enclosed switchgear, a[illegible] switches, bus bars, and fuses and fu[illegible] protection. Available from A.I.E.[illegible] headquarters, 33 West 39th Street, Ne[illegible] York, N. Y., at 40 cents per copy [illegible] Institute members (80 cents to no[illegible] members), subject to a 20 per cent di[illegible] count for quantities of 10 or mo[illegible] mailed at one time to one address. R[illegible] mittances should accompany orders.

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Backtalk

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RC Oscillator Analysis

Editor, ELECTRONICS:

The convenience of the *RC* sine wave oscillator, especially for generating audio frequencies has attracted much attention. One of these circuits was published by Delaup* and partly analysed by him. It is the purpose of this note to provide a somewhat more complete analysis of this circuit than has appeared so far. The diagram of the *RC* oscillator is shown in Fig. 1, and its equivalent circuit in Fig. 2, where

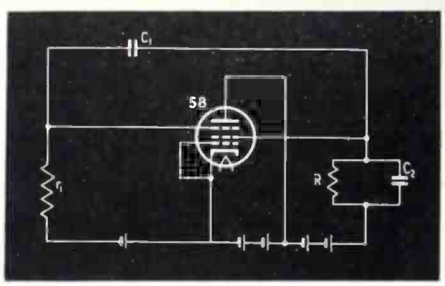

Fig. 1—RC oscillator discussed in the text

the tube is shown as a constant current generator composed of r_p in parallel with the generator whose output is $i = -e\,g_m$. For simplicity, the parallel circuit of r_p and R is designated as r_2.

The input grid voltage is

$$e = i_1 r_1 \qquad (1)$$

from which

$$i_1 = e/r_1 \qquad (2)$$

and

$$di_1/dt = (1/r_1)\,(de/dt) \qquad (3)$$

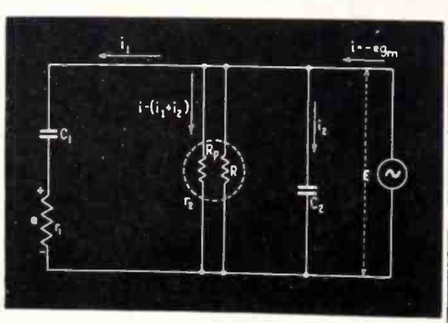

Fig. 2—Equivalent circuit of the DC oscillator

The current in the output circuit [of] the tube is

$$i = -e\,g_m$$

from which

$$di/dt = -g_m\,(de/dt)$$

From the familiar equation, $e = \frac{1}{C}$ [...] $i\,dt$, we obtain for the voltage variat[ion] across the circuit,

$$(de/dt) + \frac{i_1}{C_1} = i_2/C_2$$

and therefore

$$d^2e/dt^2 + (1/C_1)\,(di_1/dt) = (1/C_2)\,(di_2/dt)$$

Upon multiplying r_2 by the time [de]rivative of the current flowing throu[gh] r_2, Eq. (6) may also be written as

$$(de/dt) + \frac{i_1}{C_1} = r_2\left(\frac{di}{dt} - \frac{di_1}{dt}\right) - r_2 \ldots$$

By dividing by r_2C_2 and transposing [all] terms to the left hand side of the eq[ua]tion, we obtain

$$\frac{1}{r_2\,C_2}\frac{de}{dt} + \frac{i1}{r_2\,C_1\,C_2} - \frac{1}{C_2}\left(\frac{di}{dt} - \frac{di_1}{dt}\right) \ldots$$

$$\frac{1}{C_2}\frac{di_2}{dt} = 0$$

One way to solve this equation is [to] replace the currents i, i_1, and i_2 by th[eir] equivalents in terms of e and its ti[me]

