The GENERAL RADIO EXPERIMENTER

VOL. VIII. Nos. 1 and 2 JUNE-JULY, 1933

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

SOME IMPROVEMENTS IN CATHODE-RAY OSCILLOGRAPHS

THE mad search for practicable television in the past few years may or may not be considered worth while, depending upon one's own personal inclinations and commercial affiliations. There is no doubt, however, that it has given the laboratory worker a better cathode-ray oscillograph.

Television was the inspiration for the first of the so-called "brilliant" oscillograph tubes that General Radio made available two years ago. Television was also responsible for the underlying ground work of development on which the harder tubes, used in two new General Radio cathode-ray oscillographs, are based. Oscillograph tubes are highly complicated—their apparent simplicity to the contrary notwithstanding—and it is the laboratory man's good fortune that the tube manufacturers' vision of a public clamor for television tubes gets him better oscillograph tubes.

Both the common vacuum tube and the cathode-ray tube have cathodes emitting electrons which are drawn to positive anodes with velocities of the same order of magnitude (about $3x10^7$ meters per second for a fall through 2500 volts). Here, however, the similarity ends for electrons in the vacuum tube travel a very short distance. In the cathode-ray tube, on the other hand, the path may be a foot or more long, and, in addition, the electron cloud must be concentrated in a small spot on the fluorescent screen. Since each electron carries the same negative charge, diffusion rather than concentration is the natural tendency, and much of the design problem resolves itself into making the electron clouds behave.

Focusing by means of residual gas within the tube has been the conventional method. Since gas molecules become ionized on being struck by high-velocitv electrons, the electron beam drills its way through the gas and lines. its path with a layer of slow-moving positive ions, the field of which effects the desired concentration. Obviously, the amount of ionization and, correspondingly, the concentration of the

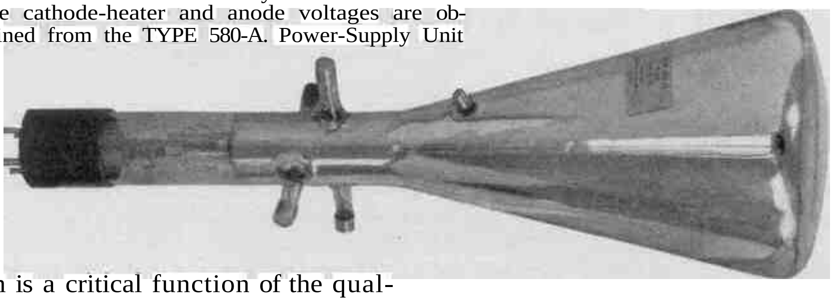


FIGURE 1. The two auxiliary voltages required by the TYPE 528-A Cathode-Ray Tube in addition to the cathode-heater and anode voltages are obtained from the TYPE 580-A. Power-Supply Unit

beam is a critical function of the quality and pressure of the gas. And "there's the rub;" in fact, the rub has at least four important points of contact with oscillograph-tube design.

(1) Anything that affects the gas in the tube, such as temperature, progressive clean-up, or pollution from occluded gas, can alter the focusing.

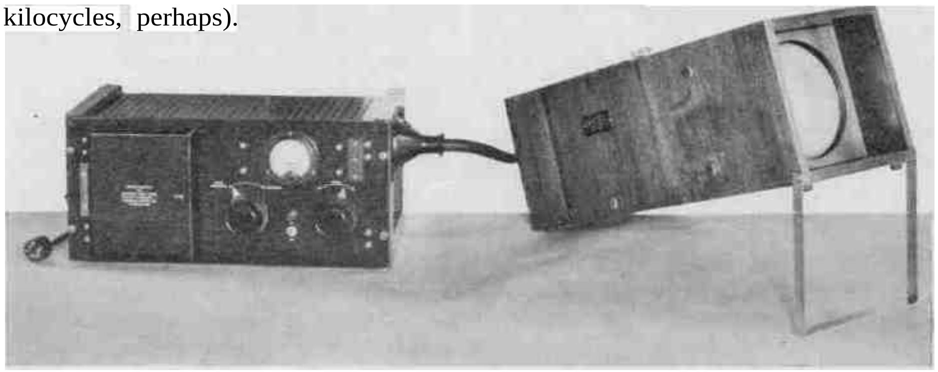
(2) The negative cathode on a gaseous tube can receive an unmerciful beating from any positive ions lobbed at it around the edges of its protecting shield.

(3) Since focusing depends on the slow ions being more or less in equilibrium, the "frequency of deflection" can easily become so high that the focusing condition never has time to re-establish itself after one deflecting impulse before the next one arrives. Hence, some gaseous tubes will not focus satisfactorily at high frequencies (above 100 kilocycles, perhaps).

(4) As the deflecting voltage passes through zero in a gaseous tube, a barely perceptible nick appears in the line on the screen due to ions in the path between deflecting plates. This seldom causes trouble in any but the most exacting work.

All of these defects of the gaseous type of tube have either been eliminated or reduced to negligibility in both tubes used in the two new oscillographs. "Hard" is an entirely relative adjective, in fact we described the older General Radio tube as "hard" (less gas), as indeed it was in comparison with previous tubes. The new tubes are considerably harder than the ordinary radio tubes of comparable voltage; only enough is left to make a

FIGURE 2. The power-supply unit, tube, and TYPE 579-A Tube Mounting



path along which electrons can return from the screen to the cathode. Hence, it, will probably be some time before the new tubes are forced into the soft class by still harder tubes.

A detailed description of focusing mechanisms in hard tubes would be out of order here—not that there is any particular secret about them—but it's a long story. Briefly, use is made of electric fields in which the electrons are guided (by shaping of the electric lines of force along which they move) in a manner directly analogous to the guiding of light rays in an optical lens. It sounds strange, but it works.

