the GENERAL RADIO Experimenter

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TO

GENERAL RADIO EXPERIMENTER

VOLUMES XXII AND XXIII

June, 1947 to May, 1949

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THE General Radio EXPERIMENTER

VOLUME XXIII No. 8 JANUARY, 1949

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

MEASUREMENTS ON I-F TRANSFORMERS WITH THE TYPE 916-A R-F BRIDGE

Also

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INTRODUCTION

In the present standard design specifications for I-F transformers, some of the quantities specified are not directly related to the actual performance of the transformer in a radio receiver, and some cannot be measured without disassembly of the unit. Mr. C. A. Hultberg, Mr. T. Vanacore, and other members of the engineering department of the Colonial Radio Corporation have proposed a new set of design specifications based on three quantities, directly related to performance, which can be measured without disassembly of the transformer. They are:

1. Coil inductances.
2. Resonant impedance or conductance of each winding with the other winding short-circuited.
3. Coupling factor.

The resonant conductances and the coupling factor in this design specification can be measured accurately and directly by the Type 916-A R-F Bridge using the methods described in this article. The coil inductances can be measured

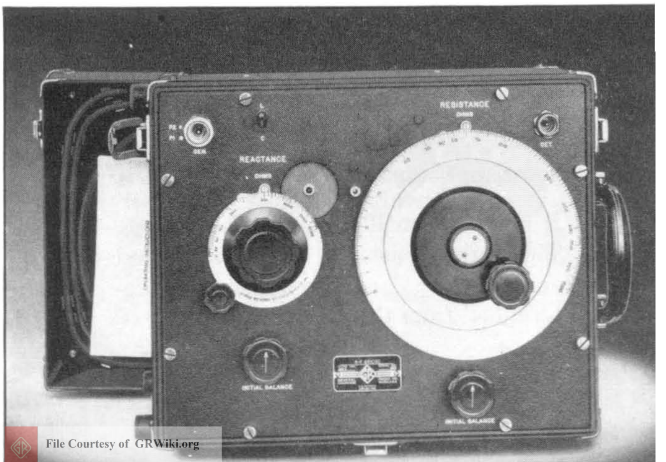


Figure 1. Panel view of the Type 916-A Radio-Frequency Bridge.

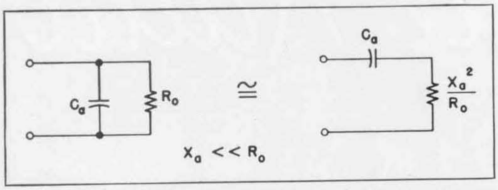


Figure 2. Equivalent series circuit of a high resistance in parallel with a capacitor.

with high accuracy on the TYPE 821-A Twin-T Impedance Measuring Circuit by the two-frequency method without disconnecting the trimmer capacitors. Equally good results can be obtained with the Radio-Frequency Bridge and an external TYPE 722-N Precision Condenser, connected for parallel substitution measurements.

CONDUCTANCE MEASUREMENTS

Although the TYPE 916-A R-F Bridge was designed for the measurement of the series components of relatively low impedances, it can easily be adapted to measure high impedances by shunting the unknown with a reactance so chosen as to bring the impedance of the combination within the range of the bridge. For the measurement of a high resistance, i.e., the resonant impedance of a parallel tuned circuit, it is possible to make the bridge direct reading in circuit conductance and to eliminate most of the calculations that usually make this method of measurement so tedious.

As shown in Figure 2, the capacitor, C_a, connected across a resistor, R_0, has an equivalent series circuit consisting of the same capacitor in series with a resistor approximately equal to $\frac{X_a^2}{R_0}$, when X_a is very small in comparison to R_0. This series resistance can be measured on the bridge and the value of G_0 determined from the expression

$$G_0 = \frac{1}{R_0} = \frac{R_m}{X_a^2} \qquad (1)$$

where R_m is the reading of the bridge resistance dial. The bridge can be made direct reading by so choosing the capacitor C_a to make X_a^2 a decimal value, thus eliminating all calculations.

In an actual measurement, the shunting capacitor alone is first connected across the bridge terminals and an initial balance made. The tuned circuit to be measured is then connected in parallel with the capacitor and a final balance made by adjusting the resistance dial on the bridge and the tuning capacitor on the circuit under test.

Since the method of measurement is based on an approximation, the accuracy and limitations of the method must be known before it can be used effectively. In the following paragraphs, the method will be analyzed and the magnitude of the errors determined.

Under the conditions outlined above, the impedance Z_1 connected across the bridge terminals during the initial balance is

$$Z_1 = jX_1 = jX_a \qquad (2)$$

where X_a is the reactance of the shunt capacitor C_a shown in Figure 3.

When the tuned circuit having a series resistance R_x and a reactance X_x is connected and the final balance made, the series resistive and reactive components of the impedance Z_2 then connected across the terminals are:

$$R_2 = R_m = \frac{X_a^2}{R_x} \cdot \frac{1}{1 + \left(\frac{X_a + X_x}{R_x}\right)^2} \qquad (3)$$

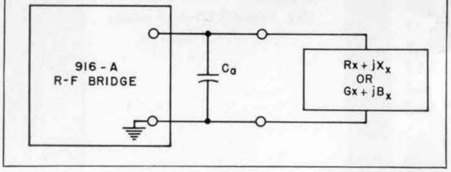


Figure 3. Bridge connections for the measurements discussed in this article.

$$X_2 = \frac{X_a + \frac{X_a X_x}{R_x^2}\left(X_a + X_x\right)}{1 + \left(\frac{X_a + X_x}{R_x}\right)^2} \qquad (4)$$

In this case, R_m is the reading of the resistance dial, and, since the reactance dial is not moved when making the final balance,

$$X_2 = X_1 = X_a \qquad (5)$$

If the expression for X_2 given in Equation (5) is substituted in Equation (4), and the resulting expression for X_x substituted in Equation (3), the result is

$$R_m = \frac{X_a^2}{R_x} \qquad (6)$$

$$X_x = -X_a \qquad (7)$$

Equation (7) shows that the resonant circuit must be detuned to produce a series reactance of magnitude $-X_a$ for balance. Detuning causes the effective series resistance, R_x, to decrease from its maximum value at resonance, R_0. The magnitude of this deviation is small if $\frac{X_a}{R_0}$ is small, and can be calculated in the following manner.

For small deviations, ΔC, from the capacitance at resonance, C_0, the effective series resistance and reactance of a parallel-tuned circuit are given quite accurately by the approximations

$$R_x \cong R_0 \left[1 + \left(\frac{\Delta C}{C_0} Q\right)^2\right] \qquad (8)$$

$$X_x \cong \frac{\Delta C}{C_0} Q R_0 \qquad (9)$$

where Q is the storage factor of the resonant circuit. The amount of detuning necessary to produce the reactance indicated by Equation (7) can be de-

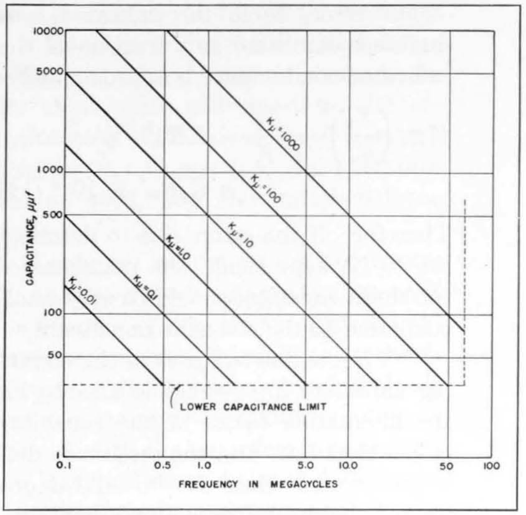


Figure 4. Shunt capacitance vs. frequency for various decimal multipliers.

termined from Equation (9). The actual deviation in R_x from its resonant value can then be determined from Equation (8). The resultant expression for the resonant conductance, G_0, is:

$$G_0 = \frac{1}{R_0} \cong \frac{R_m}{X_a^2}\left[1 - \left(\frac{X_a}{R_0}\right)^2\right] \text{ mhos} \qquad (10)$$

If we let

$$K = \frac{1}{X_a^2} \qquad (11)$$

and

$$\frac{X_a}{R_0} \ll 1,$$

then

$$G_0 \cong K R_m \text{ mhos} = K_\mu R_m\ \mu\text{mhos} \qquad (12)$$

where K_μ is the factor which converts the indicated series resistance in ohms to the resonant conductance in micromhos.

$$K_\mu = 10^6 K = \frac{10^6}{X_a^2} \qquad (13)$$

The error, E, in the indicated conductance expressed as a fraction of the indicated conductance is approximately:

$$E \cong \left(\frac{X_a}{R_0}\right)^2 = \frac{G_0^{\,2}}{K} = KR_m^{\,2}$$
$$= K_\mu R_m^{\,2} \times 10^{-6} \quad (14)$$

Therefore, if the errors due to detuning are to be kept small, the reactance of the shunt capacitor should be very small compared to the resonant impedance.

The errors due to losses in the shunting capacitor are negligible as long as the dissipation factor of the capacitor is less than 0.01 and the resistance dial is set at zero when the initial balance is made with the capacitor alone connected.

The shunting capacitances required for various values of K_μ are indicated in Figure 4. Figure 5 shows the values of conductance measurable within various accuracies as a function of K_μ. The limits indicated by the dashed lines are determined by the accuracy of calibration of the resistance dial.

EXAMPLE

The intermediate-frequency transformer chosen for this illustration is a standard double-tuned inductively-coupled unit, operating at 455 kilocycles, which is completely assembled in its shield can with its trimmer capacitors connected. In the following paragraphs the general test procedure will be described; however, in most applications a number of short-cuts will be apparent to the user.

The first step is to estimate roughly the magnitude of the conductance to be measured so a value of K_μ can be selected which will permit the measurement to be made within the desired accuracy. In the example under consideration, the conductance is of the order of 30 μmhos, and the desired accuracy is $\pm$5 per cent. From Figure 5 it can be seen that a K_μ of 0.1 meets these requirements. Figure 4 or Equation (13) shows that the shunting capacitance required for this value of K_μ at 455 kilocycles is 110.6 $\mu\mu$f.

The indicated value of shunting capacitance includes the terminal capacitance of the bridge and other stray capacitances. Hence, for greatest accuracy, the capacitor should be measured in place on the bridge. This can be done using the reactance-measuring property of the bridge itself; however, the accuracy of the determination of K_μ

Figure 5. Range of conductance measurable within given accuracy limits for various values of Kμ.

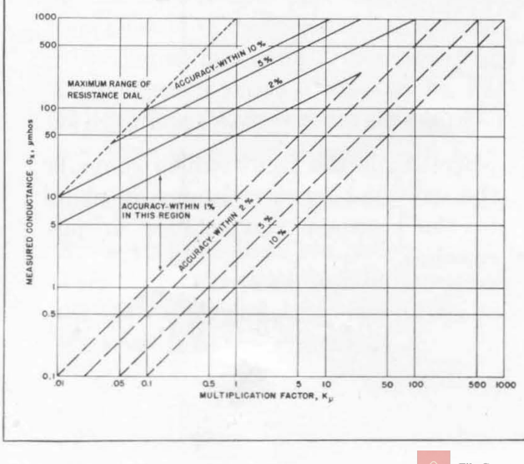
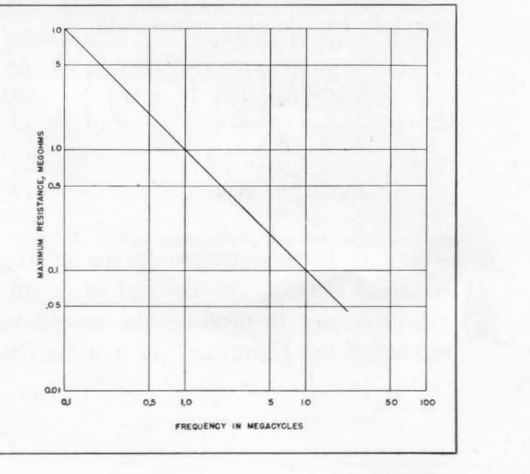


Figure 6. Resistance above which the "Boella Effect" starts to influence appreciably the parallel resistance of IRC Type F-1 Resistors vs. frequency.



under these conditions is only ±4 per cent, because the bridge accuracy for reactance measurement is ±2 per cent.

A more accurate method of determining the precise value of K_μ is to measure the conductance of a low-reactance resistor having a known conductance, using the bridge in the same manner as for transformer measurements. In this method of calibration the reactance dial is adjusted for the final balance in place of the tuning capacitor on the transformer, and K_μ is the ratio of the conductance of the standard resistor to the resistance dial reading.

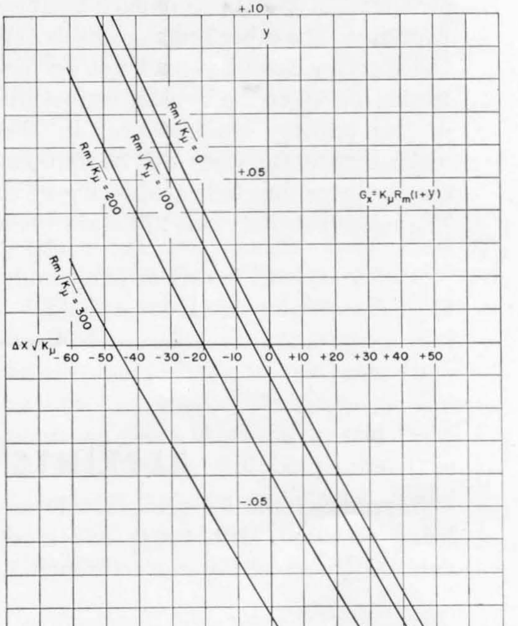
The a-c conductances of IRC Type F-1 Resistors and other similar units are very close to their d-c conductances for resistances within the limits indicated in Figure 6; deviation at higher resistances is caused by the Boella effect. In some cases the shunt capacitance of the resistor will cause small errors; however, corrections for these errors can be made using Figure 7. In this case a 100,000 ohm resistor is used as a standard and the shunting capacitance adjusted until the resistance dial reads 100 ohms.

After the shunting capacitance has been adjusted or the value of K_μ accurately determined, the capacitor is connected across the bridge terminals and the initial balance made. This balance should be made with the resistance and reactance dials both set at zero and the *L-C* switch in the *L* position if the shunting capacitance is greater than 160 $\mu\mu$f. If the shunting capacitance is less than this value, the *L-C* switch should be set in the *C* position, the resistance dial at zero, and the reactance dial at about $5000 - \frac{10^3}{\sqrt{K_\mu}} f_{Mc}$.

This procedure eliminates the necessity of making an additional initial balance with the bridge terminals shorted. In the case under consideration, the capacitance is 110.6 $\mu\mu$f so the *L-C* switch is set in the *C* position, the reactance dial at 3500, and the initial balance made.

The circuit is now set up to measure the unknown conductance. The resonant conductance of the primary alone should be measured first. This is done by short-circuiting the secondary winding leads and connecting the primary winding in parallel with the shunting capacitor on the bridge. Then a balance is obtained by adjusting the resistance dial on the bridge and the primary trimmer capacitor in the transformer. The reading of the resistance dial multiplied by K_μ gives the magnitude of the conductance. In this example the resistance dial reading is 134 ohms and, since $K_\mu = 0.1$, the measured conductance is 13.4 μmhos.

Figure 7. Correction in measured conductance for error caused by reactance in the circuit under test.



MEASUREMENT OF COUPLING FACTOR

The coupling factor, F_c, is defined as:

$$F_c = \frac{R_p}{R_{ps}} = \frac{G_{ps}}{G_p} = 1 + k^2 Q_p Q_s$$

$$= 1 + \left(\frac{k}{k_c}\right)^2 \qquad (15)$$

where R_p and G_p are the resonant primary resistance and conductance with the secondary short-circuited, R_{ps} and G_{ps} are the resonant primary resistance and conductance with the secondary resonated, Q_p is the storage factor of the primary circuit alone, Q_s is the storage factor of the secondary circuit alone, k is the actual coefficient of coupling, and k_c is the coefficient for critical coupling.

In order to determine the coupling factor, the resonant primary conductance must be measured with the transformer secondary resonated. This is accomplished by removing the short-circuit from the secondary and obtaining a new balance by adjusting the resistance dial and the secondary trimmer capacitor. The other bridge controls and the primary tuning should not be disturbed between the two measurements of the primary conductance. In this measurement the error will be approximately twice that indicated in Figure 5. The resistance dial reads 273 ohms when the secondary of the transformer under consideration is resonated, and hence its conductance is 27.3 μmhos. From Equation (15) the coupling factor is therefore

$$\frac{27.3}{13.4} = 2.04 \text{ and } \frac{k}{k_c} = 1.02.$$

The resonant secondary conductance can be measured in the same manner as outlined for the primary; and, if desirable, the coupling factor can be determined from measurements on the secondary instead of the primary. The same answer should be obtained in both cases.

The resonant conductance of other types of single and double-tuned circuits and the conductance of relatively low-reactance resistors can also be measured accurately on the TYPE 916-A R-F Bridge through the use of the method described, and, in applications in which a number of measurements are required at one or more specified frequencies, a fixture can be constructed which will mount directly on the bridge and have the required calibrated capacitors connected across the terminals by means of a switch. For tuned-circuit measurements, small external trimmer capacitors may also be provided to permit a finer tuning capacitance adjustment than can be obtained using the capacitors built in the transformer.

— R. A. SODERMAN

REPRINTS AVAILABLE

Reprints of the foregoing article are being prepared, with larger and more detailed charts of Figures 4 through 7. Copies will be available shortly and will be sent to any of our readers who request them.

— EDITOR

LABORATORY EXERCISES WITH THE VACUUM-TUBE BRIDGE

As is evident from a consideration of its circuit characteristics, the TYPE 561-D Vacuum-Tube Bridge is not limited in its applications strictly to the measurement of tubes, but is capable of measuring the voltage gain, output resistance, and effective transconductance of any three-terminal network appropriately connected to its terminals.

The versatility and adaptability of the bridge for these measurements make it particularly useful in teaching and in laboratory experiments for students. In the March, 1948, issue of *American Journal of Physics,* Professor Edward H. Green, of Brooklyn College, under the title, "A Precise Laboratory Exercise Using a Vacuum-Tube Bridge," describes a student laboratory exercise based on the TYPE 561-D Vacuum-Tube Bridge. The article covers such measurements as the gain and output resistance of triode amplifiers with and without feedback, cathode followers, negative coefficients, and the determination of the criterion for oscillation of a negative-resistance oscillator. This comprehensive and very readable article should be of interest to teachers of electronics and of electrical communications. Reprints are available and we shall be glad to send copies to all who request them.