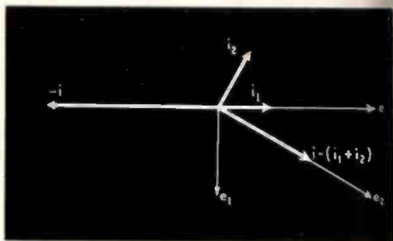

Fig. 3—Vector diagram for oscillator

derivatives, by substituting for i_1 [as] given by Eq. (2); for di/dt as given [by] Eq. (5); for di_1/dt as given by Eq. ([...] and for di_2/dt as given by both Eq. ([...] and Eq. (3), we obtain

$$\frac{d^2e}{dt^2} + \frac{de}{dt}\left(\frac{1}{r_2\,C_2} + \frac{g_m}{C_2} + \frac{1}{C_2\,r_1} + \frac{1}{C_1\,r_1} \ldots\right.$$

$$+ \frac{e}{r_1\,r_2\,C_1\,C_2} = 0 \qquad (1\ldots$$

The limiting condition for oscillati[on] comes when the second term is ze[ro]. For oscillations to occur, therefore, t[he] transconductance must be such that

$$-g_m = \frac{1}{r_1} + \frac{C_2}{r_1\,C_1} + \frac{1}{r_2} \qquad (1\ldots$$

$$= \frac{1}{r_1}\frac{C_1 + C_2}{C_1} + \frac{1}{r_2} \qquad (1\ldots$$

This result differs from that [of] Delaup* in that he obtained C_2/C_1 i[n]stead of $(C_1 + C_2)/C_1$ in the equati[on] for the condition of oscillation.

The frequency is the same for bo[th] solutions. The complete vector diagra[m] is shown in Fig. 3.

Wayne B. Nottingham
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Mass. Inst. of Tec[h.]

* Paul S. Delaup, Electronics, Ja[n]uary, 1941

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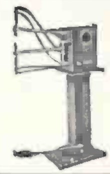

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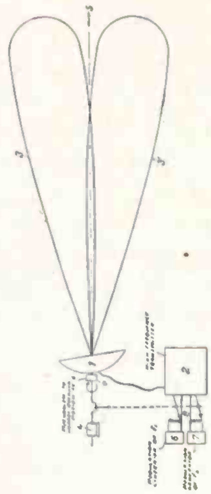

quencies whose amplitude is varied non-linearly in a mutually opposite sense in response to the motion of the emitter. No. 2,283,054. E. Gossel, [...]lin. Lorenz. Dec. 27, 1939.

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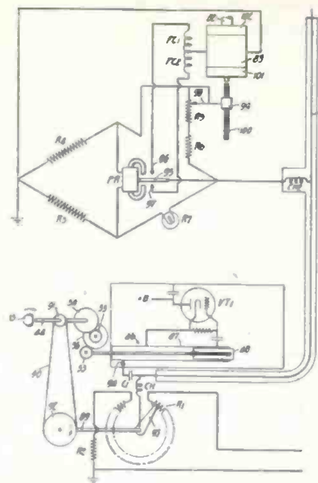
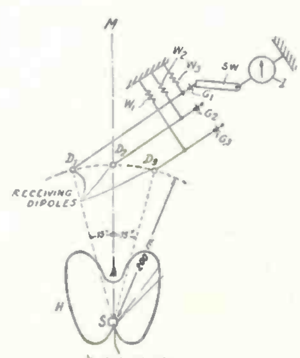


the antenna as the receiver is tuned to different frequencies. S. Y. White, Feb. 29, 1940. No. 2,283,524.

Transmission System. Means for feeding energy to an antenna in a desired ratio among several sections by proper proportioning and connection of lines to the radiating members. A. Alford, IT&T. March 1, 1941. No. 2,283,620.

Direction Indicator. Rotating and fixed members connected to amplifiers receiving energy from a directional and a non-directional antenna, the rotating members indicating the relative strength of the signals from the two amplifiers. E. J. Hefele, No. 2,282,402. April 27, 1937.

Directional Antenna. Arrangement for supervising radiation diagrams comprising means to produce radiation pattern having different energy levels in different directions, receivers at fixed



positions receiving energy at the several levels, and means for alternatively connecting shunts to receivers to equalize the energy. No. 2,283,058. April 6, 1940. W. M. Hahnemann and E. Kramer, Berlin. Lorenz.

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