TYPE 528 CATHODE-RAY OSCILLOGRAPH ASSEMBLY

This (Figure 2) is a complete oscillograph built around the TYPE 528-A Cathode-Ray Tube designed and built for General Radio by Westinghouse. Because of its large screen, it will prove to be the oscillograph best adapted to lecture room demonstrations and precision measurement problems in the laboratory. The patterns are brilliant—more so than in the older General Radio oscillograph.

The tube itself (Figure 1) has an indirectly heated cathode and a focusing system requiring the application of an adjustable positive voltage to a "first anode." In addition to this and the usual "second" or accelerating anode, there is a grid, a negative voltage applied to which decreases the brilliancy and enables the pattern to be "modulated." The four deflecting plate connections are brought out through separate glass arms, and the operating voltages, with the exception of that for the second anode, are delivered through a large five-pin base.

The silvered coating which lines the entire conical portion of the tube is the second anode, and its voltage is applied through the stud on the surface of the cone. The screen is willemite, giving a green trace of excellent visual and good photographic brilliancy.

At maximum brilliancy (anode, 3000 volts), the voltage sensitivity for either pair of deflecting plates is approximately 110 d-c volts per inch. It increases proportionally as the anode voltage (and brilliancy) is reduced to 500 volts.

The tube is guaranteed for 300 hours of operation or for one year, whichever comes first.

The power-supply unit shown at the left in Figure 2 delivers a d-c voltage between 500 volts and 3000 volts as controlled by the knob at the left of the anode voltmeter on the panel. The positive focusing voltage covers the range between 7 per cent and 21 per

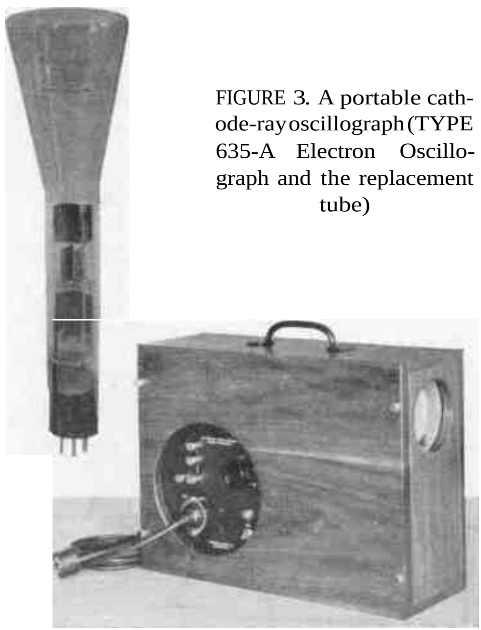


FIGURE 3. A portable cathode-ray oscillograph (TYPE 635-A Electron Oscillograph and the replacement tube)

cent of the anode voltage by means of the right-hand knob. Also on the panel, but protected by a cover, are a rheostat and voltmeter for the heater-current supply. It is designed for a maximum of 3 volts and 3 amperes. The negative grid voltage is adjustable between 0 and 15 per cent of the anode voltage by a control placed next to the filament rheostat. On the panel at the right is a jack plate through which external modulating voltages may be applied.

The tube mounting is a walnut case fitted with an elevating bracket and a door on the side through which the deflecting plates may be reached for making connections to the permanent binding post plate on the top side. The capacitance across either pair of terminals is so small as to be negligible up to frequencies where the inductance of the connecting wires becomes appreciable (say 100 Mc). A cable permanently attached to the tube mounting and fitted with a polarized plug is the means for transferring power from the power-supply unit to the tube mounting. The plug engages the jack on the side panel of the power-supply unit.

TYPE 635-A ELECTRON OSCILLOGRAPH

This instrument (Figure 3) is an effort to reduce the cathode-ray oscillograph to its lowest terms in simplicity of operation and price. Being a complete, readily portable unit, it is ideal for use in the laboratory and in the field as an auxiliary for the larger, more versatile assembly previously described.

The tube mounting and the power-supply unit are combined in one case, access to the tube being obtained by removing four thumb screws. Terminals for the deflecting plates appear on the panel immediately above the receptacle through which 60-cycle power is applied. Cathode heater power for the tube is adjusted by means of a rheostat (maximums of 2.2 amperes and 2.5 volts, respectively) located inside the cabinet. Once adjusted for the tube in use, it need not be changed. The focusing voltage is adjusted by means of the knob on the panel between 0 and 300 volts and can be made either positive or negative by reversing connections. For simplicity, the anode voltage remains fixed at 1000 volts.

The tube (Figure 3) supplied with the instrument is built for General Radio by Hygrade-Sylvania. All voltages, including connections for the deflecting plates, are brought out through the standard six-pin base. A positive focusing voltage is used. The willemite screen has essentially the same characteristics as those of the TYPE 528-A Cathode-Ray Tube and the brilliancy is slightly better for equal accelerating voltages. The voltage sensitivity is approximately 75 d-c volts per inch for one pair of plates and 100 d-c volts per inch for the other pair. The capacitance across either pair of deflecting-plate terminals as measured at the panel of the oscillograph is less than 50uuf. The effective diameter of the screen is approximately 3 inches. The tube is guaranteed for 300 hours of operation or for six months, whichever comes first.

—JOHN D. CRAWFORD

[For additional specifications, including prices, on both oscillographs, see the supplementary specifications on page 15.]