MISCELLANY

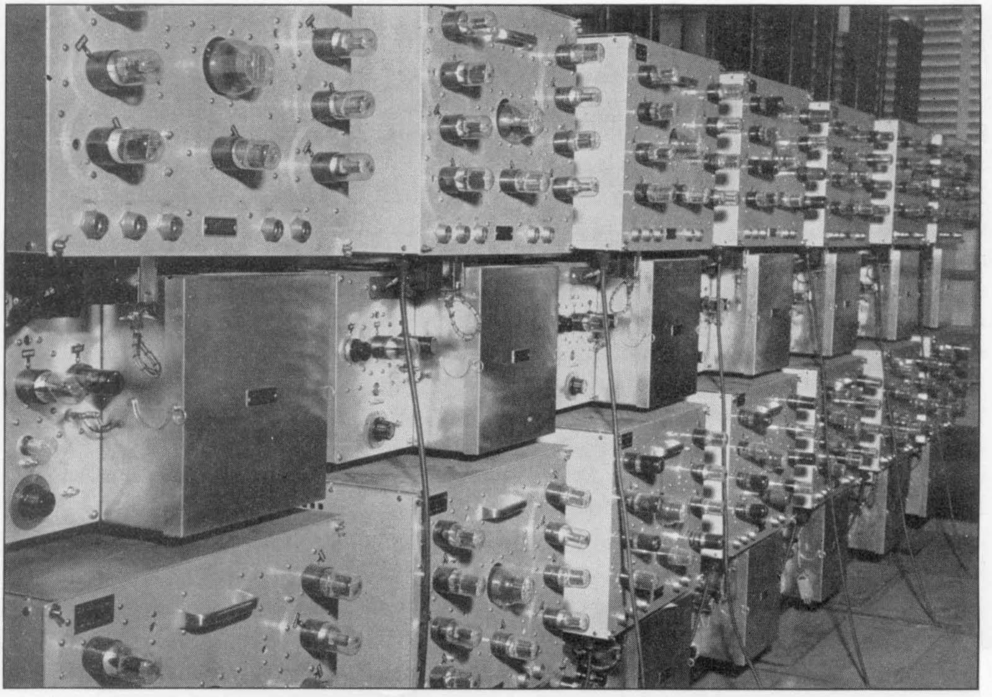
RECENT VISITORS to our plant and laboratories — Mr. John R. Pheazey, Works Director, Standard Telephones and Cables, Ltd., London; Mr. C. I. Snow and Mr. F. H. Andrews of Imperial Chemical Industries, London; Mr. K. Bogedam, Copenhagen; Dr. L. Rohde of Rohde and Schwartz, Munich; and Mr. H. S. Walker, RCA Victor Co., Ltd., Montreal.

1949 IRE CONVENTION — March 7-10 are the dates set for the 1949 Annual Convention of the Institute of Radio Engineers, which promises to be the biggest and best in the Institute's history. The Convention will open with the annual meeting of the Institute on Monday, March 7, at 10:30 A.M., when Ivan S. Coggeshall will speak on "Perpetual Youth and the IRE." On Tuesday, the President's Luncheon will honor the incoming president, Stuart L. Bailey, and on Wednesday evening, at the annual banquet, Frank Stanton, president of CBS, will speak on "Television Today."

Technical sessions will be held at both the Hotel Commodore and Grand Central Palace. A total of 170 papers will be presented during the 4-day period, covering a wide range of subjects in radio, electronics, and allied fields.

Some 200 firms will exhibit their products at the Radio Engineering Show, held at Grand Central Palace.

The General Radio exhibit will be in Booths 92 and 93, the same space that we have had for the past two years. Representatives of the Development Engineering, Sales Engineering, and Service Departments will be on hand to discuss applications of General Radio equipment and to answer questions. We hope that all our friends will drop in.



A group of Type 1100 Frequency Standards undergoing performance tests in our Standardizing Laboratory. Accuracy and stability must be well inside catalog specifications before the oscillators receive the Laboratory's O.K.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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VOLUME XXIII No. 9 FEBRUARY, 1949

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A CRYSTAL MODE INDICATOR

Also

IN THIS ISSUE

● **ONE OF THE MOST TROUBLESOME EFFECTS** encountered in the production of quartz plates for frequency control is that of "spurious" or "coupled" frequencies. These are due to modes of vibration giving unwanted response frequencies near the desired frequency. Changes in temperature can cause the interfering frequencies to move nearer to, or farther from, the desired mode, in which case the normal response may decrease or increase as the temperature changes. If the quartz plate is used in an oscillator, the amplitude of oscillation will change as the temperature changes, and sometimes oscillations cease altogether at a particular temperature.

To examine a crystal by point-by-point measurements is extremely difficult and tedious, to say the least. Such measurements are of but little value for production control since they must be repeated for each change made in the dimensions of the quartz.

During the war, an instrument for rapidly examining the response spectrum

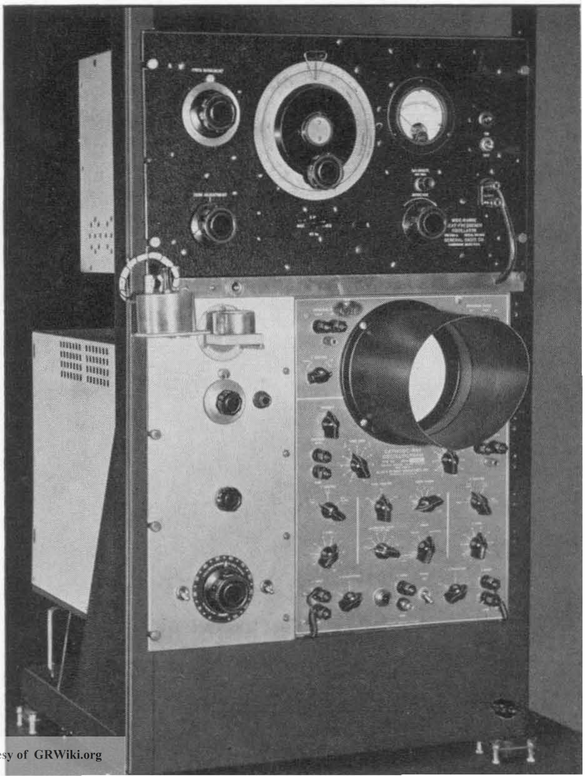


Figure 1. Panel view of the crystal mode indicator.

of quartz plates was suggested by Prof. K. S. Van Dyke, of Wesleyan University, to several manufacturers, but no instrument was produced. At the close of the war, workers at the Signal Corps Laboratories and at colleges, under Signal Corps contracts, developed instruments, one of which, built by the Signal Corps Laboratories, was exhibited at the I.R.E. Convention in New York in March, 1948.

This equipment utilized frequency modulation of an oscillator, produced by electronic means controlled by the sweep voltage of an oscillograph. The oscillator output was applied to a quartz plate and the rectified response was displayed on the cathode ray oscillograph. The shunt capacitance of the holder was balanced out, so that the pattern represented the admittance of the quartz element alone.

A simplified arrangement, utilizing a General Radio TYPE 700-A Wide-Range Beat Frequency Oscillator, with a small motor-driven (or manually operated) variable capacitor as the frequency modulation means, is easily assembled and is very useful for testing quartz plates in the range from 500 to 5000 Mc.

This crystal mode indicator, now in use in the General Radio Company's crystal grinding laboratory, is shown in Figure 1. At the top of the rack is a General Radio TYPE 700-A Wide-Range Beat Frequency Oscillator. One connecting wire is brought out at the rear, from the fixed oscillator tuned circuit, for connection to the frequency sweeping capacitor described below.

At the bottom of the rack are the control panel and the cathode-ray oscilloscope. The oscilloscope shown here is a Dumont Type 250, with a five-inch super-persistence tube. This model is particularly convenient, since d-c amplifier connections are available by use of selector switches on the panel. (A Dumont Type 208-B unit was used previously, where d-c amplifier connections are available by changing the internal wiring in accordance with instructions given by the manufacturer.)

The control panel has a rest at the upper left-hand corner for the heater unit used in bringing the temperature of the test crystal up through the normal operating temperature. The unit is a heavy aluminum cup in which are buried two cartridge-type heaters operating at a total power of 50 watts. At the upper center of the control panel is the test crystal, which plugs into jacks mounted in a polystyrene plate. Below the test crystal is the dial on the shaft of the frequency sweeping capacitor, with an adjustment knob (just to the right of the dial) for altering the spacing of the plates. This provides for altering the range of the frequency sweep.

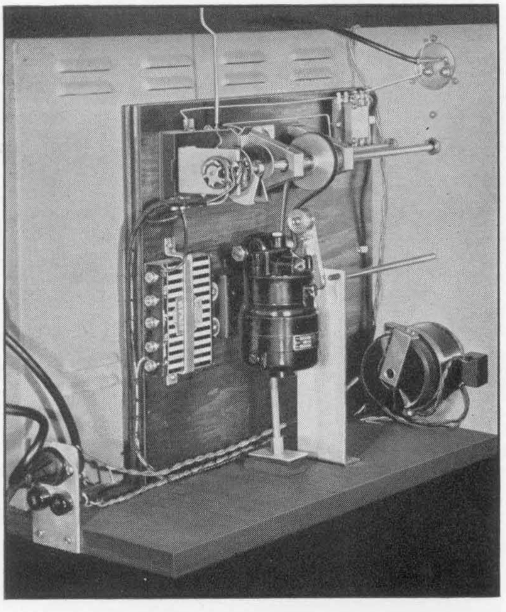


Figure 2. Rear view, showing the motor drive and frequency-sweeping capacitor.

Below these is the clutch control knob, operating a spring pressed idler wheel to be either free of the belt or to press on the belt connecting the drive motor and sweep frequency capacitor shaft. When disengaged, the sweep can be operated manually by rotating the dial. Where much routine use is made of the equipment, a motor drive is desirable. For occasional use, or for demonstration purposes, manual operation is entirely satisfactory.

At the bottom of the control panel is the Variac knob for controlling motor speed, the motor power switch, and a master power switch, which controls the battery and line supplies to the entire assembly.

In Figure 2, a view of the apparatus behind the control panel is shown. The motor, clutch-idler, belt, and the shaft of the frequency-sweeping capacitor are readily identified. On the shaft, from left to right, are (1) the potentiometer, for producing the synchronized horizontal d-c sweep voltage, (2) the blanking contactor which short-circuits the d-c vertical deflecting voltage during 120° of the rotation, and (3) the sweeping-frequency-capacitor moving plate, which gives a quite linear change in frequency for 240° of the rotation. The motor gear reduction and the applied voltage give sweep rates adjustable from about one per second to about one in twenty-five seconds. If too rapid a sweep is used, difficulty is encountered from "ringing" in the crystal.

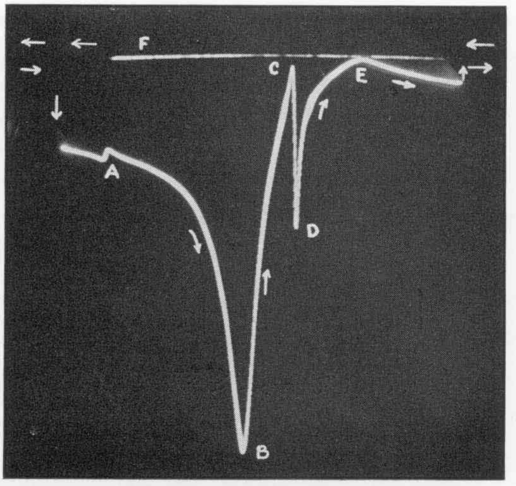


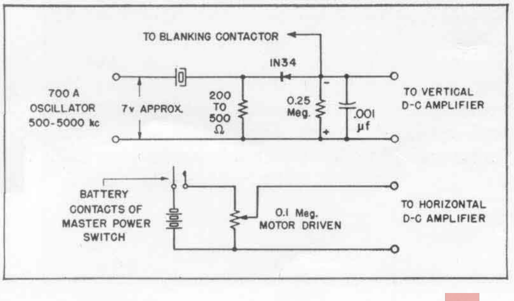
Figure 4. Oscillogram of the response of a quartz plate with two spurious response frequencies.

The fixed plate of the frequency-sweeping capacitor is a sector 15° wide supported on a guided block on the vertical base. By means of a threaded shaft this plate can be moved toward or away from the rotating plate to change the range of frequency sweep. A scale and pointer are provided so that the sweep range can be reset to desired values without the need of recalibration.

At the upper right are mounted the resistors, by-pass capacitor, and germanium rectifier used for obtaining a rectified d-c response voltage from the quartz crystal under test. The essentials of the circuit are shown in the schematic diagram of Figure 3. (For convenience in viewing, the germanium rectifier is poled to give negative deflections on the screen.)

An unretouched photograph of the response of a 1400 kc *AT*-cut quartz plate, before edge grinding, is shown in Figure 4. The sweep cycle starts at the

Figure 3. Schematic diagram of the electrical circuit.



upper left, with the spot moving to the right. As the blanking contact is closed, there is no vertical deflection. When the blanking contact opens, the spot drops downward along a vertical line, the distance depending on the shunt capacitance of quartz crystal and holder and on the frequency. Then as the spot moves to the right, in synchronism with the change in frequency, the response of the quartz crystal is traced. At the right edge of the figure the spot jumps up to the zero line when the blanking contact closes and finally returns along the zero line, *F*, to the initial position.

The response of a normal quartz crystal consists of a smooth curve from region *A* to a minimum, at series resonance, at *B*, followed by a smooth rise to a maximum at parallel resonance, at *E*, followed by a smooth drop.

In Figure 4, a small spurious response is indicated at *A*, and a larger one at *D*. Both of these move toward the left (toward lower frequencies), with respect to the principal resonance *B*, as the temperature is increased. The response at *D* increases rapidly in magnitude, with rising temperature and at some temperature *D* reaches the same level as *B*. The quartz crystal then has two response frequencies where the series impedances are low and equal. Any slight change in temperature then causes one response to be larger than the other. Under these conditions the frequency of an oscillator in which the quartz crystal is used will jump from one value to another. At *E* parallel resonance occurs between the quartz plate (acting as an effective inductance) and the total shunt capacitance. The impedance is high as evidenced by the spot returning to the zero line.

Suitable edge grinding causes the responses *A* and *D* to move to the right (toward higher frequencies). To produce a satisfactory quartz crystal, the grinding must be continued until response *A* has been carried clear through the operating region to a frequency well above the region shown in the photograph. All this is very straightforward, but the practical difficulties sometimes pile up when such edge grinding brings in additional responses, from the lower frequency side of the picture, which must, in turn, be moved out at the high frequency side — which brings in more low frequency responses, which must, in turn, . . . etc.

Only one difficulty has been experienced in setting up and operating this equipment, and that is frequency modulation of the oscillator output produced by mechanical vibration. Possible causes lie in the power supply of the instrument, where transformer vibration mechanically modulates some part of the two oscillator circuits, and in vibration transmitted from the motor or Variac to the sweep frequency capacitor, connecting wires, or to the oscillators of the source. The amount of such frequency modulation is minute, but, on a very steep portion of a quartz crystal response curve, it is readily observed as a lengthening of the spot. This difficulty is greatly reduced by use of sponge rubber mountings.

— J. K. Clapp

The crystal mode indicator described in the foregoing article is not manufactured for sale by the General Radio Company. The oscillator, oscilloscope, Variac, and motor are standard commercial products, as are many of the other parts. The complete assembly can be built in a well-equipped model shop, and crystal manufacturers will find it a valuable production tool.

— Editor

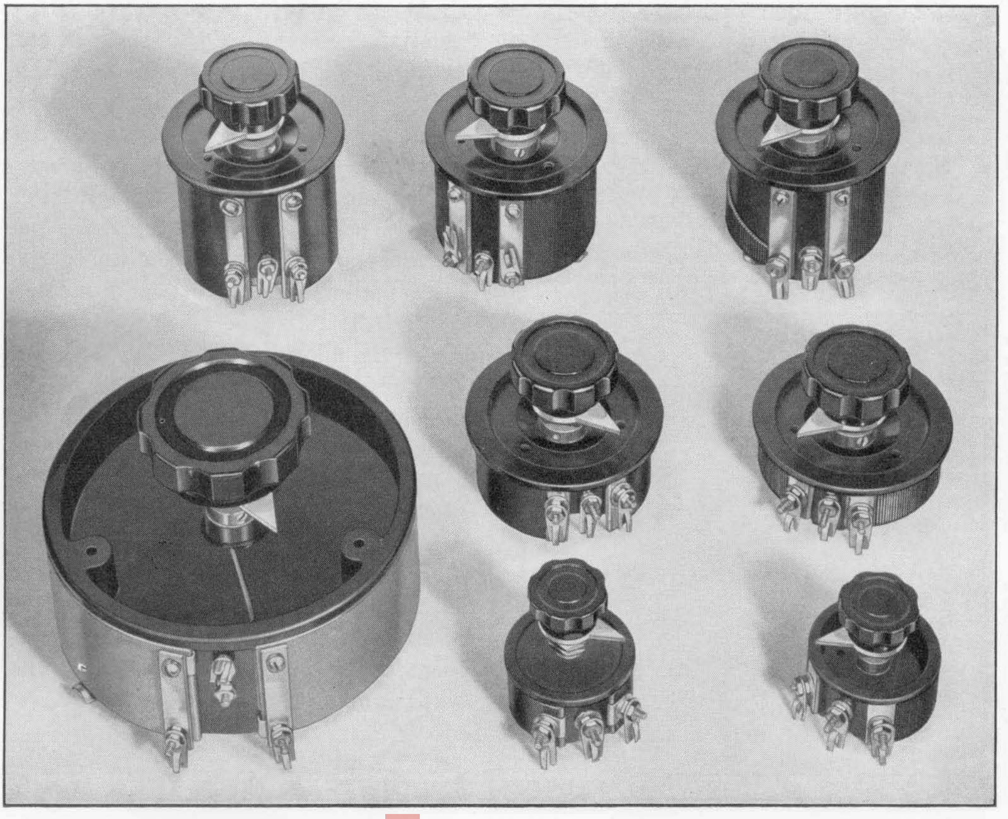
THE VERSATILE VOLTAGE-DIVIDER

PART I

A wire-wound potentiometer, or more accurately a voltage-divider, is superficially a very simple device. It consists of nothing more than a little resistance wire, wound around a supporting mandrel, with some sort of traveling brush arrangement to adjust the position at which contact is made to the wire. But the simple appearances are deceptive. This gadget is really insidious in its potential complexity. The circuit designer optimistically sees in it a panacea for all his troubles. He wants a potentiometer that will meet myriad requirements, many of which turn out to be mutually contradictory. He may want small size, high operating temperature, extreme linearity, very high resistance value, and a closely held curved relationship between resistance and rotation, which is often a curve having very steep portions.

When one of these "impossible" specifications comes to a potentiometer designer, he has to make up his mind whether to regard it as a challenge, or just to let the little men in the white coats come and get him. What he really does is to determine, with the circuit engineer, the best compromise between what is wanted and what can economically be done, probably dreaming up some new method or dodge under the pressure of the compromise to approach more closely the ideal desired.

Figure 1. A group of General Radio potentiometers showing the various sizes available.