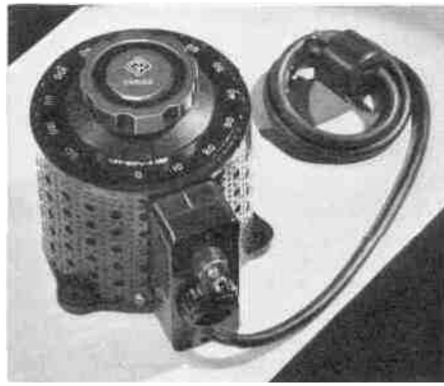
THE VARIAC—A NEW ADJUSTABLE TRANSFORMER

IT is frequently necessary to obtain various voltages from the standard 115-volt, 60-cycle mains. Transformers having several taps are generally used for the purpose, but have the disadvantages that a change in voltage necessitates an interruption of current, since, even with a switching arrangement, one tap must be disconnected before another is connected in order that there shall be no short-circuited turns at any time. Due to the large potential difference between taps on a transformer of this kind, no very fine degree of control can be had. Transformers in which the coupling coefficient between the windings is varied generally result in poor regulation.

To meet the need for a continuously variable source of 60-cycle alternating voltage, the General Radio Company has developed a new unit which has been named the *VARIAC.* This is a toroidal auto-transformer with which the desired results are obtained by using a sliding contact on the transformer winding. Shorting of turns with consequent overheating is eliminated by means of a carbon brush which has sufficient resistance to limit the current caused by connecting two adjacent turns together.

Since the potential between adjacent turns is of the order of 0.5 volt, the circulating current carried by the brush is not great. The brush itself is mounted in a metal holder of sufficient size to dissipate effectively the small amount of heat generated.

The *VARIAC,* since it is wound on a toroidal core, is quite similar in appearance to a heavy-duty potentiometer. Because of the small potential difference between turns, very close adjustment of the output voltage is possible. When the *VARIAC* is connected across a 115-volt, 60-cycle line the output voltage may be varied from 0 up to 130 volts by merely turning the large calibrated dial. The calibration on the dial is only approximate, since, of course, the output voltage will vary somewhat with load, but for all rated load values, the output voltage may be adjusted by means of the calibrated dial within ±2.5 volts r-m-s, providing, of course, the line voltage is 115 volts. The unit will safely carry currents up to 5 amperes.



The TYPE 200-CM Variac is an adjustable auto-transformer delivering voltages between 0 and 130 volts from the 115-volt line. (Patent applied for)

An almost unlimited number of uses may be found for the *VARIAC.* For instance, such a unit is of great value in controlling theater lights and other decorative lighting installations. Manufacturers of a-c operated household appliances or radio receivers may use the *VARIAC* to check the performance of their products over a wide range of line voltages.

The *VARIAC* is manufactured in

two different models: (TYPE 200-CM) the one shown in the photograph, and the other (TYPE 200-CU), without the shield, terminal plate, switch, and cord for mounting on a panel. The latter has screw terminals.

The maximum power loss in the unit is about 30 watts and provision should be made for sufficient air circulation.

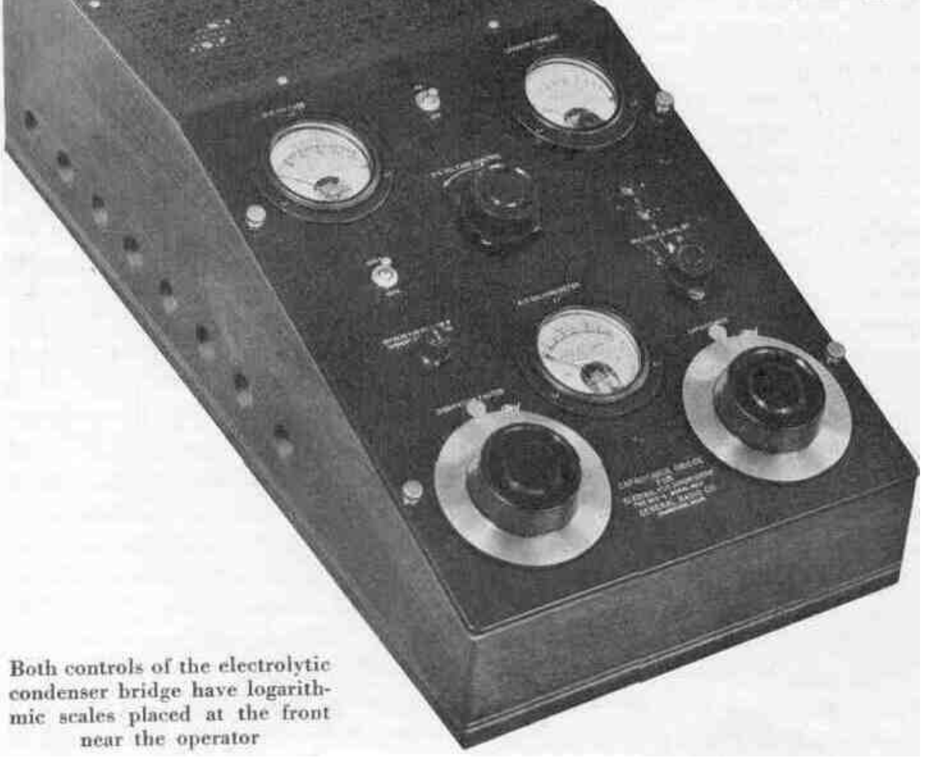
—H. H. SCOTT

[For additional data, see page 15.]

A BRIDGE FOR TESTING OF ELECTROLYTIC CONDENSERS

ELECTROLYTIC condensers are characterized by high capacitance, large power factor, appreciable leakage current, and polarizing d-c voltage. In addition, they must be tested at their operating frequency, either 60 **or** 120 cycles.

The TYPE 632-A Capacitance Bridge has been designed to meet these special requirements of electrolytic condensers. It will measure capacitance over four decades, from 0.01 uf to 250 uf, power factor from 0.5 per cent to 50 per cent, and leakage current from 0.05 ma to 50 ma, for polarizing voltages up to 600 volts with 10 volts at 60 cycles applied



Both controls of the electrolytic condenser bridge have logarithmic scales placed at the front near the operator to the condenser. These ranges cover all electrolytic condensers now manufactured, both wet and dry, except the low-voltage condensers for filament filters of 1000 uf to 4000 uf capacitance.

The appearance of the instrument is shown in Figure 1. The bridge controls are placed at the front of the panel near the operator. The bridge is balanced for capacitance and power factor by two logarithmically tapered rheostats.

The CAPACITANCE dial is calibrated over two decades from 0.25 uf to 25 *uf*, the main decade extending from 2.5 *uf* to 25 uf and covering three-quarters of the dial. Its range is extended up and down one decade by a multiplier switch having three multipliers (0.1,1,and 10).

The DISSIPATION FACTOR dial is calibrated in per cent power factor from 0.5 per cent to 50 per cent. Dissipation factor $D = RwC$ is the same as power factor except at large values.

The null detector is a two-stage resistance coupled amplifier using 57-type tubes and operating a TYPE 488-B A-C Voltmeter through a transformer tuned to 60 cycles. This meter is protected by a high series resistance from deflecting off-scale, even if the bridge is completely out of balance, as when condensers are disconnected. At the same time, its sensitivity for the small voltages obtaining near balance is not materially lowered. This feature is made possible by the non-linear resistance characteristic of the copper-oxide rectifier.

The D-C VOLTAGE is controlled by a large potentiometer and measured by a double-range voltmeter. The LEAKAGE CURRENT is measured by a d-c meter having a semi-logarithmic scale covering three decades from 0.05 ma to 50 ma. This valuable feature is obtained by the use of a copper-oxide rectifier shunt and depends on the non-linear properties of this material. Owing to the large values of leakage current occurring at the instant of application of the polarizing voltage to an electrolytic condenser, it is highly desirable that this meter have a wide range without the use of manually controlled shunts. The resulting decrease in accuracy of this meter is unimportant because of the wide momentary fluctuations in leakage current which occur even under normal operating conditions.

The CAPACITANCE dial is calibrated to within 2 per cent over its main decade. It can be set to 0.5 per cent. The accuracy of calibration of the DISSIPATION FACTOR dial is 10 per cent. The accuracy of reading two dials should be 5 per cent and 20 per cent, respectively. The polarizing voltage may be read to within 2 per cent of full-scale reading. The leakage current may be read to within 10 per cent for 50 ma, 20 per cent for 5 ma, and 100 per cent for 0.05 ma.

The power for the entire bridge is obtained from the 110-volt, 60-cycle supply. The 600-volt polarizing voltage is also used for the two-stage amplifier. —ROBERT F. FIELD

[For additional data, see page 16.]

BRIDGE + VACUUM TUBE = MEGOHM METER

THE rapid and easy measurement of high resistances by means of a portable instrument has always been attended with considerable difficulty.

The bridge method demands the use of a suspended coil galvanometer, using a telescope or spot of light. This is necessary to make up for the loss of sensitivity due to the relatively low resistance of the galvanometer. The direct reflection method also needs a sensitive galvanometer and, in addition, a high voltage supply. The unknown resistor is either compared with a lower resistance standard by means of a calibrated galvanometer shunt or is measured directly in terms of a calibrated scale. For the latter case, the high voltage is frequently supplied from a hand-cranked generator.

The TYPE 544-A Megohm Meter is a bridge having a vacuum-tube voltmeter as the null detector. It has sufficient sensitivity so that the indicating meter may be a pointer-type galvanometer. The bridge is balanced by means of a logarithmically tapered rheostat, calibrated directly in megohms, over two decades from 0.1 MΩ to 10 MΩ. The larger decade from 1 MΩ to 10MΩ covers three-quarters of the dial, or $5^3/4$ inches, and provides approximately constant fractional accuracy of reading. Five multiplying factors (0.1, 1, 10, 100, and 1000) are provided by a switch which varies the resistances in two arms of the bridge in decimal steps. The complete range of the bridge is six decades from 0.01 MΩ to 10,000 MΩ, with a total scale length of 44 inches.

This range of resistance covers most of the high resistances met with in practice. All grid leaks and coupling resistors for vacuum tubes may be measured. The insulation resistance of all low-voltage electrical apparatus, such as motors, transformers, and heating devices; of sufficiently long lengths of high-voltage cables; of paper condensers; and of slabs of most insulators may be determined. The extremely long scale allows the effects of temperature and humidity on insulating materials to be studied.

The operation of the meter is as follows. With the control switch set at CHECK, the galvanometer is brought to zero by means of the ZERO ADJUST knob. The pointer and knob move in the same direction. The control switch is then set at OPERATE and the MULTIPLIER switch turned until the galvanometer pointer swings through zero. Final balance is obtained by means of the MEGOHMS dial.

The principle of operation of the bridge is shown diagrammatically in Figure 2. The two low-resistance arms A and B are connected across the supply voltage of 90 volts. The two high-resistance arms P and Q, one being the unknown resistor, are tapped across them.

The voltage on the bridge varies from 90 volts down to 1 volt. The various voltages for the vacuum tube are supplied through a drop wire connected across the supply. In thus using a common voltage for bridge and detector, it is no longer possible to connect the grid and filament terminals across opposite junctions of the bridge. Instead, the grid is connected alternately to these junctions. Such a procedure would ruin all the advantages of an ordinary null detector. But because for a vacuum-tube voltmeter the initial plate current must be balanced out, no sacrifice of sensitivity occurs with this method.

The grid current of the 32-type screen-grid tube depends on the voltage of the screen-grid tube and the negative bias of the control grid. It is due to positive ions and is about 300 *uua* as used in this meter. The possible error due to this grid current is eliminated by so arranging the control switch that the two high-resistance arms are included in the grid circuit in the CHECK position.