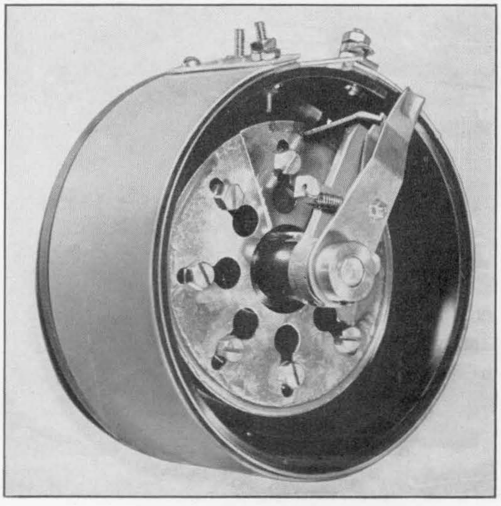
Potentiometers were among General Radio's earliest products. In producing them, the policy has been to aim for the quality rather than the quantity market, supplying highly critical users with a product for applications where the quality of materials and workmanship should be high with correspondingly long life, or where rigorous electrical specifications are to be met. Potentiometers, which can, of course, be used as rheostats by a change in connections, are stocked in standard resistance values which are decimal multiples of 1, 2, and 5. For specialized applications, units can be built to order, when the quantity desired is large enough to permit economical design and manufacture.

FEATURES

These potentiometers currently offer a number of features to provide flexibility of choice for the circuit designer, although combinations not listed in our current catalog are available only on special order:

1. *Sizes.* Molded bases are available having drum diameters, around which the flat-wound resistance strips are bent for attachment, between 1⅝″ and 5″. The larger sizes are used where more resistance or more power-handling capacity is needed. Sometimes, as will appear later in this article, one of the larger sizes is also needed where a steep resistance-rotation curve is to be met.

Figure 2. A 5-inch-barrel potentiometer with justifying mechanism. This resistor is used in the Type 650-A Impedance Bridge.



2. *Mandrel Widths.* Different widths of mandrel, that is, depth behind panel, are available. In particular, the 2½″ barrel-diameter bases are available with four mandrel widths. The reasons for changing widths are similar to those for changing sizes of base, with the additional reason that the width required is dependent on whether the takeoff brush is a single one riding on a narrow flat edge, or a multifingered one traversing part of the inside cylindrical surface.

3. *Shafts.* ⅜″ O.D. shafts are regularly available in centerless-ground stainless steel, paper-base phenolic tubing, or steel-cored phenolic. For special purposes, of course, shafts of other materials could easily be used such as brass, aluminum alloy, solid phenolic rod, etc. ¼″ O.D. shafts are generally available only in centerless-ground stainless steel.

4. *Resistance Alloys.* There are many resistance alloys available having controlled composition and resistivity. These vary in resistivity from 10.6 ohms per circular-mil-foot for copper, up to 800 ohms per circular-mil-foot for Evanohm or 331 Alloy. In general, as the resistivity of the alloy increases, the hardness, wear-resistance, and tensile strength increase, and the temperature coefficient of resistivity decreases. The higher-resistivity alloys are employed where high total resistance is desired without using too fine a wire. The low-resistivity alloys are used where it is important that the resistance per turn be low, or, in other words, that there be fine adjustment of the potentiometer because the total number of turns is large.

5. *Justifying Mechanism.* The largest, or TYPE 433, potentiometer, having a 5″ diameter barrel, can be provided with an adjustable justifying mechanism (see Figure 2). This mechanism provides a means by which the contact arm can be made to travel at a different rate from the driving shaft. This enables the user to make the potentiometer track more closely a predetermined (perhaps etched) scale than it would as it comes from normal manufacture. The justifying mechanism consists of a flexible cam, the shape of which can be altered by screwdriver adjustments (see illustration).

6. *Range.* By changing the many parameters that will effect the total, resistance values from 1 ohm (or even below) to 1 megohm can be obtained.

These parameters include:

a. Wire size.

b. Use of ribbon instead of round wire.

c. Spacing of wires.

d. Wire alloy.

e. Size of molded base.

f. Shape of winding mandrel.

7. *Accuracy.* For catalog models, the accuracy specification is ±5%. By using a continuously variable speed changer to drive the carriage feed on the winding lathes, and by continuous monitoring of the results, it is possible to maintain an accuracy of ±1% in total resistance. However, for some extreme mandrel shapes, which are discussed later, not even the catalog accuracy of ±5% can be guaranteed.

8. *Linearity.* If linearity of voltage division is an important property, this can be improved by close attention to dimensions of parts and by keeping the winding lathe free of looseness, or lash.

9. *Materials and Dimensions.* A number of the details of these voltage-dividers have been given particular attention in order to secure superior performance.

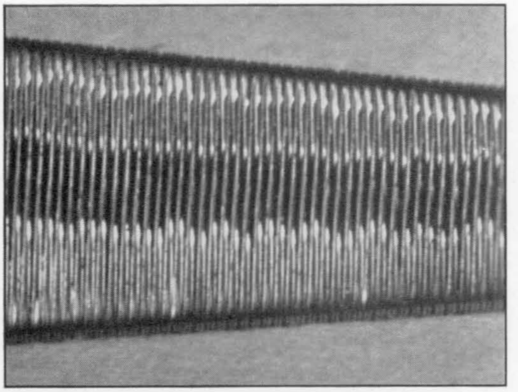


Figure 3. Close-up view of an Ayrton-Perry non-inductive winding on a tapered form.

Shafts are all centerless ground to control diameter closely, are made of stainless steel if of metal, or of a special grade of wrapped molded phenolic paper-base tubing having surface hardness controlled to resist damage from the points of set screws. The shafts run in journals of brass molded into the bases, which practice allows the shaft hole to be cylindrical and to be controlled for diameter better than a hole molded into the base. Shortly, when equipment now under construction is available, these shaft holes will be bored, rather than reamed, for still better control of size and direction (±0.0005″) on the diameter.

The mandrels on which the resistance wire is wound are made from a special grade of linen-base (rather than paper-base) phenolic sheet, in order to guarantee better flexibility for forming the mandrel around the molded base without cracking. Where bend radius is small, or where the mandrel has a narrow portion, a more expensive, nylon-fabric-base phenolic sheet is used, which has much better flexibility and tensile strength. A woodworking molder has been adapted to machine-finish the edges of these mandrels, assuring straightness and parallelism of the two long sides and a controlled smooth contour thereof, approximately semicircular.

These controls of width and edge contour are important if extreme linearity of voltage division is to be obtained (when a very linear voltage-divider is needed) or a particular curve is to be tracked accurately. It is also necessary to add another operation for turning the outside barrel of the molded base concentric with the shaft bushing, in order to remove eccentricity and molding taper, and to control the barrel diameter.

If accurate tracking of a resistance-rotation curve other than a straight line is to be attained, it is necessary also to control closely the thickness and the width of the mandrel (actually what needs to be controlled is the sum of thickness and width, which determines the length of wire per turn at a given rotation). If a number of voltage-dividers are to be gang mounted, it is sometimes necessary that the base of the molding be machined to be normal to the axis, in order to minimize the inevitable difficulties in such a structure in getting the shaft to run smoothly and easily.

10. *Non-Inductive Winding.* Where it is important to minimize inductance of the unit, the Ayrton-Perry method of winding can be employed (see Figure 3).

— P. K. McElroy

(*To be continued*)

This is Part I of a three-part article by Mr. McElroy on the design, performance, and application of wire-wound potentiometers. The other two parts will be published in early issues of the *Experimenter* and will cover such subjects as design tricks, limitations, economics, and examples of use.

— Editor

COAXIAL CONNECTORS FOR RG-8/U CABLE

We have received a number of inquiries about Type 874 Coaxial Connectors to fit the widely used Army-Navy Type RG-8/U concentric cable, and we are glad to announce that these are now available, as listed below. They are identical with the standard connectors for General Radio Type 874-A7 Cable previously announced,* except that the transition pieces, which connect to the cable, are designed specifically to fit RG-8/U cable.

Type		*Net Weight*	*Code Word*	*Price*
874-C8	**Cable Connector**	$1\frac{1}{4}$ oz.	COAXCORDER	**$2.00**
874-P8	**Panel Connector**	$2\frac{1}{4}$ oz.	COAXPUTTER	**2.25**
874-PC8	**Panel Connector with Cap**	$2\frac{1}{4}$ oz.	COAXTOPPER	**2.75**

This connector is licensed under U. S. Patent No. 2,125, 816.

*W. R. Thurston, "A Radically New Coaxial Connector for the Laboratory," *General Radio Experimenter*, October, 1948

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THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VOLUME XXIII No. 10 MARCH, 1949

A NEW BRIDGE FOR IMPEDANCE MEASUREMENTS AT FREQUENCIES BETWEEN 50 KILOCYCLES AND 5 MEGACYCLES

Also

IN THIS ISSUE

In recent years there has been a steadily increasing amount of activity in the frequency range from 50 kc to the lower end of the standard broadcast band. In particular the widespread use of frequencies in this band for various short- and long-range navigation systems for both ships and aircraft has led to a demand for impedance measuring devices to allow simple, accurate measurements to be made of antennas, circuit components, and various networks. The TYPE 916-A R-F Bridge has proven to be a very useful instrument for making this type of measurement in the broadcast band and up to about 60 Mc, but it is not very satisfactory for use at frequencies below about 400 kc. In order to cover this range satisfactorily, a modification of the TYPE 916-A R-F Bridge has been developed which is called the TYPE 916-AL R-F Bridge. This new bridge has a nominal frequency

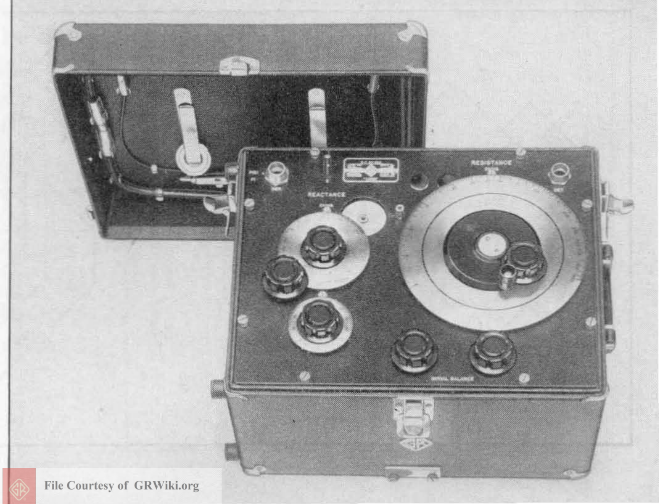


Figure 1. Panel view of the Type 916-AL Radio-Frequency Bridge.

range of 50 kc to 5 Mc, but it can be used at frequencies as low as 15 kc with some sacrifice in accuracy and sensitivity. Besides being useful at lower frequencies, it also has several advantages over the TYPE 916-A Bridge in the broadcast band, the most important of which is an increased sensitivity.

The basic circuit and method of operation of the new bridge are similar to those of the TYPE 916-A R-F Bridge[1,2]. A modified Schering bridge circuit is used in which the resistive and reactive components of the unknown impedance are measured in terms of incremental capacitances. The resistance of the unknown is indicated on a dial calibrated from 0 to 1000 ohms, and the reactance of the unknown is indicated on a main reactance dial calibrated from 0 to 11,000 ohms at 100 kc and an incremental reactance dial calibrated from 0 to 100 ohms at 100 kc. The resistance range is independent of frequency, and the reactance range is inversely proportional to frequency.

[1] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Mc," *General Radio Experimenter*, Vol. XVII, No. 3, August, 1942.

[2] Sinclair, D. B., "A Radio-Frequency Bridge for Impedance Measurements from 400 Kilocycles to 60 Megacycles," *Proceedings of the I.R.E.*, Vol. 28, No. 11, pp. 497-503, November, 1940.

Bridge Circuit

The basic bridge circuit is shown in Figure 2 and is the same as that of the TYPE 916-A. A complete analysis of this circuit has been published in previous articles,[1,2] and it will suffice to indicate here only the basic balance equations.

The relationships between the various bridge parameters necessary to obtain an initial balance with the unknown terminals short-circuited are given by the expressions:

$$R_p = \frac{R_B}{C_N} C_{A1} \quad (1)$$

$$C_{p1} = \frac{C_N}{R_B} R_A \quad (2)$$

After the final balance has been made with the circuit under test connected to the unknown terminals, the expressions for the unknown impedance in terms of the bridge parameters are:

$$R_X = \frac{R_B}{C_N} (C_{A2} - C_{A1}) \quad (3)$$

$$X_X = \frac{1}{\omega}\left(\frac{1}{C_{p2}} - \frac{1}{C_{p1}}\right) \quad (4)$$

As can be seen from Equations (3) and (4) the unknown resistance, R_X, is proportional to the change in capacitance of C_A, and the unknown reactance, X_X, is equal to the change in reactance of

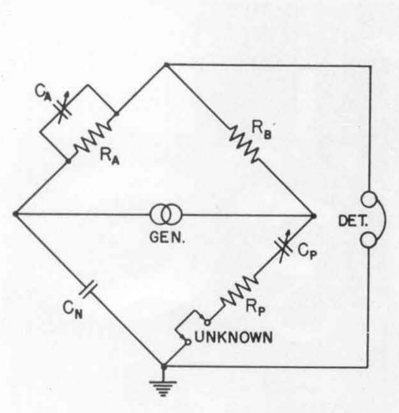


Figure 2. Basic circuit of the Type 916-A and Type 916-AL R-F Bridges.

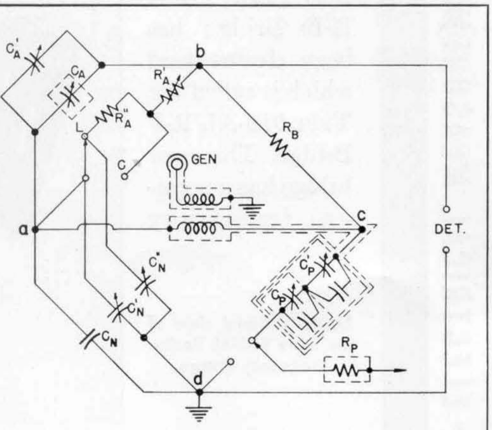


Figure 3. Complete circuit diagram of the Type 916-AL R-F Bridge.

C_p and has the opposite sign. This is the series-substitution method of measuring reactance. As a result of these relationships, the C_A dial can be calibrated directly in resistive ohms with the calibration independent of frequency and the C_p dial can be calibrated in reactive ohms at one frequency, with the calibration inversely proportional to frequency.

The new low-frequency bridge differs slightly from the higher frequency model in the method of setting the initial reactance balance, and in the type of standard resistor used. The capacitor C'_p, used only for the initial reactance in the older bridge, is calibrated in incremental reactance in the new bridge, and has a range of 0 to 100 ohms, with one ohm as the smallest division. The initial balance is made with an Ayrton-Perry, wire-wound rheostat, R'_A, for the coarse adjustment, with the incremental reactance dial furnishing the fine adjustment. The incremental reactance calibration greatly increases the accuracy of measurement of small reactances.

The standard resistor, R_A, in the low-frequency bridge is 2250 ohms as compared to 330 ohms in the high-frequency model. To increase bridge sensitivity, the reactances of the *a-d-c* arms, shown in Figure 3, have been lowered, and so C_N and C_p are larger than in the high-frequency model. Hence, for a resistance range of 1000 ohms, R_B must be made larger to get the same value of $\frac{R_B}{C_N}$ which is the multiplying factor for the resistance capacitor in Equation (3). It is difficult to manufacture a TYPE 663 Resistor of the required size, and so a unifilar construction on a mica card is used, similar to those used in the TYPE 510 Decade Resistors. At these lower frequencies the performance of this type of resistor is entirely satisfactory. A very small adjustable capacitance connected in parallel with the resistor compensates for small differences in the reactance of different resistors resulting from variations in the number of turns of wire.

As can be seen from Figure 4, the circuit changes just mentioned make the open-circuit sensitivity, that is, with an infinite impedance detector, considerably greater than that of the TYPE 916-A Bridge. The input impedance to the generator terminals also is higher, which increases the sensitivity obtained when a high impedance generator is used to drive the bridge, and the detector terminal output impedance is lower, which also tends to increase the actual signal input to the detector.

Operation

The operating techniques for the TYPE 916-A and 916-AL Bridges are very similar. The main differences are that on the TYPE 916-AL Bridge coarse and fine initial reactance-balance controls are provided and that the measured reactance is the algebraic sum of the dif-

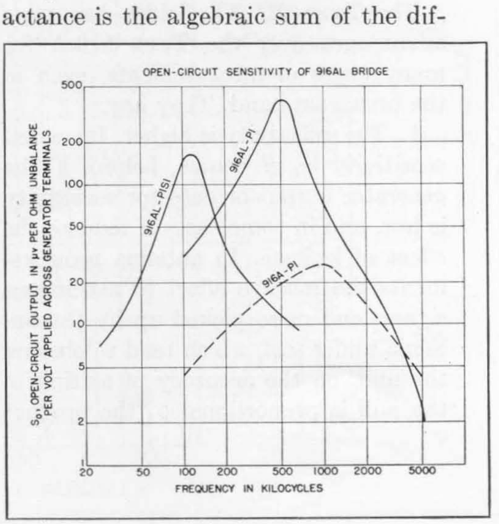


Figure 4. Sensitivity vs. frequency for the Type 916-A and Type 916-AL Bridges. Both the P1 and the P1S1 Transformers are supplied with the Type 916-AL. The P1 Transformer is used at low frequencies with the Type 916-A.

ferences between the final and initial settings of both the main and incremental reactance dials. The incremental reactance dial is mainly useful when the measured reactance is small; however, it also has been found to be very helpful when a series of measurements are to be made at the same frequency, as the main reactance dial can be initially set up scale at 1000 or so and a wide range of reactances of both positive and negative signs measured accurately without changing the initial balance.

As in the Type 916-A Bridge, the dielectric loss in the main reactance capacitor causes an error in the measured resistance of a circuit having a large reactive component of impedance. In most cases the error is negligible, as it amounts to about 0.03% of the measured reactance for large reactances and is somewhat less for smaller reactances. A chart is provided to correct for these errors when they are of importance.

Accuracy

The Type 916-AL R-F Bridge is particularly well suited to the accurate measurement of relatively low-impedance circuits over the frequency range from 50 kc to 5 Mc. The accuracy for resistance measurements is $\pm(1\% + 0.1\Omega)$, after correcting for the dielectric loss in the reactance capacitor at low frequencies. The accuracy of the reactance measurement at the higher frequencies is appreciably affected by residual parameters in the bridge circuit, that is, stray capacitances and inductances, particularly when the resistive component of the measured impedance is large. In fact, these residual parameters largely determine the upper frequency limit of the bridge. For frequencies up to 3 Mc, the accuracy is

$$\pm\left(2\% + 0.2 \times \frac{100}{f_{\text{kc}}}\,\Omega + 3.5 f_{\text{kc}}^{2} R \times 10^{-10}\Omega\right)$$

where R is the measured resistance and f_{kc} is the frequency in kilocycles. The errors in reactance when circuits having large resistive components of impedance are measured increase rapidly at frequencies above 3 Mc, and at 5 Mc the accuracy is $\pm(2\% + 0.01\Omega + 2.3R^{1.4} \times 10^{-3}\Omega)$.