The MEGOHMS dial is calibrated to 2 per cent over its main decade. It can be set to 0.5 per cent. The two smaller standards are wire-wound and adjusted to 0.25 per cent. The large standard used on the two highest MULTIPLIER steps is of the sputtered-filament type and is adjusted to 10 per cent. It may be easily measured in terms of the middle valued standard, the correct value of which is supplied with the instrument. The readings of the bridge should be accurate to 3 per cent for the three lower MULTIPLIER steps and to 5 per cent for the two highest steps, when this correction is applied.

The megohm meter is mounted in a shielded cabinet with a hinged cover and carrying handle. Space for the power supply is provided in the rear of the panel. Either dry batteries or an a-c power pack (see specifications, page 16) may be used.

—ROBERT F. FIELD

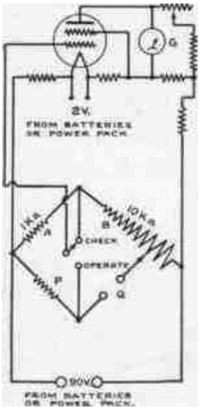


FIGURE 2. Schematic diagram for the TYPE 544-A Megohm Meter

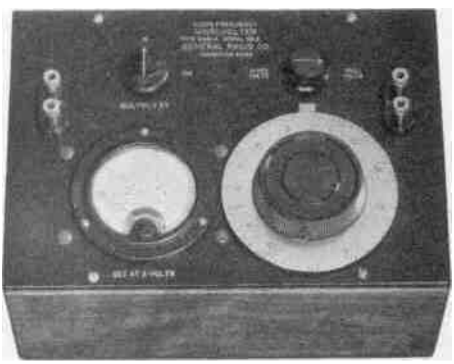
FIGURE 1. The MEGOHMS dial and MULTIPLIER switch are placed in the most convenient operating position. Above them are the ZERO ADJUST knob, control switch, and zero-center galvanometer

A METHOD OF SECURING SMALL AUDIO VOLTAGES

SINCE the advent of the vacuum. tube, quantitative measurements of its performance have involved voltages so small as to be below the range of the most sensitive voltmeters. It has been necessary, therefore, to use the vacuum tube itself as a voltmeter.

The great difficulty in obtaining accurate results has been in knowing the gain—or sensitivity—of the vacuum-tube voltmeter. As a result, a special technique has been developed for measurements of this character. It is well illustrated by the method of gain measurements described in the General Radio *Experimenter* for January, 1931.

The fundamental principle involves starting with a voltage large enough to be determined accurately by convenient and stable voltmeters. This voltage is then attenuated by some known amount, with the result that there is available a voltage comparable in magnitude to the unknown voltage in question. An amplifier of suitable form is now switched alternately between the known and unknown voltages, and the known voltage is adjusted until the output of the amplifier is the same in both cases. While such methods are commonly referred to as comparison measurements, it will be seen that, in effect, the gain of the amplifier is being determined for each setting, inasmuch as the input voltage for a given indicated output is known.



When supplied from a low-power oscillator, the audio-frequency microvolter enables known voltages between 1 volt and less than a microvolt to be obtained

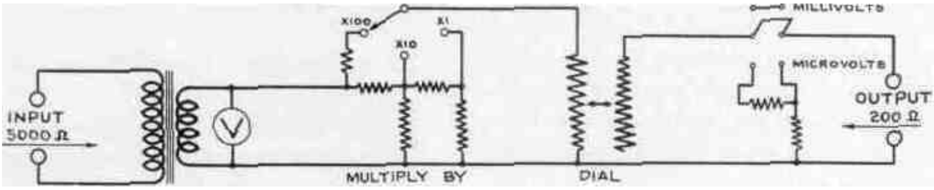
It will be recognized that the essential element in such a measurement is the calibrated attenuator. For moderately low voltages, reasonably accurate results may be obtained with a potentiometer arrangement. For potentials of the order of one microvolt, however, considerable care must be taken in the design in order that extraneous voltages (due either to capacitance coupling or to leakage) do not exceed a value which would cause an appreciable error in the output voltage.

For convenience in use, and in the computation of results, it is desirable that the impedance of the attenuator as measured at its output terminals should be constant.

These several essential features have been included in the new calibrated attenuator recently developed.

The attenuator is in three sections. One, controlled by a three-position switch, reduces the voltage by decimal increments. A second, controlled by a two-position switch, alters the output voltage by a factor of 1000 to 1.

The third is a specially designed slide wire covering a range of two decades and having an exponential scale. The general arrangement of the scale on this element is similar to that of the resistance arm of the TYPE 650-A Bridge, described in the last issue of



Schematic diagram of the TYPE 546-A Audio-Frequency Microvolter. The open-circuit voltages shown by the calibration are obtained when the voltmeter reads 2 volts

the *Experimenter*. The slide-wire attenuator is provided with a compensating resistance by means of which the impedance is maintained constant.

In view of the very considerable range of voltages covered by this instrument—from 1 volt to below 1 microvolt—the selection of the attenuation steps has been made with a view to simplifying the reading of the instrument. The dial of the slide-wire unit reads from 1 to 10 *on* the decade covering the major portion of the scale. The extension is calibrated from 1 to 0.1. With the two-step attenuator out of circuit, these units correspond to millivolts, the three-step attenuator serving as a multiplier, having factors of 1, 10, and 100. Under these conditions, therefore, the three-step attenuator and the slide wire cover a range from 0.1 volt to 1 volt. By cutting in the 1000 to 1 attenuator, these voltages are reduced by a factor of 1000, and, consequently, are most conveniently expressed as microvolts.

The voltage indicated by the three attenuators (after the input voltage has been adjusted for a 2-volt deflection on the voltmeter) refers to the open-circuit voltage at the output terminals of the instrument. When working into a load of finite impedance the equivalent generator resistance of 200 ohms must be taken into account.

Inside the instrument is an impedance-matching transformer preceding the alternating-current voltmeter. This has been designed to give the instrument an internal input impedance of 5000 ohms. It is possible, as a result, to obtain sufficient power from oscillators such as the TYPE 377-B, TYPE 513-B, or TYPE 613-A, to maintain a reference potential of 2 volts.

While the transformer has been designed to have a reasonably flat characteristic over the frequency range, it is evident, since it precedes the voltmeter, that transformer losses do not enter into the measurements in any way. For convenience, the switching arrangement provides for maintaining constant the impedance of the attenuator as seen from the generator side. While this is not essential from the standpoint of voltage computations, it is convenient to avoid the necessity for readjusting the input power as the attenuation is altered.

This new unit has many applications in measurement work involving low voltages. It is useful for conveniently adjusting the output of vacuum-tube oscillators or other sources of alternating current. Used with the TYPE 486 Output Meters or a TYPE 583-A Output Power Meter it provides all the equipment necessary for measuring gain.

—J. W. HORTON

WAVE ANALYSIS

IN DECIDING whether to use 2A3 tubes or 2A5 tubes in a power amplifier we should like to know, not only the total distortion, but also how much 60-cycle and 120-cycle voltages are present and how much the output is modulated by the power frequencies. Further, in designing the amplifier, it is desirable to see whether or not the transformers introduce distortion at low frequencies and whether or not, in a push-pull stage, the second harmonic remains balanced out at high audio frequencies. Perhaps it is never absolutely necessary to answer questions like these—amplifiers have been built without them—but the ability to get answers when it seems necessary is a very valuable tool. It at least enables one to remove all technical doubts and to spend his time in developing a good design rather than in wondering what is happening in the circuit.

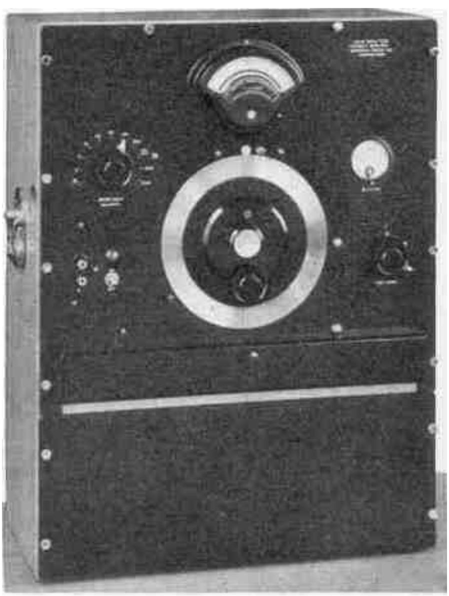


FIGURE 1. Above the frequency -control dial of the wave analyzer is the voltmeter shown in FIGURE 2. At the left is the meter multiplier

This is to describe a heterodyne wave analyzer which has been built to meet this need. The unit as completed is essentially a wide range voltmeter, responding to one very narrow band in the vicinity of any frequency between 0 and 15,000 cycles as chosen by the setting on a dial. The instrument consists of three parts, a heterodyning oscillator, a balanced modulator, and a 50,000 cycle amplifier, employing two quartz-crystal filters.

The oscillator frequency can be varied between 50,000 cycles and 35,000 cycles by means of a suitably shaped air condenser similar to that used in General Radio beat-frequency oscillators. An 8-inch dial is engraved to read directly the difference between the oscillator frequency and 50,000 cycles.

The balanced modulator circuit is shown in Figure 2. Its operation may be readily understood by considering the static case where a carrier signal of frequency *P* is applied in the common branch of the grid circuit and the voltage *Q* from grid to grid is varied.

When this voltage is zero, it is obvious by symmetry that no signal appears at the output. When grid *1* is positive with respect to grid *2*, the mutual conductance of tube *1* will be greater than that of tube *2* so that its output will be greater than that of the second tube and a signal will appear between the two plates. Further, for small unbalances the amplitude of the plate-to-plate signal will be proportional to the grid-to-grid unbalance.

When the tube is worked dynamically by applying a sinusoidal signal

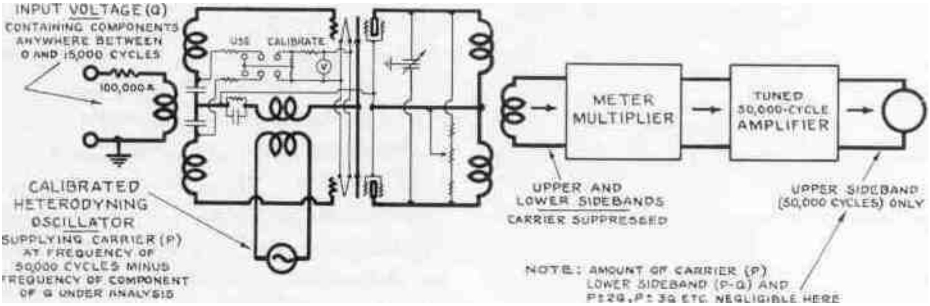


FIGURE 2. The TYPE 636-A Wave Analyzer has better frequency discrimination as well as other advantages over the conventional tuned-circuit analyzer

from grid to grid, the output will consist of the upper and lower side-bands, the carrier *P* being suppressed. The envelope of the output will be a series of half sine waves like the output of a full-wave rectifier.