COMPARISON OF THE TYPES 916-A AND 916-AL BRIDGES FOR OPERATION IN THE BROADCAST BAND

The Type 916-AL Bridge has some advantages over the Type 916-A for many types of measurements, even in the broadcast band. They are:

1. The sensitivity is higher. Increased sensitivity is, of course, helpful if the generator output or detector sensitivity is low, and in some cases it reduces the effect of leakage. In antenna measurements the relative effect of extraneous signals and noise picked up by the antenna under test, which tend to obscure the null, on the accuracy of setting to the null is proportional to the product of the sensitivity and the attenuation of the bridge between the circuit under test and the detector. In the normal connection of the generator and detector the Type 916-AL Bridge is much superior to the Type 916-A in this respect; however, a great improvement in the attenuation of undesired signals can be made in some cases with the Type 916-A Bridge by interchanging the generator and detector connections.[3] When this is done, in many cases the product

[3] Soderman, R. A., "Sensitivity of the Type 916-A R-F Bridge," *General Radio Experimenter*, Vol. XXII, No. 8, pp. 3, 4, January, 1948.

of sensitivity and attenuation may not be greatly different for the two bridges.

2. Small reactances can be measured accurately and conveniently and often much time can be saved by eliminating the need for frequent changes of the initial balance to obtain high accuracy when a series of measurements are made at one frequency. Even in applications in which the increased accuracy of the reactance measurement is unnecessary, the incremental reactance dial may be helpful as the expanded scale makes it much easier to read than the reactance dial on the TYPE 916-A.

The TYPE 916-AL Bridge has at least one disadvantage compared to the TYPE 916-A, which is that the maximum direct reading reactance range is smaller. At 1 Mc, the reactance range on the TYPE 916-AL is ± 1100 ohms, while it is ± 5000 ohms on the TYPE 916-A. However, the reactance range of the TYPE 916-AL is satisfactory for most measure-

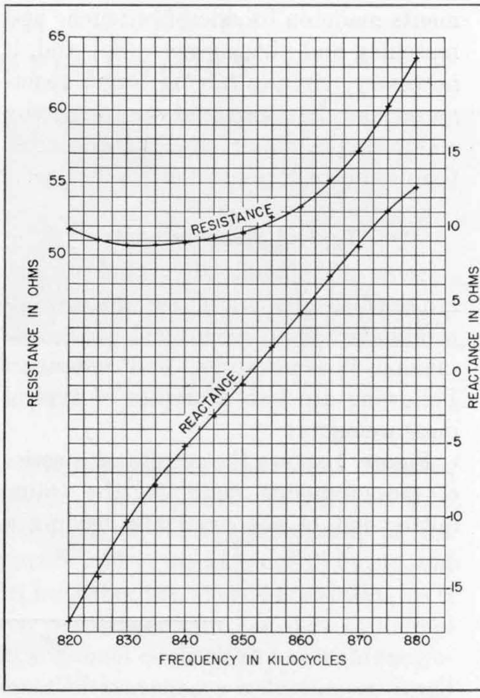
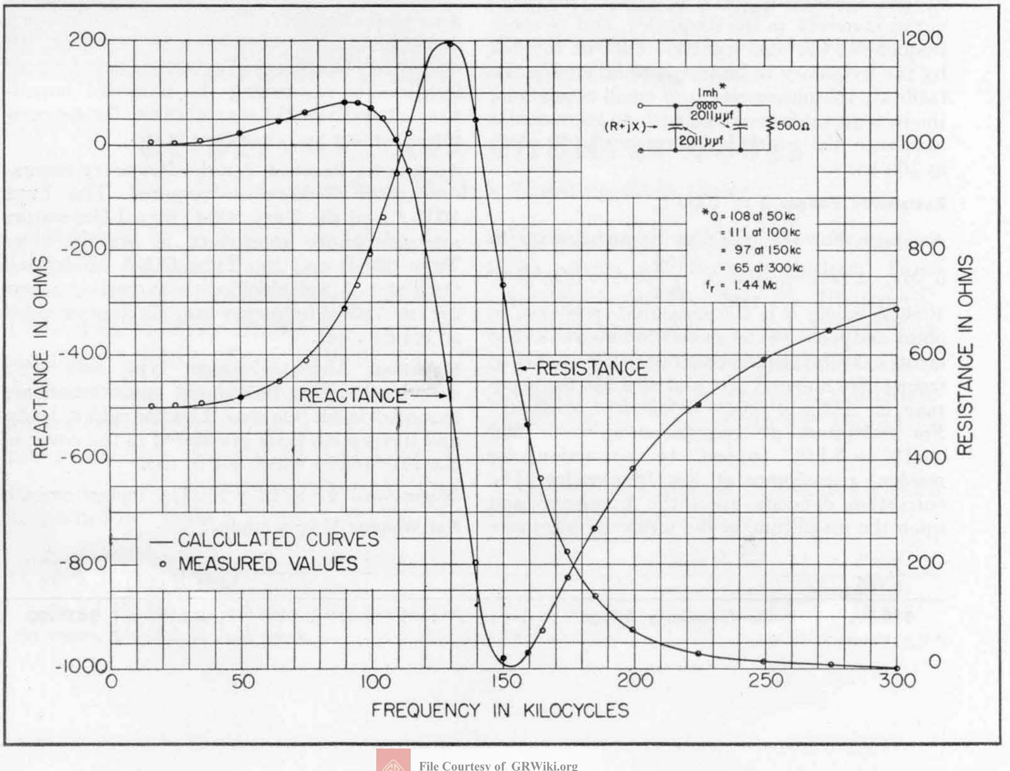


Figure 5. Measured input impedance of a coaxial transmission line feeding a 3-element antenna array.

Figure 6. Measured and calculated input impedance of a constant-K-type filter.



ments made on broadcast antennas and matching and phasing networks, and, if necessary, circuits having larger reactances can be measured indirectly by connecting a shunt capacitance across the unknown terminals of the bridge.

Typical Measurements

Some of the applications of the bridge are the measurement of resistors, capacitors, inductors, conventional and transmission line networks, and antennas. Following are two examples of typical measurements:

Figure 5 shows the results of a series of measurements made on the transmitter end of a coaxial line feeding a three-element antenna array with its associated matching and phasing networks. The probable accuracy of the generator frequency is about ± 1 kc, which explains some of the spread in the points from a smooth curve due to inaccuracies in the measurement of frequency.

The results of a series of measurements of the input impedance of a constant-K type, low-pass, π-type filter over the frequency range from 16 kc to 300 kc are indicated by the circles in Figure 6. The solid lines drawn on the graph are the theoretical values of the resistance and reactance calculated from the circuit constants.

—R. A. Soderman

SPECIFICATIONS

Frequency Range: 50 kc to 5 Mc.

Reactance Range: 11,000 Ω at 100 kc. This range varies inversely as the frequency, and at other frequencies the dial readings must be divided by the frequency in hundreds of kilocycles. To facilitate the measurement of small reactances, the instrument is provided with an incremental reactance dial which has a range of 100 ohms at 100 kc.

Resistance Range: 0 to 1000 Ω.

Accuracy: For reactance at frequencies up to 3 Mc, $\pm(2\% + 0.2 \times \frac{100}{f_{kc}}\Omega + 3.5 f_{kc}{}^2 R \times 10^{-10}\Omega)$ where R is the measured resistance in ohms and f_{kc} is the frequency in kilocycles. The errors in reactance increase relatively rapidly at frequencies above 3 Mc; and at 5 Mc the accuracy is $\pm(2\% + 0.01\Omega + 2.3\ R^{1.4} \times 10^{-3}\Omega)$. For resistance, at frequencies up to 5 Mc, $\pm(1\% + 0.1\Omega)$, subject to correction for residual parameters at low frequencies. The correction depends upon the frequency and upon the magnitude of the unknown reactance component. A plot of this correction is given in the instruction book supplied with the bridge.

Accessories Supplied: Two input transformers, one covering the range from 50 to 400 kc, the other from 400 kc to 5 Mc; two leads of different lengths (for connecting the unknown impedance); two Type 774 coaxial cables for connecting generator and detector.

Accessories Required: A radio-frequency generator and a detector are required. The Type 1001-A and the Type 805-C Signal Generators are satisfactory generators, as are the older Type 605-B and the Type 684-A Modulated Oscillator. A well-shielded radio receiver covering the desired frequency range is recommended as the detector.

Mounting: Airplane-luggage type case with carrying handles. Both input transformers are mounted inside the case. Coaxial cables, leads, and instruction book are stored in the cover of the instrument when not in use.

Dimensions: 17 × 13½ × 11⅛ inches overall.

Net Weight: 34¾ pounds.

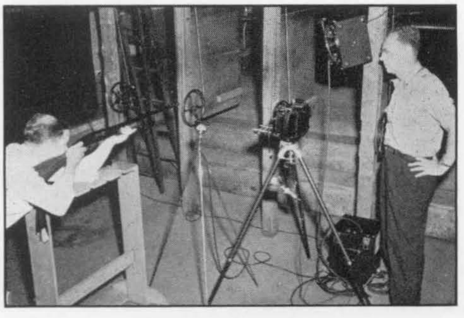
Type		*Code Word*	*Price*
916-AL	**Radio-Frequency Bridge***	CLUCK	**$450.00**

* U.S. Patent 2,376,394.

THE MICROFLASH LOOKS AT SHOTGUN COMPENSATORS

Game bird hunters and skeet shooters among our readers will be interested in the article entitled "Shotgun Compensators," which appeared in the October, 1948, number of *The American Rifleman.* Detailing the results of an investigation by National Rifle Association's Edwards Brown and Massachusetts Institute of Technology's Harold E. Edgerton, this article compares the performance of eight well-known types of chokes and compensators under a standardized set of conditions.

Figure 1.



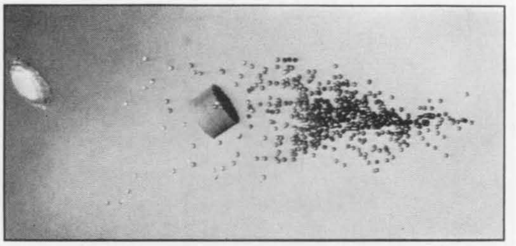


Figure 2.

Photographs of the shot patterns, taken at one-millionth of a second with the General Radio Microflash, at the muzzle and at distances of 10 inches and 10 feet from the muzzle are shown, as is the percentage of total shot contained in a 20-inch circle at 20 yards. Measurement of percentage reduction in recoil were also made by means of a ballistic pendulum.

The set-up used for photography is shown in Figure 1, and Figure 2 is a typical shot-pattern photograph at 10 feet from the muzzle.

GEIGER-MUELLER COUNTER TUBES

For Use with Type 1500-A Counting-Rate Meter

Two counter tubes, as listed below, are now available for use with the General Radio Counting-Rate Meter. They differ mainly in the thickness of the mica window. Type 1500-P4 has a thick window (3 to 4 milligrams per square centimeter), while Type 1500-P5 has a window density of less than 2 milligrams per square centimeter. The thin-window tube, Type 1500-P5, is intended for detecting low-energy particles such as Beta radiation from Carbon 14 and Sulphur 35. In general, it should be used wherever the particles to be counted have energies below about 0.3 mev. For higher energies, the thick-window tube, Type 1500-P4, should be used.

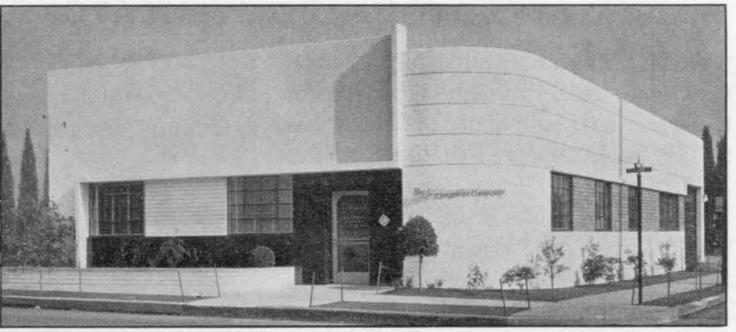
These tubes supersede Types 1500-P2 and 1500-P3 previously listed.

Type	*Window*	*Code Word*	*Price*
1500-P4	**Mica — 3 to 4 mg. per sq. cm.**	WORRYLOBBY	**$50.00***
1500-P5	**Mica — less than 2 mg. per sq. cm.**	WORRYLOCAL	**75.00***

* For export, add 10% to these prices.

BACK AT THE OLD STAND

Frederick Ireland



General Radio at Los Angeles.

General Radio's Los Angeles office, after two and a half years at a different address, is now back at its original location, 1000 North Seward Street. Under the capable direction of Frederick Ireland, of the factory engineering staff, this office is equipped to supply to West Coast customers any desired information on the characteristics, price, and delivery of General Radio products and to recommend equipment to meet specific requirements.

Many orders for popular items and parts of our manufacture can be shipped from stock maintained at Los Angeles. For items not stocked, this office will forward your order to our factory and will have information on hand regarding the date of shipment.

Please note that the telephone number at our Los Angeles office is HOllywood 9-6201.

MISCELLANY

PAPERS — At the 1949 I.R.E. National Convention, "A Device for Admittance Measurements in the 50- to 500-Mc Range," by W. R. Thurston, Engineer; and "The Measurement of Non-Linear Distortion," by A. P. G. Peterson, Engineer.

RECENT VISITORS to our plant and laboratories include Mr. J. P. A. Lochner, South African Council for Scientific and Industrial Development, Pretoria, South Africa; and Mr. J. V. Foll, Managing Director, Muirhead and Co., Ltd., Beckenham, Kent, England.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VARIAC MOTOR SPEED CONTROLS

INTRODUCTION

The Variac would appear to be an ideal component of a motor speed control, and much consideration has been given to the problem of developing a system employing it which would be suitable for general application. A study of the characteristics of various types of a-c motors operating on adjustable voltage has shown that, although series motors and straight repulsion motors are satisfactory with fans or with relatively constant loads, large changes of speed take place under varying load. A summary of the work on arrangements of this kind appeared in the *Experimenter* for February, 1944.

The Variac can be used also with a rectifier to supply adjustable armature voltage to a d-c shunt or compound motor, the field remaining fully excited over the speed range. This system can give a range of

Figure 1. View of a Type 1700-A Variac Speed Control installed on a bench lathe.

control of 15 to 1 or more. Use of this arrangement, however, has been limited, because it is considerably more complicated than the simple Variac control and, as usually constructed, leaves much to be desired in the way of regulation.

Recent development work on the Variac-rectifier system, however, has overcome many of the earlier limitations. As a result, the TYPE 1700-AL and TYPE 1700-AH Variac Speed Controls are now offered as compact single-unit controls having a maximum rating of ⅓ h.p. and with regulation characteristics entirely adequate for a large variety of applications. These controls, however, are not intended to replace the more complicated electronic controls for uses where very close regulation of speed with load is required.

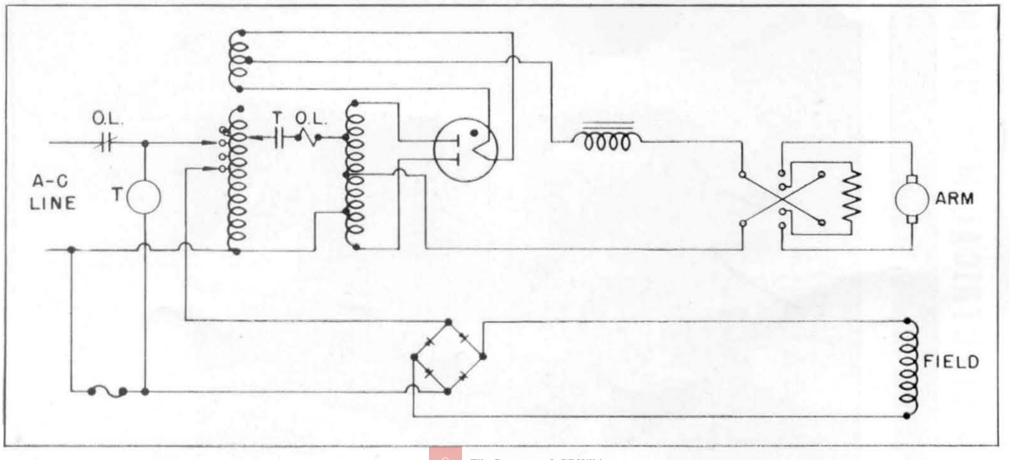
The external appearance of the new control is shown in Figure 1. Much of the design work was directed to achieving a compact construction which would permit the control to be placed beside a machine in the location of the usual push-button station. A manual start-stop-reverse switch is built into the control so that the need of a button station and separate box for the reversing contactors is eliminated. Only the control box and the motor are required for the complete system. This arrangement not only reduces the cost but also very much simplifies installation. Other important characteristics are the low ripple current in the armature circuit and the large overload capacity available for quick starting and reversing.

CIRCUIT DETAILS

The circuit is shown in Figure 2. The Variac supplies a full-wave xenon rectifier through a step-up autotransformer. A separate winding of a few turns on the Variac supplies filament power for the rectifier. The rectifier output goes through a choke and a three-position reversing switch to the motor armature. In the "off" position of the switch, a dynamic braking resistor is connected across the armature to stop the motor quickly. The coil of an overload breaker interrupting the input line is connected in the primary circuit of the autotransformer. The breaker serves also as the line switch.

A selenium rectifier bridge supplies the field current. Extra taps on the Variac permit boosting the input to the rectifier so that 230 volts dc can be obtained across the field from an a-c input voltage of the same value. Other taps can be used to reduce the field ex-

Figure 2. Circuit of the speed control unit. Industrial, rather than radio, symbols have been used for those elements that are peculiar to industrial equipment. Hence, the symbols T, T refer to the timing clock and its associated switch, and O.L. refers to the overload breaker.



citation and thus increase somewhat the maximum speed. To prevent damaging the rectifier tube, a timing clock delays application of plate voltage for 40 seconds after the filament is turned on. This delay unit recycles in less than a second and so protects the tube against interruptions of line voltage. It will not break the circuit on transient dips of voltage, however, and so prevents needless interruptions of service. The timing clock is connected beyond the field fuse so that armature power cannot be supplied unless this fuse is intact and in place.