Quite obviously the ratio of side-band amplitude to input signal amplitude will be proportional to the ratio of unbalanced carrier output to the grid-to-grid unbalancing voltage. This fact is made use of in calibrating the instrument. Thus the heterodyning oscillator is set to the frequency of the tuned amplifier and known incremental biases are inserted in the grid circuit. An uncalibrated volume control is then varied until the amplifier gives a predetermined output. This calibration is entirely self-contained and is dependent solely on the ratio of incremental bias and signal voltage. Detector tubes of a different type might, for example, be substituted, yet the

TWO EXAMPLES OF WAVE-ANALYZER PERFORMANCE

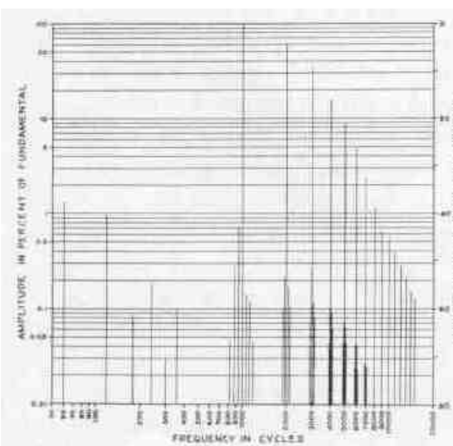


FIGURE 3. Output of a 1000-cycle multivibrator after amplification in an a-c-operated amplifier. This accounts for the presence of 60-cycle harmonic components as well as the upper and lower side-band frequencies of the 1000-cycle harmonics

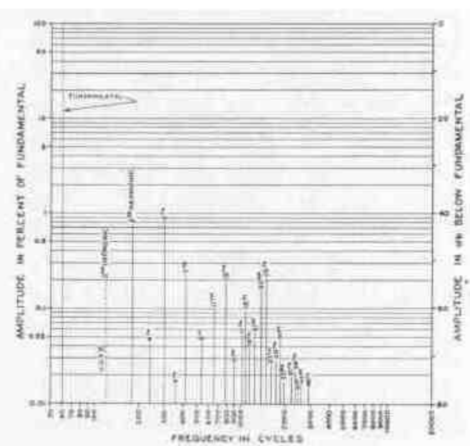


FIGURE 4. Wave analysis on a commercial 60-cvcle circuit for components up to the 50th harmonic. The relative amplitudes were obtained directly from the analyzer's voltmeter by adjusting the fundamental for a deflection of 100 volts

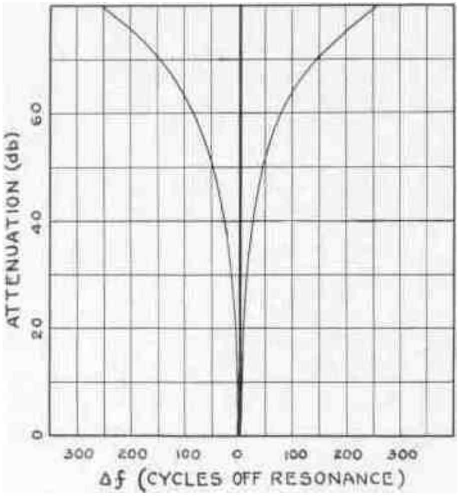


FIGURE 5. Over-all characteristic of the 50,000-cycle quartz-crystal filter in the wave analyzer. This filter passes the upper side-band only

same calibration would hold throughout

The circuits have been so arranged that the frequency characteristic is negligible. It will be noticed that the input circuit has an impedance of 100,000 ohms. The amplifier with output meter has been arranged with a multiplier to have full-scale value for 11 points between 1 millivolt and 2 volts.

The important question about the detector is this: if a pure signal of frequency Q were impressed on the grid, what response would be obtained corresponding to the products $P+2Q$ and $P+3Q$? It turns out that in a totally unbalanced amplifier, as long as the signal Q is kept below a 2-volt limit, the suppression of $P+2Q$ with respect to $P+Q$ will be greater than 60 db, that of $P+3Q$ greater than 80 db. In a perfectly balanced modulator the same suppression would be obtained to $P+3Q$, while $P+2Q$ would disappear entirely. Without using selected tubes we have had no difficulty in getting a suppression of 70 db for $P+2Q$, a value which is ample for most work. In particular research problems the fundamental Q might be filtered out (by a distortion factor meter, for example) before measuring the harmonics.

The tuned amplifier presented quite a practical problem, because it was found necessary to use two crystal filters to get the required selectivity, but the individual crystals were so sharp that some difficulty was expected in matching them. One of the crystals arranged in a three-electrode filter, as measured in a proper circuit where careful precautions have been taken to avoid regeneration and reaction of the measuring circuits, has a Q of about 25,000 giving a half-band width for 6 db of only 2 cycles. In practice, one of the crystals was allowed to operate at a Q of about 20,000 while the Q of the other is decreased to about 5000 by electrical damping. This makes it easy to match the two crystals and also keeps the amplifier from becoming too sharp for practical work. The filter characteristic is given in Figure 5. Three electrically-tuned circuits (included for other reasons) avoid possible trouble with other modes of vibration.

A carefully shielded 10-megohm multiplier has been made which permits the instrument to be connected almost anywhere in a circuit without using by-pass condensers or taking any other precautions. The shielding is so effective that no frequency error could be detected up to 50,000 cycles. Using this multiplier, the full-scale readings of the instrument range between 0.1 and 200 volts or a full range of 0.02 to 200 volts, since the meter may be used at approximately 1/10 scale. Probably this arrangement will be found the most convenient one in the majority of cases.—L. B. ARGUIMBAU

SUPPLEMENTARY SPECIFICATIONS

A Summary of Data Not Included in the Article Describing the Instrument

TYPE 528 CATHODE-RAY OSCILLOGRAPH ASSEMBLY

(See *page 1 also)*

NOTE: This equipment includes the following 3 units:

TYPE 528-A Cathode-Ray Tube
TYPE 579-A Tube Mounting
TYPE 580-A Power-Supply Unit

TUBES: The TYPE 528-A Cathode-Ray Tube should be ordered separately. *Code Word:* CAMEL. Price, $115.00. The rectifier tube is included in the power-supply unit.

POWER SUPPLY: The TYPE 580-A Power Supply Unit supplies filament, anode, and focusing voltage for the TYPE 528-A Cathode-Ray Tube *from* the 115-volt, 60-cycle mains. A TYPE 143-D Rectifier Tube is included. *Code Words:* TYPE 580-A, CULPA; TYPE 143-D (replacement), FAIRY. *Prices:* TYPE 580-A, $170.00; TYPE 143.D (replacement), $3.00.

TUBE MOUNTING: The TYPE 579-A Tube Mounting is a convenient means of supporting the tube, of protecting it against accidental breakage, and of making connections. It includes the cable and jack for making power connections to the power-supply unit. *Code Word,* COFIN. *Price,* $45.00.

DIMENSIONS: TYPE 580-A, (width) 19% x (height) $9^{1/}8$ x (depth) 10 inches, over-all. TYPE 579-A, (length) 25 x (height) 10 x (depth) 9 inches, over-all exclusive of cable.

NET WEIGHT: TYPE 580-A, 36 pounds. TYPE 579-A, 18 1/2 pounds, including TYPE 528-A Tube and Cable.

PRICE: $330.00. See TUBES, POWER SUPPLY, and TUBE MOUNTING (above) for prices of the three components of this assembly.

TYPE 635-A ELECTRON OSCILLOGRAPH

(See page 1 also)

TUBES: The TYPE 635-P1 Cathode-Ray Oscillograph Tube required for this instrument is supplied.

POWER SUPPLY: The instrument operates from the 115-volt, 60-cycle mains. A 6-foot attachment cord is supplied.

DIMENSIONS: (Height) 13 1/2 x (width) 16 x (depth) 6 1/4 inches, over-all.

NET WEIGHT: 19 pounds, including tubes.

CODE WORDS: TYPE 635-A, CUPID; TYPE 635-P1 Cathode-Ray Tube (replacement), CURLY; TYPE 143-D Rectifier Tube (replacement), FAIRY.

PRICE: TYPE 635-A Electron Oscillograph, $90.00, including tubes. TYPE 635-P1 Cathode-Ray Tube (replacement), $30.00. TYPE 143-D Rectifier Tube (replacement), $3.00.

TYPE 200 VARIAC

(See *page 5 also)*

DIMENSIONS: TYPE 200-CM, (height) 5% x (diameter) 6 7/8 inches, over-all. TYPE 200-CU, (depth behind panel) 4 1/8 x (diameter) 6 inches, over-all.

NET WEIGHT: 8 pounds.

CODE WORDS: TYPE 200-CM, BALMY; TYPE 200-CU, BAKER.

PRICE: TYPE 200-CM, $16.50; TYPE 200-CU, $14.00.

Continued on following page

SUPPLEMENTARY SPECIFICATIONS (Concl'd)

TYPE 544-A MEGOHM METER

(See *page 7 also)*

TUBES: One 32-type required and supplied with the instrument.

POWER SUPPLY (BATTERIES): *Filament, two* No. 6 dry cells. *Plate,* two 45-volt block batteries. Burgess No. 5308 or equivalent. Space for mounting all batteries is provided inside the cabinet. Connections are made by a 7-prong plug and coded cable supplied. Batteries are not supplied. *Weight of Batteries,* 7 1/2 pounds.

POWER SUPPLY *(60-cycle* a-c): A TYPE 544-P1 Power Supply Unit that fits the battery compartment can be ordered separately to supply both plate and filament power from a 115-volt line. The 82-type and 874-type tubes and the line cord required are supplied. *Net Weight, 7 1/2* pounds. *Code Word,* ALOOF-APACK. *Price,* $35.00 with tubes.

DIMENSIONS: *Cabinet with cover closed,* (width) *8 1/2 x* (length) 22 1/2 x (height) 8 inches, over-all.

NET WEIGHT: 13 1/2 pounds without batteries.

CODE WORD: ALOOF.

PRICE: $165.00 including tubes, but without batteries or TYPE 544-P1 Power-Supply Unit.

TYPE 632-A CAPACITANCE BRIDGE

(For Electrolytic Condensers)

(See page 6 also)

TUBES: The two 57-type and one 523-type tubes required are supplied with the instrument.

POW ER SUPPLY: All power is derived from the 115-volt, 60-cycle mains, a 6-foot cord for connecting which is included.

DIMENSIONS: *Panel,* (width) 12 x (depth) 15 inches. *Entire instrument,* (width) 12 x (depth) 24 1/2 x (height) 8 inches, over-all.

NET WEIGHT: 46 pounds.

CODE W ORD: BEADY.

PRICE: $300.00 including tubes.

TYPE 546-A MICROVOLTER

(See page 10 also)

DIMENSIONS: (Width) 7 1/8 x (length) 10 x (height) 5 3/4 inches, over-all.

NET WEIGHT: 8 1/4 pounds.

CODE WORD: CROWN.

PRICE-$70 00

TYPE 636-A WAVE ANALYZER

(See *page 12 also)*

TUBES: Three 41-type and two 78-type tubes are required and supplied with the instrument.

POWER SUPPLY: *Filaments,* from 6-volt storage battery by means of plug-and-clip leads supplied. *Plates,* from three 45-volt blocks, mounting space for which is available in a compartment behind the lower panel section of the instrument.

DIMENSIONS: *Panel (2 sections),* (width) 19 x (height) 24 1/4 inches. *Cabinet,* (width) 20 1/2 x (height) 25 x (depth) 11 inches, over-all.

NET WEIGHT: 65 pounds.

CODE WORD: ABOVE.

PRICE: $475.00 with tubes but without batteries.