CONSTRUCTIONAL FEATURES

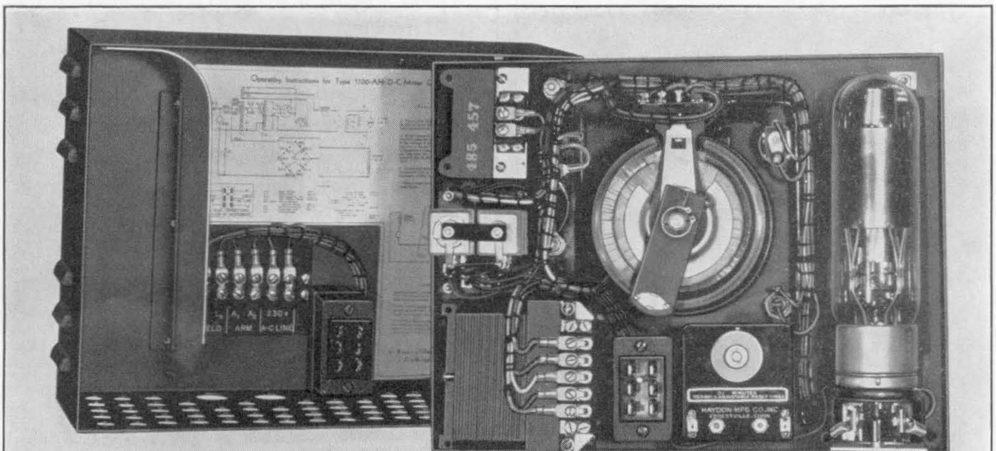
Several problems were encountered in making the entire control small enough to be placed beside a machine for direct control by the operator. An interior view of the control is shown in Figure 3. The box size is only 9 x 12 x 4½ inches so that little space is available between the components for assembly and wiring. This difficulty was overcome by mounting all components on the lid, permitting the wiring cable to be installed without interference from the sides of the box. This construction and the use of a plug and jack between the box and lid permits the box, also, to be permanently installed and the unit removed when desired for servicing without disturbing the installation wiring. Where several controls are in use, a spare can be kept and can be used to replace in a few seconds a unit needing attention.

Another design problem was to control the flow of heat from the rectifier tube, which is between 50 and 100 watts, so that overheating of the other components is prevented. To accomplish this, side louvers are provided and an aluminum baffle plate is placed between the tube and the remainder of the enclosure. The plate not only guides the heated air stream up to the louvers but also reflects back radiant heat from the tube. The Variac, transformer, and choke are mounted in close thermal contact with the lid, the outer surface of which provides considerable radiating area. The effectiveness of these measures is indicated by the fact that three hundred watts of armature power and forty watts of field power can be provided continuously by a unit of such small dimensions without overheating.

REGULATION CHARACTERISTICS

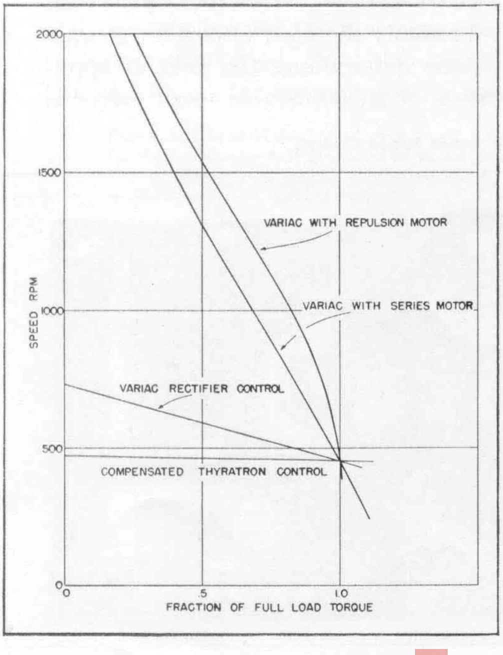
Probably the most important characteristic determining the field of application of an adjustable speed motor is

Figure 3. Interior view of the Variac Speed Control.



the speed regulation or change of speed which takes place when the load is varied. Close speed regulation in an adjustable speed motor is an expensive commodity, and it is wasteful to provide it for applications where it is not required. Information on the regulation of the Type 1700 Controls in comparison with that of a thyratron control and with the simpler controls should indicate the general fields of usefulness of each. Considerable saving in the cost of an installation can be made if the characteristics of the motor and control are properly matched to the regulation requirements of the load.

The Type 1700 Controls provide a quality of regulation which is very much better than that of the simple controls such as a Variac with an a-c commutator motor, although not so good as is obtainable with the fully compensated thyratron control. This is illustrated in Figure 4 which shows the speed as a function of load for different motor and control combinations, all adjusted to about one quarter of the maximum speed at full load.



The upper curve is for a repulsion motor with a Variac. The next curve is for a similar arrangement using an a-c series motor. The two are essentially similar except that the repulsion motor "breaks down" or suddenly loses speed like an induction motor, but at a much lower fraction of synchronous speed. The series motor loses speed more or less uniformly as the torque is increased in the neighborhood of full load. For both motors at this setting the speed at one-quarter load is about four times the full-load speed and even a slight change in load results in a considerable change in speed. The improvement with the Type 1700 Control is shown in the third curve. The rise in speed when the torque is reduced to one-quarter of its full-load value is only 210 rpm or 47 per cent instead of 300 per cent or more noted for other arrangements. A curve for 5 per cent regulation, readily achieved with the compensated thyratron control, is shown for comparison.

The rise in speed in rpm between full load and no load is the same at all speed settings for the new control. This performance is not necessarily obtained with a system of this kind, because on light loads the back emf of the motor, which is proportional to the speed, tends to rise to the peak value of the rectified wave. Use of a properly designed choke will prevent the rise of voltage above the average value and greatly improve the regulation. Figure 5 shows regulation curves at various speed settings for the Type 1700–AH Control and shows by dashed lines for comparison the performance of a similar system without a choke. The marked improvement is apparent. Since the rpm rise in speed

Figure 4. Comparison of the performance of various types of control systems adjusted for one-quarter maximum speed at full load.

between full load and no load is the same at all settings, the percentage regulation is inversely proportional to the speed setting. Thus at the rated speed of 1750 rpm the regulation is only 16 per cent instead of the larger value corresponding to the reduced speed setting used in Figure 4.

MOTOR LOSSES AND EFFICIENCY

In comparison with a speed control of the thyratron type, the new control gives considerably reduced motor losses, because the a-c ripple in the armature circuit is very much less. This characteristic is partly due to the fact that the firing point is not delayed by grid action and partly due to use of the choke. Use of the diode rectifier in the new control makes it possible to obtain good filtering using only a small choke, while it is not usually feasible to attempt to filter the sharply peaked waveform of the thyratron rectifier circuit.

The net result is that the form factor of the armature current of the thyratron control at full load is about 1.55 at all speed settings[1], and for the Variac Rectifier Control varies between 1.16 at full speed to 1.02 at one-tenth of maximum speed. Curves of form factor as functions of load at various speeds are given in Figure 6.

Since it is the low-speed losses that usually limit the rating of an adjustable-speed motor, the result in practice is that no derating of the motor due to ripple is required with the new control.

1 Raymond W. Moore, "Performance of D–C Motors Running on Thyratron Rectifiers," ELECTRICAL MANUFACTURING, Vol. 37, pp. 124-127, 210, 212, 214, March, 1946.

With the thyratron control the motor must be derated about one-third. For many applications employing the Variac control, it is a convenience as well as an economy not to have to use an oversize motor to take care of the ripple current in the armature circuit.

STARTING CURRENT AND OVERLOAD CAPACITY

The full-wave xenon rectifier is more compact and less expensive than a pair of thyratrons of equal rating, so that it is economically feasible to provide tube capacity in the Type 1700-AH Control almost five times the full-load armature current rating of the motor. The rectifier tube, in addition, has a three-second overload rating 50 per cent greater than its continuous-duty rating. This permits about seven times the full-load motor current for three seconds on starting or reversing, and the momentary initial surge of current may be even greater. The circuit breaker is of the inverse-time-delay type and its delay characteristics are approximately

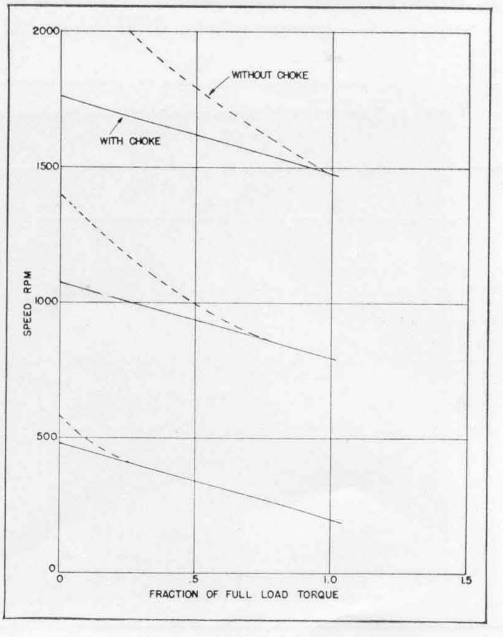


Figure 5. Regulation curves at various speeds for the Type 1700-AH Variac Speed Control. Dotted lines show performance of a similar system without choke.

matched to the overload rating of the rectifier tube, as shown in Figure 7. With this protection, advantage can be taken of the short-period overload capabilities of the tube without risking destruction in the event of a stall or the application of a load of excessive inertia. The TYPE 1700–AL Control for 115-volt operation, employing the same tube, has the same current rating at half the voltage so the overload and starting margin is reduced. Even in this case 350 per cent of full-load current, ample for ordinary work, is available for starting, and full protection is provided by the breaker.

The quick-starting feature of the control is frequently of great importance in production work. Many of the thyratron controls provide protection of the tubes by automatically limiting the starting current to 150 or 200 per cent of the full-load current. This is sometimes necessary in special cases for protection of the driven load, but for ordinary work the relatively slow start is a definite drawback. The TYPE 1700 Controls should prove their value in many applications where fast starting or reversing is desirable.

APPLICATIONS

Many fields of application of adjustable speed motors which have been assumed to require a control of close regulation can be served by the TYPE 1700 Controls. This is because the choice has hitherto been limited, essentially, to controls of either very good or very poor regulation. It has been found, with the new control, that even the speed rise of 100 per cent or more which takes place at the lower speed settings when the load is removed is not ordinarily objectionable. In work with small lathes or drill presses, for example, the operator merely turns up the control until the desired cutting speed is obtained under load. It is believed that work of this kind within the torque limits of a ⅓ h.p. motor will generally be found suitable for the TYPE 1700 Controls.

An application for which the new control seems ideally suited is to winding machines of various types. Here a wide range of operating speeds is desirable in addition to a gradual start under control of the operator. Considerable production time, also, can be saved if, after starting, the speed can be turned up to

Figure 6. Form factor of armature current as a function of load at various speeds.

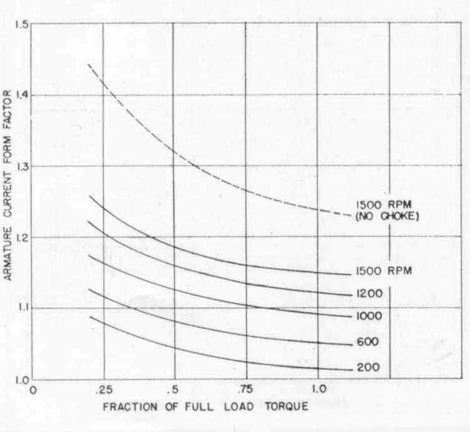
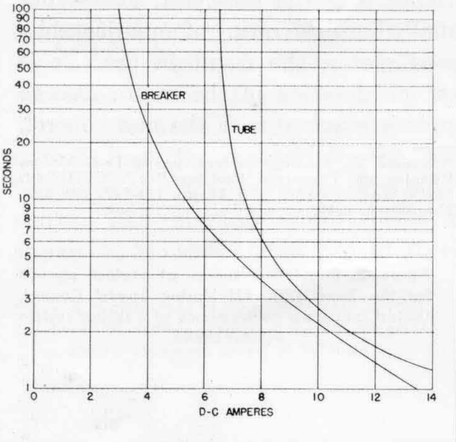


Figure 7. Overload characteristic of rectifier tube and delay characteristic of circuit breaker.



the maximum which is safe for a given set of winding conditions. Universal winding machines are generally supplied with adjustable speed motors of the brush-shifting type. These have characteristics similar to those of a repulsion motor operated with a Variac and, particularly at the lower-speed settings, are very sensitive to load, as shown in Figure 4. The speed tends to creep badly and even warm-up of the lubricating grease can cause the speed to double. In our own factory we have found that use of the Type 1700 Control gives a marked increase in the stability of operation of machines of this type with a corresponding increase in production efficiency.

Another application which should prove important is to processing of various kinds where the timing of an operation must be adjustable over a fairly wide range. Examples are blueprinting machines, photographic developing equipment, electroplating, etc. In work of this kind the load is nearly constant, and the motor will hold the set speed very closely. Slight changes of speed will occur with line voltage variations, but the speed changes less than in proportion to the voltage change. This is because in a shunt motor the change in field excitation partially compensates for the armature voltage variation.

The limitations of the control must be kept in mind in order to apply it successfully. The intermediate quality of the regulation characteristics has already been discussed. Much machine work, including precision grinding, requires that speed be very closely maintained under fairly wide variations of load. For such applications, the control is clearly not suitable. Another limitation common to many adjustable-speed motors is that torque rather than horsepower must be kept within a limiting value over the speed range. If an adjustable speed motor replaces a fixed speed motor using several pulley ratios, the available horsepower instead of being the same at the various fixed speeds will be proportional to the speed. This is not as serious as it might appear because many types of load have a constant torque characteristic or a torque that decreases as the speed is reduced. The point should be borne in mind, however, in estimating the size of motor required for a given application. Because of the torque limitation, it is important to choose the pulley or transmission ratio so that the working speed range is near the upper limit of the control.

Figure 8. Panel view of the Type 1700-AH Variac Speed Control.

If the characteristics of the control and motor are properly matched to the load requirements, it is believed that a wide field of application will be found for the TYPE 1700 controls, and that the advantages of adjustable speed operation can be extended to many fields where the cost of other suitable systems is prohibitive.

— W. N. TUTTLE

SPECIFICATIONS

Ratings	*Type 1700-AL*	*Type 1700-AH*
Supply Frequency	50–60 c	50–60 c
A–C Input Voltage	105–125	210–250
D–C Output Armature Voltage	0–115	0–230
D–C Output Armature Current		
Continuous	2.6 a	1.35 a
30 Seconds	9.6 a	9.6 a
D–C Output Field Voltage	115, 105, 95, 78	230, 210, 190, 156
D–C Output Field Current	0.4 a	0.2 a

Speed Range: Motor rated speed down to zero at constant torque. Usual operating range 10:1 or 15:1.

Motor: Any d-c shunt or compound motor within the above ratings may be used with the control. A motor with a commutating pole is preferable because improved commutation is obtained over the speed range. We can supply motors as listed below.

A motor of ¼ h.p. rating can be operated continuously at about 20% overload by the TYPE 1700–AL Control and at about 25% overload by the TYPE 1700–AH Control. A motor of ⅓ h.p. rating can be used with either control for intermittent duty or for continuous duty when the armature current is within the limits given in the ratings.

Overload Protection: A time-delay magnetic circuit breaker protects the rectifier tube against excessive starting current but does not protect the other components or the motor against sustained overloads. For applications requiring continuous duty near full load, the armature current requirements should be checked with a meter.

Reversal and Dynamic Braking: A manually operated start-stop-reverse switch and a dynamic braking resistor are included in the control. Strong braking action is obtained in the stop position.

Mounting and Wiring: Holes are provided in the back of the box for mounting on a wall or bracket. Mounting must be vertical and must permit free access of air through the bottom of the cabinet. Two holes for BX or conduit wiring are located in the center of the bottom of the box.

Dimensions: Box, 9 5/16 x 12⅜ x 4⅝ inches; dimensions over knobs and louvers, 9 5/16 x 12¾ x 6 inches.

Net Weight: 31¼ pounds; G. E. motor 30 pounds.

Tube: One TYPE EL-6C supplied with the control.

Type		*Code Word*	*Price*
1700–AL	**Variac† Speed Control,** 115-v., 50-60 c.	ABASE	**$175.00**
1700–AH	**Variac† Speed Control,** 230-v., 50-60 c.	ABOVE	**175.00**
BC46AB29	**G. E. ⅓ h.p. Semi-enclosed, sleeve-bearing, compound-wound motor,** 1750 rpm, 115 v. dc, for use with TYPE 1700–AL	MOTOR*	**45.79**
BC46AB30	**G. E. ⅓ h.p. Semi-enclosed, sleeve-bearing, compound-wound motor,** 1750 rpm, 230 v. dc, for use with TYPE 1700–AH	MOTOR*	**47.59**
EL–6C	**Full-wave xenon rectifier tube** (Spare)		**15.70**

*To order speed control with motor, use compound code word, ABASEMOTOR or ABOVEMOTOR.
†Trademark registered in U.S.A. U.S. Patent No. 2,009,013.

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THE General Radio EXPERIMENTER

VOLUME XXIII No. 12 MAY, 1949

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A HIGH-POWER, LOW-SPEED STROBOSCOPE

Also

IN THIS ISSUE

●**STROBOSCOPIC OPERATION** at low speeds, below, say, about 600 r.p.m., has been hampered seriously by the lack of a really powerful lamp, giving sufficient light to impress a positive image on the retina of the eye, in spite of normal room lighting and the comparatively long interval between flashes.

At low speeds the light flashes from the more usual stroboscopic lamps are sufficiently short to arrest the motion under observation, but the other factor usually considered necessary for successful stroboscopy, namely, persistence of vision, is no longer present. At speeds of 10 a second, flicker is evident, becoming more pronounced as the flash speed is lowered. The amount of light reaching the eye per unit of time also becomes progressively less, and successful observations can often be made only in darkened surroundings.

To a great degree, this difficulty can be overcome by increasing the power in the flash, so that the image from the flash is much more intense than that from the background light. For use where lighting conditions are favorable, the General Radio Company has supplied special Strobotacs with an additional low-speed range, 10-to-1 down from the standard low range. These have been used

Figure 1. View of the Strobolume with lamp mounted in case.

with considerable success in a number of industries, but they have never been catalogued, because their successful use depends so greatly on the experience and ingenuity of the user.

In the TYPE 1532-A Strobolume the problem of adequate light has been successfully solved. This new stroboscope gives a brilliant light flash of about 10-microsecond duration, so intense that, for prolonged observation, goggles are recommended. This high-power flash overrides background illumination sufficiently to make possible successful repetitive observations at speeds as low as one per second. When adjustable density Polaroid goggles are used, the illumination level can be controlled, so that background lighting is effectively eliminated, and the stroboscopic image reaches the eye at a comfortable level. The tendency of the eye to try to follow the motion of the subject between flashes is also removed by this procedure.

As shown in Figure 1, the strobolume is a small compact unit containing a power supply and a lamp. The lamp is removable from the case and connects to the power supply by a 15-foot cable (see Figure 4). The lamp housing is

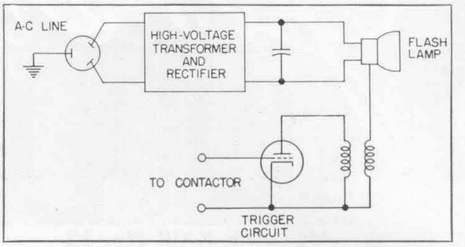


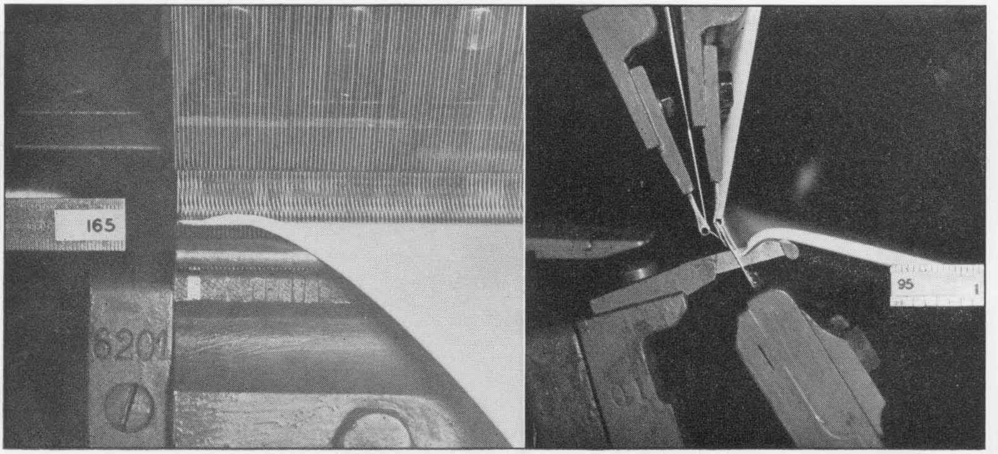
Figure 3. Functional circuit diagram of the Strobolume.

tapped for tripod mounting (¼-20 thread).

The power supply consists of a transformer and rectifier, which charge a 4-μf capacitor to about 2000 volts, giving an energy per flash of 8 watt-seconds. The flash is triggered by a pulse from a high-voltage Strobotron, which ionizes the gas in the lamp sufficiently to initiate the discharge of the capacitor through it. The average rate of energy dissipation during the discharge is several hundred kilowatts. The elementary circuit of the Strobolume is shown in Figure 3.

The Strobolume can be flashed from a push button, a contactor, or a special slow-speed Strobotac. For observations of machinery, the TYPE 549-P2 Hand Contactor is often used. For single flashes, the push button, which is furnished as an accessory with the Strob-

Figure 2. Front view (left) and side view (right) of a warp knitter in operation, as seen by the Strobolume.



olume, is adequate. For general observation and measurement work, the TYPE 631-BS18 Strobotac provides a flashing means that is adaptable to a variety of applications. To connect the Strobotac to the Strobolume, a TYPE 1532-P2 Cable must be used.

The Strobolume opens up for stroboscopic measurement a vast field of slow-speed machinery. Looms, printing presses, heavy grinding and crushing equipment, and packaging machines are a few of these. In addition to its use as a stroboscope, it is an excellent light source for single-flash, ultra-high-speed photography, two examples of which are shown in Figure 2.

The range of flashing rates obtainable with the Strobolume is shown in the specifications below. Note that the safe operating time varies with the flashing rate. A built-in circuit breaker gives assurance that this time will not be exceeded and hence protects the instrument from damage.

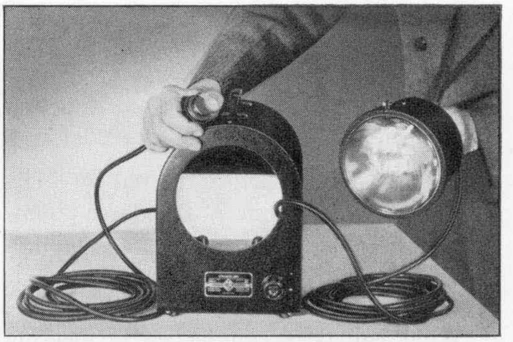


Figure 4. View showing lamp removed from case.

—W. R. SAYLOR

SPECIFICATIONS

Duration of Flash: Approximately 10 microseconds.

Flashing Control: External contactor or Strobotac. Special Strobotacs for these low speeds can be supplied.

Tubes:

1	Rectifier	Type 816
1	Strobotron	Type OA5
1	Flash Lamp	Type 1532-P1 (GE Type FT-220)

Flashing Speed Range: Continuous, 45 flashes per minute, maximum; intermittent, or for short periods, up to 1200 flashes per minute. Maximum safe operating time is as follows:

TABLE I

Flashes per Minute	*Approximate Time for Breaker to Open*
60	——
300	1 min. 45 sec.
600	30 sec.
900	20 sec.
1200	15 sec.

Accessories Supplied: Power cord with ground terminal; push button; flash control cord for connection to contactor or push button.

Other Accessories Required: None, if lamp is to be flashed manually by push button. For stroboscopic work, a contactor or a special Strobotac is needed.

Mounting: Metal case with rounded top; lamp is removable; storage space for lamp cable is provided in case. Tripod mounting thread (¼-20) is provided in lamp housing.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles.

Power Input: 70 watts at 60 flashes per minute; 500 watts at 1200 flashes per minute.

Dimensions: 13 x 7½ x 11 inches, over-all.

Net Weight: 18½ pounds. Lamp only, 2 pounds.

Type		*Code Word*	*Price*
1532-A	**Strobolume**	TITLE	**$225.00**
1532-P1	**Replacement Lamp**	TOWEL	**24.50***

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*Including Federal tax.

THE VERSATILE VOLTAGE-DIVIDER

PART II

DESIGN TRICKS

The usual departure desired by a circuit designer from a standard potentiometer having a rectangular mandrel is a resistance-rotation curve which is something other than a straight line. What can be accomplished in meeting the requirement depends almost entirely on the shape of the curve. There are a number of tricks that can be employed. In general, the greater the curvature, the more drastic are the tricks required and the greater their cost. Some of the methods of meeting curves are these:

1. **Sectional Windings.** The most usual dodge employed in the industry is to wind the mandrel with two or more different wires, differing from one another in diameter, resistivity, or both. Naturally, such a scheme does not really meet the curve. Rather, it produces a dog-leg instead of a curve, a succession of straight lines, approximately chordally related to the desired curve. The locations of the intersections of the chords can be chosen to minimize the deviations from the curve. The more sections there are, each using different wire, the more chords there are, and the more closely the curve is approximated. Unfortunately, the method is somewhat costly, and there is possibility of trouble in meeting the curve at the several joints between sections. The joints are also a possible danger source if they open up.

2. **Tapered Mandrel (Trapezoidal).** The next easiest mandrel shape to make, other than a rectangular one with parallel sides, is a trapezoidal or straight-tapered one. These are very easily manufactured by use of a long rectangular notching punch and die. The resistance-rotation curve from such a form wound with one size and kind of wire is part of a parabola. The curve does not start at the origin, since the narrow end does not have zero width. The ratio of widths between wide and narrow end determines how nearly the small end of the parabolic curve approaches the origin. In general, it is possible to wind such mandrels with any desired spacing between wires without collapse of turns. Hence, adjustment of wire spacing can be employed as a means of making the over-all resistance accurately the desired one.

3. **Double Sawtooth (2 Trapezoids).** Where it is necessary that the ratio between the slopes at the two ends of the resistance-rotation curve must be greater than can be realized with one trapezoid (something like 8 or 10:1), the mandrel can be shaped to have two trapezoidal sections (see Figure 4). The wire size and/or resistivity must be changed between sections to provide the proper resistance per unit area of the mandrel.

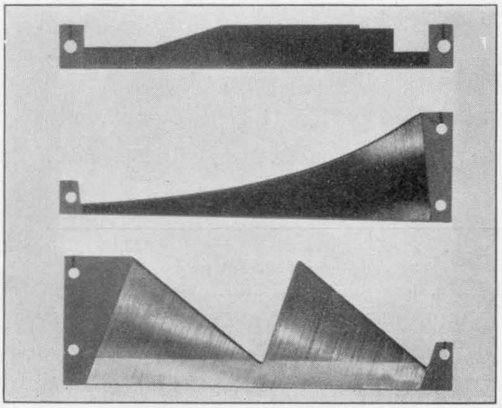

Figure 4. Three types of mandrels shaped to give desired resistance variations. At the foot is a double sawtooth, in the center a logarithmic, and at the top a combination of shapes.

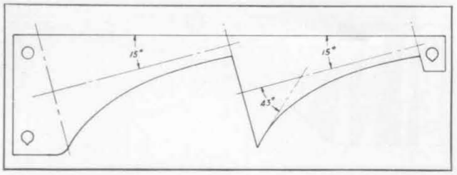

Figure 6. Double logarithmic mandrel for 30-db range.

4. **Logarithmic Shape.** Another desired type of resistance variation with rotation is the logarithmic one (see Figure 4). Such a potentiometer used as a rheostat in a Wheatstone Bridge will be adjustable with constant fractional accuracy at all parts of an attached dial. The mandrel is made with one edge straight and the other edge curved. The logarithm of the width of the mandrel is proportional to the rotation angle. In practice, since the mandrel and the wire have some thickness, it is necessary to make allowance for these facts by reducing the width of the mandrel at the narrow end, because what must vary exponentially is really the resistance per turn of the winding, hence, the length of each turn.

5. **Double Logarithmic.** A single logarithmic mandrel for a Type 371 Potentiometer, having a 2½″ diameter barrel and a 2⅙″ mandrel width cannot be made for more than 20 db or a 10:1 ratio between extreme turn lengths, without making the mandrel impractically fragile at the narrow end. The same trick of using a double sawtooth, as described in (3) can be used to get a higher ratio. A considerable number of double sawtooth 30-db (about 30:1) logarithmic potentiometers have been made using the mandrel shown in Figure 6.

6. **Combinations.** If the resistance-rotation curve is too steep at the high end to be windable, it is sometimes still possible to provide an acceptable approximation. The mandrel might have a curved shape for the majority, say 75 or 80%, of the rotation. Over this area a single sort of wire would be wound. The remaining small portion of the mandrel would have parallel sides, and one, two, or more sections could be wound with different wires to provide a chorded approximation to the steep end of the curve (see Figure 7). This dodge can, of course, only be employed if the closeness of tracking at the steep end is not as critical as it is elsewhere.

Another combination mandrel shape is shown at the top of Figure 4.

LIMITATIONS

In the listing of Design Tricks given above for meeting special resistance-rotation curves, no indications have been given of the limitations imposed on the universal applicability of such tricks by the materials used and the

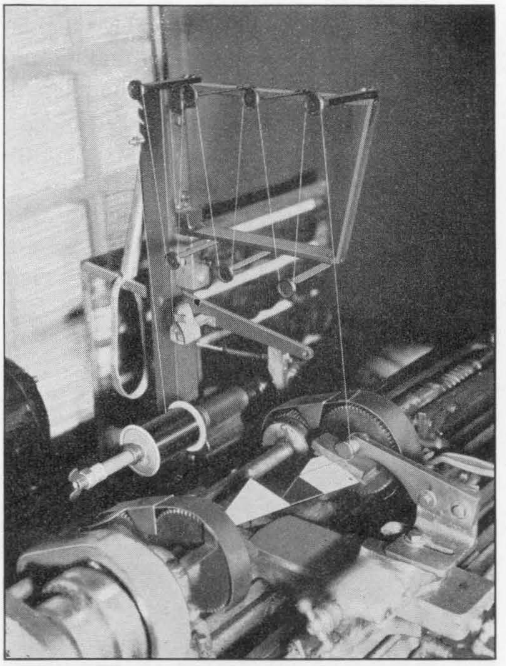

Figure 5. View of double-sawtooth card being wound. Note the arrangement of pulleys and springs to take up variations in tension as the card is rotated.

equipment available for manufacture. Such limitations, however, do exist:

1. **Ratio of End Widths.** There is a limit to the ratio of end widths which eventually limits the curve shape no matter which of the tricks mentioned are employed to secure desired curvature. This ratio depends on mandrel width and is naturally larger for wider mandrels. It will be obvious, for instance, that the trapezoidal shape has to be trapezoidal; it cannot be made triangular. There must be a finite width at the narrow end to provide juncture with a projecting end or tab to be used for fastening to the molded base.

2. **Minimum Width at Narrow End.** The narrow end width is limited by at least two factors. In the case of the edge-contacting potentiometers, the limitation is the strength of the narrow end. When being wound, the mandrel is mounted under tension between jaws in a lathe (see Figure 8). Also, the mandrel in assembly is bent around the base, sometimes with a protective enveloping strip which helps strengthen it at the weak point. However, the width must be great enough to prevent breakage in either of these operations. A minimum width of 3/16″ is preferred, although with some difficulty minimum widths of 5/32″ or even 1/8″ can be handled. In determining ratios of end turn lengths, the thickness of mandrel and diameter of wire should be allowed for. In the case of multifingered take-off brushes (Types

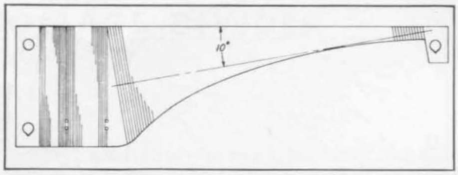

Figure 7. A combination mandrel, on which the curved portion is wound with a single kind of wire and the straight portion with several different kinds to approximate the desired characteristic.

314 and 471), the narrow-end width of either single-straight-taper or double-sawtooth mandrels must be greater than the width of the contacting fingers. It *should* be the full width of the projection of the mandrel in assembly above the barrel portion of the molded base. This minimum is around 7/16″.

3. **Maximum Slope at Wide End.** The width at the wide end is usually the maximum that will be accommodated by the molded base, in order that the maximum winding area can be obtained. The limitation at that wide end is the largest slope of the curved edge of the mandrel (see illustration, in Figure 6, of a so-called 30-db form for a Type 371 Voltage Divider, each half of which is logarithmic for 15 db when provided with a proper series end resistor). It is probably quite apparent that there will be some slope above which successive turns will not stay anchored to one another, but will slide down the slope and collapse. The 30-db form illustrated represents about that limit.

The speed of winding on steep slopes is drastically reduced and occasionally it is necessary to hand-wind small portions of such mandrels, as shown in Figure 9.

It should here be noted that this mandrel is windable only as a result of

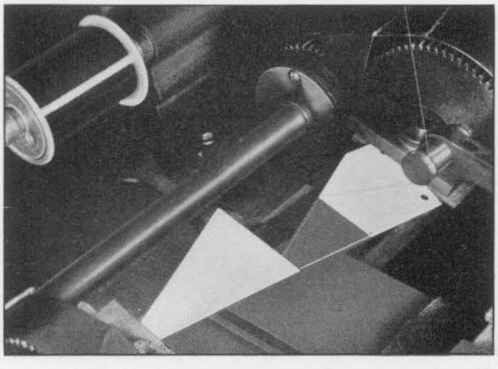

Figure 8. Close-up of the double sawtooth during winding, showing how the mandrel is clamped in the lathe.

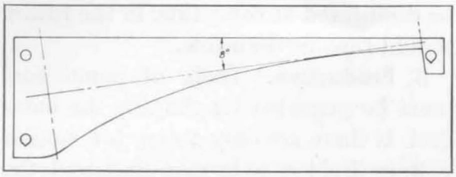

Figure 10. Mandrel widths are laid out perpendicular to the winding axis as shown here by the center line.

minimizing the slope somewhat by so locating the mandrel when clamping it in the winding machine that the winding axis is at a fair angle to the straight edge. This angle is determined by having the winding axis bisect the chords of the shaped mandrel at the extreme narrow and wide ends as illustrated in Figure 6. This angle for the 30-db form is about 15°, and the expedient of tilting the form when winding reduces the effective slope at the widest portion by almost the whole of this 15°. The maximum slope with respect to the winding axis is about 43°.

4. **No Spacing Between Turns.** The slope of the curved side of the mandrel at the steep end of logarithmic potentiometers is generally so great that adjacent turns must be wound immediately against one another in order to prevent sliding down hill of the turns and complete collapse. This means that spacing the turns at will cannot be used as a means of making the total resistance come out to any arbitrary desired value. Except as the outside diameter of the enameled wire varies slightly, the resistance values which can be obtained on forms having very steep portions occur in a series having equal geometric spacing. In the B & S gauge system, adjacent wire sizes are related in diameter by the factor of $\sqrt[6]{2}$ (very closely) and in area by the $\sqrt[3]{2}$. This means that, for a change of one wire size, the resistance on a mandrel will be changed by the $\sqrt{2}$. It is then possible that, under the most unfavorable conditions, the resistance value realized might be related to the desired resistance value by the $\sqrt[4]{2}$, or might come anywhere between 84% and 119% of desired value. If it is necessary to come closer than this, resort must be had to the questionable expedients of looking for wire nominally the same, but actually different, in diameter, or of hoping that a wire of different size and different resistivity will fall nearer to the wanted value.

A rough means of ascertaining the maximum slope and the minimum width of a mandrel is as follows: First, plot on cross-section paper the curve of resistance vs. rotation. By matching a straight edge to the curve at successive points, to simulate a tangent, determine the slope of the curve at these points. The units in which the slope is expressed are unimportant so long as they remain the same for all points. The largest slope corresponds to the full width of the mandrel (for example, 2¹⁄₁₆″ for Type 371) and the widths corresponding to other slopes can be determined by simple proportion, making correction, of course, for the mandrel thickness.

Next, a scale drawing of the mandrel must be prepared. The mandrel widths should be laid out perpendicular to the

Figure 9. Hand winding, as shown here, is often used on steeply sloping mandrels.

winding axis, rather than to the straight edge of the form, if the two are not parallel (see Figure 10). From this drawing, the maximum slope can be measured, while the minimum width comes directly out of the width table.

ECONOMICS

It is probably not difficult to see that there may be considerable difference between what is possible technically and what is advisable economically. Each new mandrel shape requires a number of separate operations, each individually tailored to the particular requirement.

1. **Design of Mandrel.** The process described just above must be gone through, but with somewhat more accuracy, since the purpose this time is the manufacture of a complying article. If the resistance-rotation curve can be expressed analytically by an equation, it is usually simpler thus to calculate the slopes needed to determine the mandrel shape, by the use of the differential calculus rather than graphical methods. A logarithmic voltage divider is a case in point.

2. **Drafting.** Sufficient new drawings must be prepared to assure that a proper article is manufactured, and that it can be duplicated at some time in the future should that be desirable.

3. **Production.** Tools of some sort must be provided for shaping the mandrel. If there are only a very few similar voltage dividers to be manufactured, the mandrels can be prepared by hand by the use of a nibbler, notcher, milling machine, band saw, filing machine, or even by hand with a hacksaw and file, with or without a guiding steel template. If the quantity is as great as 50 or 100, it will probably pay to purchase one of the inexpensive short-run punch-and-die combinations from a tool concern specializing in making such tools. Such a punch and die can often be obtained for $35.00 to $75.00, after which the punching by the tool manufacturer costs only a few cents per piece, if ordinary rectangular mandrels are supplied him from which to work. Control of dimensions to a very few thousandths is possible by this method.

Whether or not a given project is feasible must be decided on its own merits. The cost involved must justify itself to the purchaser, and the amount of engineering required must not be so inordinate as to make it seem not worth while to the manufacturer.

—P. K. McElroy

This is the second installment of a three-part article By Mr. McElroy. Part I appeared in February. Part III will be published in an early issue.

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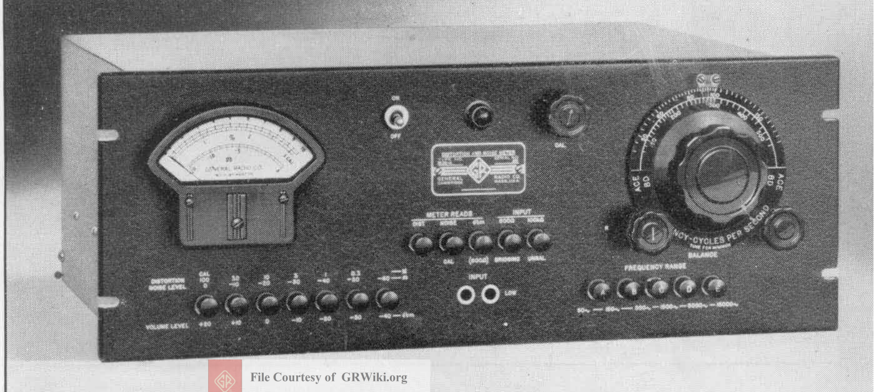
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

DISTORTION MEASUREMENT IN THE BROADCASTING STATION

● **THE MEASUREMENT** of audio fidelity, distortion, and noise in the broadcasting station has long been considered desirable in order to maintain the high quality service of which modern transmitting equipment is capable. This measurement takes on new importance with the requirement for proof-of-performance checks to comply with the amendments to the Federal Communications Commission Rules and Regulations, Sections 3.254 and 3.46, effective August 1, 1949. These amendments call for a determination of the over-all noise and distortion of the complete broadcasting station at least once a year, with one such measurement to be made during the four months immediately preceding the date of application for renewal of license. Many stations already make these measurements at frequent intervals as a routine maintenance operation.

The measurement of over-all distortion and noise requires the use of an audio test oscillator of low inherent distortion, a distortion and noise meter, and a demodulator for conversion of the transmitted r-f wave back into audio-frequency voltages. This demodulation facility is generally provided by the modulation monitor (Type 1931–A Amplitude Modulation Monitor, Type 1170–A F–M Monitor).

Figure 1. Panel view of the Type 1932-A Distortion and Noise Meter.



RECOMMENDED EQUIPMENT

The Type 1301–A Low-Distortion Oscillator is a convenient and reliable source of audio voltage for test purposes, with distortion less than 0.1% over the range from 40 to 7500 cycles, and less than 0.15% distortion up to 15,000 cycles. The general features of this oscillator are described on page 6.

The Type 1932–A Distortion and Noise Meter provides means for the measurement of sine-wave voltages, distortion, and noise throughout the audio range. The over-all pass-band of the voltmeter circuit extends to 45,000 cycles, thus including all noise and distortion products contained in this range. In particular, the third harmonic of a 15,000-cycle test signal is included.

The continuously tunable null network covers the range from 50 to 15,000 cycles. The voltmeter circuit makes use of a half-wave rectifier and is calibrated in root-mean-square volts. The meter receives all the uni-directional pulses coming from the rectifier and acts as an electro-mechanical integrator. The half-wave rectifier with un-bypassed meter is the equivalent of a full-wave rectifier for noise and distortion measurements, and is somewhat more convenient to use.

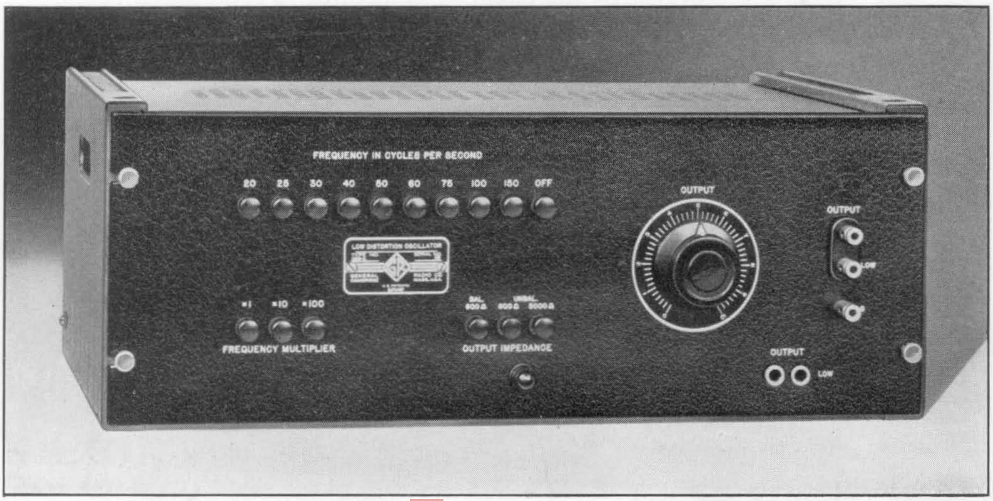
With the audio test source connected, combined distortion and noise are measured by (1) setting the voltmeter circuit for full-scale deflection, (2) balancing out the fundamental frequency of the test oscillator, and (3) reading the value of the residual distortion and noise. Details of the Type 1932–A Distortion and Noise Meter are given on page 5.

A typical installation for measuring the audio linearity, distortion, and noise in a broadcasting station is shown in the diagram. The modulation monitor supplies the necessary low-distortion demodulation device. As will be apparent from this diagram, a large broadcasting plant with several studios, or more than one transmitter site, may find it desirable to use more than one set of distortion-checking equipment.

ACCURACY

The Type 1932–A Distortion and Noise Meter, together with the Type 1301–A Low-Distortion Oscillator, makes a combination which will perform the measurements required in both f-m and a-m stations. All the required audio check frequencies are covered for both services. The f-m requirements for maximum allowable distortion are the

Figure 2. Panel view of the Type 1301-A Low-Distortion Oscillator.



most stringent. The maximum total allowable distortion is 2.5% between 100 and 7500 cycles, no more than half of which, or 1.25%, may be contributed individually by (a) the transmitter, (b) the studio-transmitter circuit, or (c) the audio facilities. With only 0.1% distortion in the source (TYPE 1301-A) and the distortion meter able to measure distortion and noise down to below 0.1%, it is fair to assume that the error in measurement of distortion cannot be greater than the arithmetic sum of these two quantities or 0.2%. Hence the allowable distortion of 1.25% may be measured easily without the necessity for subtracting a large amount of distortion contributed by the test source and the distortion meter.

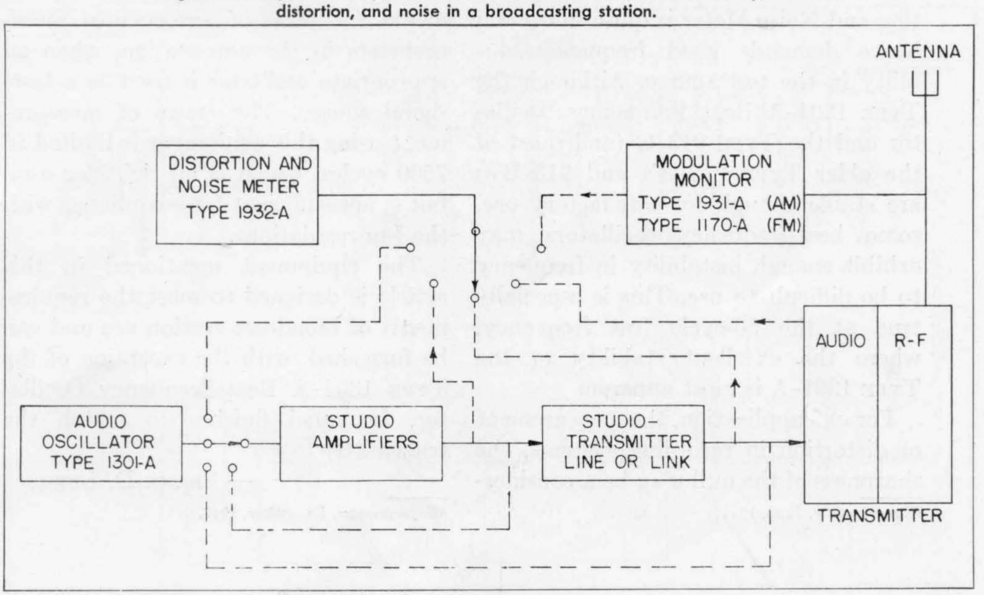
Since the TYPE 1932-A Distortion and Noise Meter does not require a separate simultaneous connection to the test oscillator, it is possible to make remote measurements. Because the distortion in the test oscillator is so low, these measurements can be made with the assurance that the distortion observed is in the equipment under test and not in the test source.

The distortion indicated by the TYPE 1932-A Distortion and Noise Meter is proportional to the average value of the wave that remains after the fundamental component is suppressed. The difference between this average value and the root-mean-square[1] value of distortion is small, and the distortion percentage indicated may be considered to be identical with the r-m-s distortion percentage within the accuracy specification of the distortion and noise meter. The catalog specification on accuracy is ±5% of full scale, which allows both for this difference between the average and r-m-s values and for the usual accuracy limitations of the metering system.

The percentage distortion can be based on the amplitude of the fundamental alone or on the amplitude of the total signal. The total signal is used as a reference in the TYPE 1932-A Noise and Distortion Meter. The difference between the two reference values is negligible for values of distortion less than 10%, but should be considered when higher values of distortion are measured.

[1] The r-m-s distortion is identical with the quantity designated as root-sum-square distortion by the FCC.

Figure 3. Diagram of a typical installation for measuring audio linearity, distortion, and noise in a broadcasting station.



ALTERNATIVE EQUIPMENT

Some broadcasters prefer to use the beat-frequency type of audio oscillator for checking frequency response, and consequently they would like to use the same oscillator as a test source for distortion measurements. The TYPE 1304–A[2] Beat-Frequency Oscillator is one of the lowest distortion models commercially available and has a satisfactorily low value of distortion over the audio range from 50 to 15,000 cycles when operated with NORMAL output. Between 100 and 7500 cycles, distortion will not exceed 0.25%, with approximately 0.5% at 50 cycles. For f-m, at the required frequencies of 10,000 cycles and 15,000 cycles, the distortion will be less than 0.5% and 0.75% respectively on the NORMAL output range. As is apparent from the data above, the TYPE 1301–A Low-Distortion Oscillator, owing to its lower inherent distortion, is preferable for use as a test source in distortion measurements.

Another aspect of the problem of distortion measurement is related to the type of circuit used to suppress the fundamental of the test frequency. The null-circuit in the TYPE 1932–A Distortion and Noise Meter is quite sharp and hence demands good frequency stability in the test source. Although the TYPE 1304–A Beat Frequency Oscillator and the TYPE 913–C (and most of the older TYPE 913–A's and 913–B's) are stable enough for satisfactory use, some beat-frequency oscillators may exhibit enough instability in frequency to be difficult to use. This is especially true at the 50-cycle test frequency, where the excellent stability of the TYPE 1301–A is most apparent.

For one application, the measurement of distortion in recording systems, the sharpness of the null may be a considerable handicap because of "wow" or frequency instability in the recording-reproducing equipment, and the TYPE 1932–A Distortion and Noise Meter is not recommended for such uses. The slight variation in frequency of the test signal may result in imperfect suppression of the fundamental and hence an erroneous distortion reading. For measurements on recording systems, the older TYPE 732–B Distortion and Noise Meter is recommended, together with the TYPE 732–P1 Range-Extension Filters.[3]

The use of the TYPE 732–B Distortion and Noise Meter is possible with a test source having lower frequency stability since the fundamental is suppressed by a high-pass filter and not by a sharply tuned null circuit. Hence measurements on recording equipment, such as disk transcription, sound-on-film, and magnetic wire or tape recorders are easily carried out.

A number of a-m stations are already equipped with the TYPE 732–B Distortion and Noise Meter and TYPE 732–P1 Range Extension Filters, which were designed before f-m broadcasting started. These stations can meet all the requirements for proof-of-performance measurements in the a-m station, when an appropriate oscillator is used as a test-signal source. The range of measurement using this equipment is limited to 7500 cycles, which is all right for a-m, but is not sufficient for compliance with the f-m regulations.

The equipment mentioned in this article is designed to meet the requirements of broadcast station use and can be furnished, with the exception of the TYPE 1304–A Beat-Frequency Oscillator, in panel finishes to match the transmitter.

— FRANK D. LEWIS

[2] *Experimenter*, June, 1948.

[3] *Experimenter*, December, 1947.

TYPE 1932-A DISTORTION AND NOISE METER

Principles of Operation

The Type 1932–A Distortion and Noise Meter consists essentially of a null network continuously variable in frequency, followed by a calibrated vacuum-tube voltmeter, as shown in the elementary diagram below.

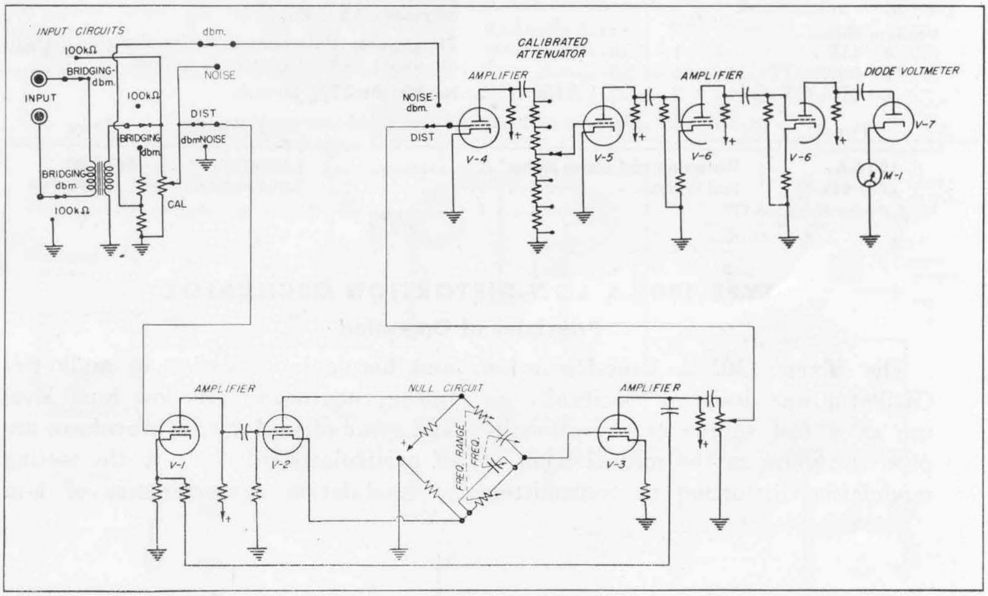
When the switches are set at NOISE, the instrument operates as a sensitive vacuum-tube voltmeter and can be used for noise measurements. The calibrated attenuator has a direct-reading dbm scale for the purpose of determining the program level in 600-ohm lines. Ratio scales, reading in db and per cent, are also provided.

For noise measurements, the instrument is set at 100% (0 db) for the desired reference level by means of the CAL control, and then upon removal of this reference signal, the attenuator is changed in known increments until a deflection of the meter is obtained. The ratio between the two settings, as read directly on the attenuator and meter scale, is the signal-to-noise ratio.

The null network attenuates the frequency, f, to which it is tuned, by more than 80 db, while $f/2$ and all frequencies below, and $2f$ and all frequencies above up to 45,000 cycles, are passed without attenuation. The instrument is calibrated, in the same way as for noise measurements, with the null network not in circuit and with a sine-wave signal applied to the device under test.

When the switches are set to Dist, the null network is introduced and must then be adjusted for a null at the frequency of the test source. Attenuation of the fundamental component by 80 db or more leaves a signal comprising distortion products, including power-line interference, and noise within a band of 30 to 45,000 cycles. The attenuator setting and meter reading now give a direct measure of the distortion level expressed as a percentage of the total signal. Note that the distortion includes all extraneous signals present and

Figure 4. Elementary schematic diagram of the Distortion and Noise Meter.



not just the harmonics of the fundamental test signal. For this reason the apparent minimum detectable distortion level may be limited by the residual noise level, should the latter be permitted to reach a comparable level.

SPECIFICATIONS

Distortion Range: Full-scale deflections for 0.3%, 1%, 3%, 10%, or 30% distortion.

Noise Measurement Range: 80 db below 100% modulation, when the distortion meter is operated from the Type 1931-A Modulation Monitor or the Type 1170-A F-M Monitor; or 80 db below an audio-frequency signal of zero dbm level.

Audio-Frequency Range: 50 to 15,000 cycles (fundamental) for distortion measurements; 30 to 45,000 cycles for noise and hum measurements.

Dbm Range: From + 20 to –60 dbm. Full-scale values of +20, +10, 0, –10, –20, –30, and –40 dbm are provided. Reference level is one milliwatt in 600 ohms.

Input Voltage Range: Between 1.2 and 30 volts for the 100-kilohm input, and between 0.8 and 30 volts for the 600-ohm bridging input.

Accuracy: For distortion measurements, ±5% of full scale for each range ± residual distortion as noted below; for noise and dbm measurements, ±5% of full scale.

Residual Distortion Level:
100-Kilohm Input: 0.05%, maximum, below 7500 cycles;
0.10%, maximum, above 7500 cycles.
Bridging Input: 0.10%, maximum, between 50 and 70 cycles;
0.05%, maximum, between 70 and 7500 cycles.
0.10%, maximum, above 7500 cycles.

Residual Noise Level: Less than –80 db.

Input Impedance: Two input impedances are provided — 100,000 ohms unbalanced and 600-ohm bridging input (10,000 ohms) balanced or unbalanced.

Vacuum Tubes:

4—6J5	1—6H6
1—6SN7-GT	1—6X5
1—6K6-GT/G	2—0D3/VR150

Accessories Supplied: Line connector cord and cable for connecting to the Type 1931-A Modulation Monitor.

Other Accessories Required: For measuring the distortion in oscillators and other audio-frequency sources, no additional equipment is required. For measurements on amplifiers, lines, and other communication networks, a low-distortion oscillator is required to furnish the test tone. Type 1301-A Low-Distortion Oscillator is recommended. When the modulated output of a radio transmitter is to be measured, a linear detector to produce the audio envelope is necessary. The Type 1931-A Modulation Monitor and the Type 1170-A F-M Monitor are recommended for this purpose. However, any detector system having minimum undistorted output of 1.5 volts rms can be used.

Terminals: Input terminals are provided at the rear of the instrument for direct connection to the modulation monitor. A Western Electric jack is provided at the panel also, as an auxiliary input circuit. Plugging into this jack automatically disconnects the rear connectors.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. The line input power is 65 watts. The power supply is voltage regulated. Line surges have no appreciable effect.

Mounting: The instrument is relay rack mounted. Walnut end frames are available to adapt the instrument for table mounting. (See price list below.)

Panel Finishes: Standard General Radio black crackle. Certain standard grays which can be processed in quantity can be supplied at a price increase of $11.00.

Dimensions: Panel (length) 19 x (height) 7 inches; depth behind panel, 12 inches.

Net Weight: 37¾ pounds.

Type		*Code Word*	*Price*
1932-A	**Distortion and Noise Meter***	TABOO	**$575.00**
ZFRI-412-P1	**End Frames**	ENDFRAMDIG	**16.50 Pair**

*U.S. Patent No. 2,298,177.

TYPE 1301-A LOW-DISTORTION OSCILLATOR

Principles of Operation

The Type 1301-A Low-Distortion Oscillator was designed specifically for use as a test source of exceptionally pure waveform in the measurement of modulation distortion in transmitters and harmonic distortion in audio-frequency equipment. Its low hum level and symmetry of output waveform are of particular significance in the testing of modulation characteristics of a-m and f-m transmitters, especially at high and low modulation frequencies.

Figure 1 shows the oscillator in simplified form.

The oscillator is essentially an RC type employing automatic gain control. The oscillating amplifier is arranged to have almost complete degeneration at all frequencies above and below the frequency of the null network, and consequently a small amount of regeneration will cause the circuit to oscillate at the frequency of maximum gain. This is the frequency of the null network, since degeneration is essentially zero at this frequency.

Since the circuit is highly degenerative at all other frequencies, harmonics of the oscillation frequency are suppressed. To control the oscillation level, the amount of regeneration is varied. This is done by the d-c bias applied to the "Regeneration Control Tube," a variable-μ type. The AVC amplifier has a fixed delay-bias applied to it. The oscillator amplitude must reach a critical level before this amplifier is effective. As the amplitude tends to increase above this point, the AVC amplifier applies a signal voltage to the AVC diode, whose output is connected to the "Regeneration Control Tube" in such a manner as to result in a reduction in net gain, thus opposing the original increase.

The power supply for the oscillator employs electronic regulation which reduces the effects of line-voltage variations upon the oscillator frequency and amplitude to a negligible value.

The oscillator is designed to have a high degree of frequency stability in order that it may be used effectively with the Type 1932-A Distortion and Noise Meter at low audio frequencies, when measuring extremely low distortion levels of the order of 0.1%.

SPECIFICATIONS

Frequency Range: 27 fixed frequencies between 20 and 15,000 cycles.

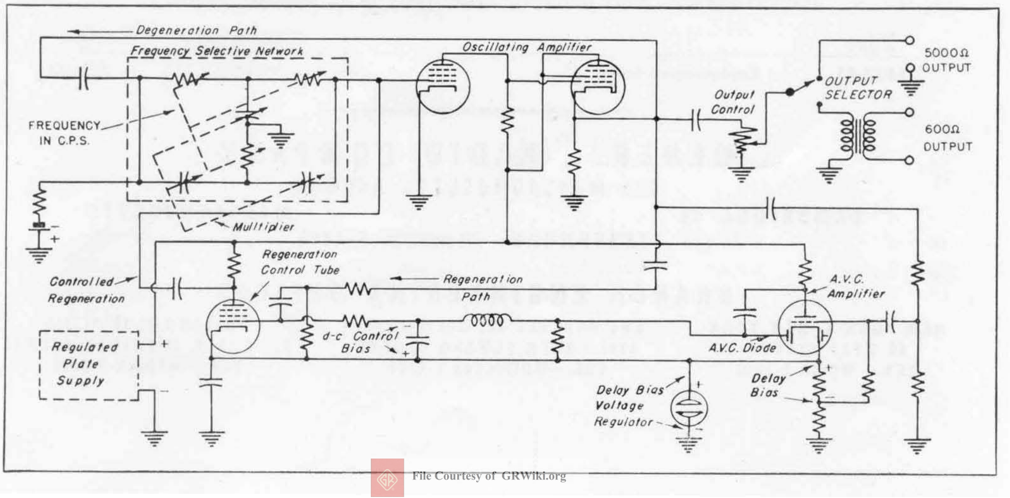
Frequency Control: The frequency is controlled by two push-button switches. The first provides frequencies of 20, 25, 30, 40, 50, 60, 75, 100, and 150 cycles, while the second multiplies these frequencies by 1, 10, and 100. The frequencies included cover practically the entire audible range in approximately logarithmic increments.

The Type 1301-P1 Range Extension Unit is available to provide a multiplying factor of 0.1 (see price list). This range extension unit plugs directly into jacks provided inside the oscillator.

Frequency Calibration: Each instrument is adjusted within $\pm(1\frac{1}{2}\% + 0.1$ cycle).

Frequency Stability: The internal voltage regulator eliminates frequency changes resulting from changes in plate supply. Changes in load

Figure 5. Elementary schematic diagram of the Low-Distortion Oscillator.



have no effect upon the frequency. The frequency drift is not greater than 0.02% per hour after the first 10 minutes of operation.

Output Impedance: Three output circuits are provided. Selection among them is obtained by means of a push-button switch on the panel. The output impedances are as follows:

1. 600-ohm balanced to ground.
2. 600-ohm unbalanced.
3. 5000-ohm unbalanced.

The volume control is a potentiometer in the 5000-ohm circuit. The actual output impedance of the 5000-ohm circuit will vary between 1000 and 6000 ohms, depending upon the setting of the volume control. Suitable resistance pads keep the impedance of the 600-ohm output circuit essentially constant, regardless of the volume control setting. The 600-ohm balanced output circuit is balanced at all frequencies when operating into a balanced load of any impedance.

Output Power: 18 milliwatts into 600-ohm load, or 6.6 volts open circuit; 100 milliwatts into 5000-ohm load, or 30 volts open circuit. The output voltage, for either impedance position, will remain constant within ±1 db throughout the frequency range.

Waveform Distortion:

5000-ohm output: — Not more than 0.1% between 40-7500 cycles.
Not more than 0.15% at other frequencies.

600-ohm output: — Not more than 0.1% between 40-7500 cycles.
Not more than 0.25% between 20-40 cycles.
Not more than 0.15% above 7500 cycles.

Power Supply: 105 to 125 (or 210 to 230) volts, 25 to 60 cycles ac. The total power consumption is approximately 45 watts.

Tubes:

1—6Y6-G	1—6X5
1—6SJ7	1—6B4-G
1—6SK7	1—6SL7-GT
1—6SQ7	1—0D3/VR150
1—NE-17	

Terminals: Jack-top binding posts with standard ¾-inch spacing and standard Western Electric double output jack are provided on the panel. A ground terminal is also provided. A standard multipoint connector provides duplicate output terminals on the rear of the instrument for relay-rack installation. These terminals are disconnected when a plug is inserted in the Western Electric-type panel jack.

Accessories Supplied: Line connector cord and multipoint connector.

Mounting: The instrument is relay-rack mounted. Walnut end frames are available to adapt the instrument for table mounting. (See price list below.)

Panel Finishes: Standard General Radio black crackle. Certain standard grays which can be processed in quantity can be supplied at a price increase of $11.00.

Dimensions: Panel (length) 19 x (height) 7 inches; depth behind panel, 12 inches.

Net Weight: 31½ pounds.

Type		*Code Word*	*Price*
1301-A	**Low-Distortion Oscillator***	OZONE	**$395.00**
1301-P1	**Range Extension Unit (2 to 15 c.p.s.)**	OVATE	**70.00**
ZFRI-412-P1	**End Frames**	ENDFRAMDIG	**15.60 Pair**

*U.S. Patent No. 2,173,427.

CORRECTION

The price of the Type 1532–P1 Replacement Lamp for Strobolume was incorrectly given in the May issue of the *Experimenter*. The price of this item is as follows:

Type		*Code Word*	*Price*
1532-P1	**Replacement Lamp**	TOWEL	**$30.00**

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW DECADE INDUCTOR

Also IN THIS ISSUE

●**DECADE RESISTANCE UNITS,** as exemplified by the TYPE 510 or 602 series, and decade capacitors, such as the TYPE 380 or 219 series, have long found use as standards in electrical measurements and as components of experimental circuits in the laboratory. General Radio Company now offers a companion set of high-quality decade inductors which cover the range from one millihenry to ten henrys, and are intended primarily for use at audio and the lower ultrasonic frequencies. Each TYPE 940 Decade Inductor Unit consists of four individual inductors having nominal values 1-2-2-5, which are assembled with a TYPE 920-A Switch joining them in series to achieve the ten steps of the decade. The TYPE 1490 Decade Inductors provide a wide range of adjustment by combining three or four TYPE 940 Decades in a single cabinet.

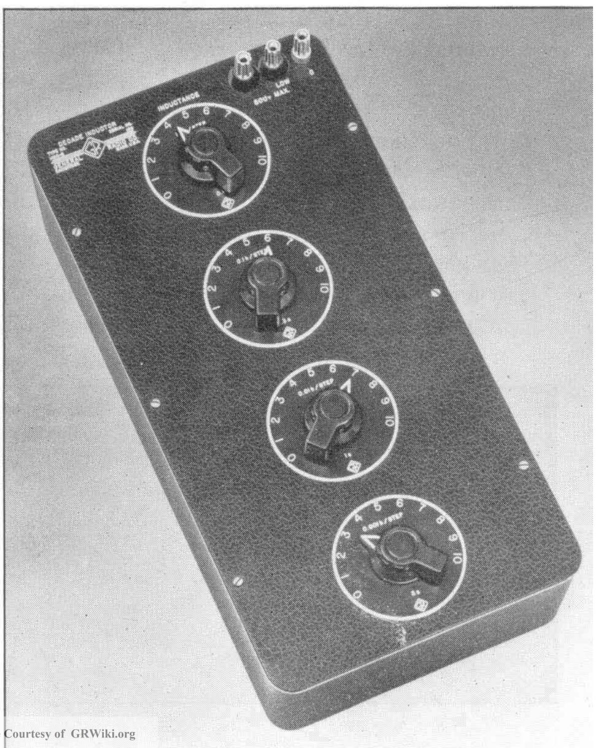


Figure 1. View of a four-dial Type 1490-B Decade Inductor covering a range of 0 to 11.11 h in steps of 0.001 h.

DESIGN CONSIDERATIONS

These inductors possess, to a considerable degree, the most desirable characteristics of a standard inductor. In the first place, in contrast with variometers and solenoid windings, it is important that such inductors be astatic, so that voltages are not induced in them by stray magnetic fields and, correspondingly, they do not create external fields when in use. This is accomplished by winding each individual inductor on a toroidal form with a uniform distribution of its turns around the complete circumference of the toroid. Such a toroidal winding will be astatic except for the equivalent of a single turn loop having the mean circumference of the toroid. These individual inductors may then be stacked in close proximity with a negligible mutual inductance between them.

To minimize their d-c ohms-per-henry ratios, and thus to increase their low frequency storage factors Q, a multiple layer winding is required. To minimize distributed capacitance and to raise their natural frequency and their high-frequency storage factors, a banked winding, rather than a succession of layers around the toroid, is required. A special toroidal winder was developed for this purpose.

To achieve a high value of maximum Q with a minimum of bulk, and to have this maximum occur within the operating frequency range, required a ferromagnetic core. Since the permeability of a ferromagnetic medium is markedly a function of the flux existing in it, such a core must be diluted with a non-magnetic material to minimize the eddy current losses within the operating frequency range, and should have low hysteresis loss. Finally, for stable calibration, the core should have a minimum temperature coefficient of permeability. A stabilized molybdenum permalloy dust core meets these requirements successfully and, for the first time, permits a satisfactory decade inductor to be constructed which has the operating characteristics described below.

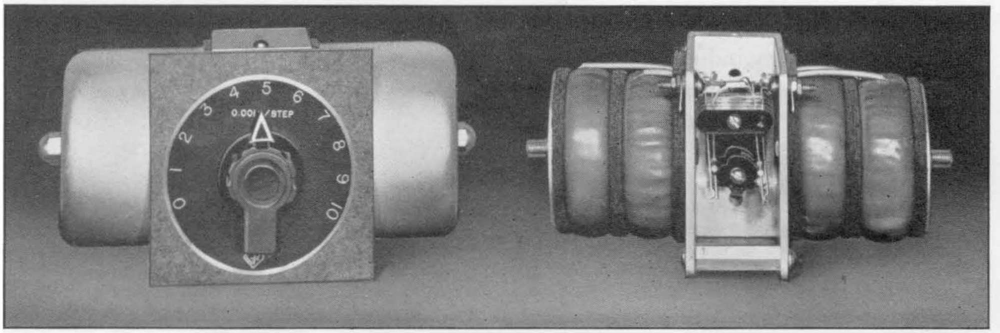
CONSTRUCTION

Molybdenum Permalloy Dust Cores

The Type 940 Inductors are wound on stabilized molybdenum permalloy dust toroids, which were developed by the Bell Telephone Laboratories for loading coils and filter elements, and which are described in a noteworthy paper[1] by Legg and Given. Grain size is 120-mesh, giving a mean diameter of 42 microns and an r-m-s diameter of 50 microns. Quoting their data, the 2-81 molybdenum permalloy (molybdenum 2, nickel 81, iron 17) shows a positive temperature coefficient of permeability of about $180/10^6$ per degree C. To this alloy is added a small quantity of another permalloy containing 12 per cent molybdenum which, having a Curie point slightly above room temperature, shows a large negative coefficient at room temperature. As indicated in Figure 3, the resultant

[1]Bell System Technical Journal, Vol. 19, July, 1940.

Figure 2. Front and rear views of a Type 940 Decade Inductor Unit.



mixture gives a "stabilized" core which has a negative coefficient of about $24/10^6$ per degree C. (a 7.5 fold reduction) over the range 16–32 degrees C. Below 5 degrees C. and above 50 degrees C. these stabilized cores regain the large positive coefficient of the 2–81 alloy. Legg and Given also show maximum permeability occurring at about 6.5 oersteds and exceeding the initial value by about 2%, and indicate that the effective permeability has dropped to its initial value when H is increased to about 16 oersteds.

Winding and Calibration

Since these inductors are intended primarily for use at audio and somewhat higher frequencies, an available core type having a nominal permeability of 125 was chosen. Each core is initially measured in an eleven-turn jig. The correct number of turns for a specified inductance can then be predetermined within a turn or two. A suitable adjustment of the toroidal winder then insures a full circumferential distribution of the winding. After winding, each inductor is checked against a standard unit with a comparison bridge and is adjusted, if necessary, within prescribed fractional limits. The ultimate limits, obviously, must be broadened as the inductance is reduced. After impregnation a set of four inductors having values 1-2-2-5 is mounted into a decade assembly.

Electrostatic Shielding

Each of the Type 940 Decades is electrostatically shielded. As supplied, neither terminal is connected to the chassis. If the terminal marked LOW is grounded to the chassis, a minimum of capacitance is placed across the 5-unit toroid and gives the largest minimum value of natural frequency for the decade. The Type 1490 Assemblies are mounted in a metallic cabinet. No point in circuit is internally connected to the chassis. A terminal post, marked G, is mounted on the cabinet panel which, if desired, may be connected to the inductor terminal marked LOW. This will place a minimum of capacitance across the highest-valued decade in the assembly and give the largest minimum value of natural frequency for the entire assembly.

ELECTRICAL CHARACTERISTICS

Variation of Inductance with Applied AC

The Rayleigh[2] equation gives the variation of the permeability μ of a ferromagnetic material from its initial value in terms of the applied magnetizing force H:

$$\mu = \mu_o + \alpha H \qquad (1)$$

This equation holds for diluted cores, provided that the initial value of their effective permeability μ_o is substantially greater than unity.

These Type 940 Inductors are calibrated in terms of their initial inductance L_o corresponding to μ_o. In terms of Equation (1) and the core geometry, for

[2]Bell System Technical Journal, Vol. 15, January 1936, page 44.

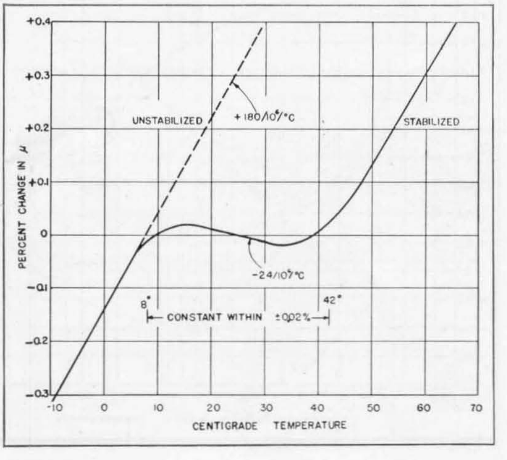


Figure 3. Temperature characteristic of molybdenum permalloy dust core (Courtesy Bell System Technical Journal).

any individual L_o (absolute henrys) carrying any r-m-s current (amperes) the corrected value will be given by:

$$L = L_0(1 + \beta I\sqrt{L_0}) \qquad (2)$$

or in terms of the r-m-s applied volts and the frequency:

$$L = L_0\left(1 + \frac{\beta E}{\omega\sqrt{L_0}}\right) \qquad (3)$$

It was found that the initial values of α and β are 0.84 and 2.03. These numerical coefficients hold *constant* (Rayleigh's law) up to an H of about 300 millioersteds, corresponding to a value 0.0010 for the product $I\sqrt{L_0}$ and an increase of 0.20 per cent above the initial inductance. The variation of β at higher values of $I\sqrt{L_0}$ is shown in Fig. 4. When the correction factors in (2) and (3) are used they must be applied individually to the toroids actually in circuit and the results added. Ordinarily it is necessary to do this only to the larger units of a series. Further data are given in the specifications below.

Incremental Inductance

To a close approximation, when a d-c biasing current I_b is passed through these inductors, their initial inductance is reduced in a degree proportional to I_b if the product $I_b\sqrt{L_0}$ in amperes and henrys remains less than 0.010. The equation for this correction can be written:

$$L = L_0(1 - \gamma I_b\sqrt{L_0}) \qquad (4)$$

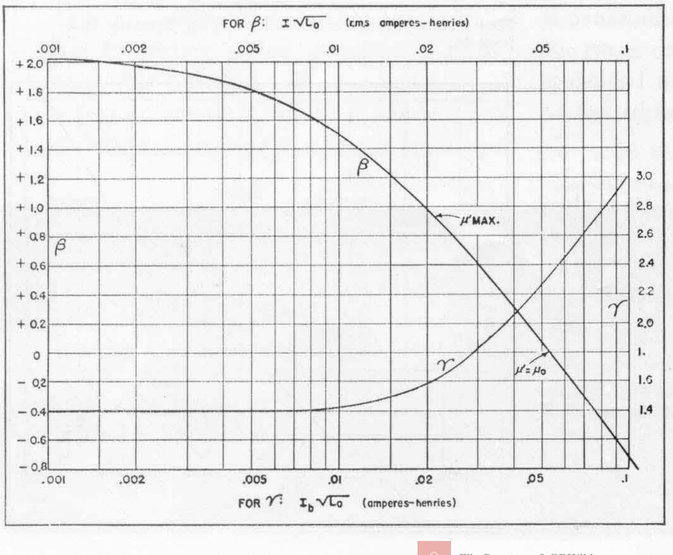
The coefficient γ will vary somewhat with the simultaneous a-c excitation, but a typical value of 1.4 can be used. The increase of γ with higher biasing levels is indicated in Fig. 4.

Frequency Correction

Any inductor possesses a certain distributed capacitance, which resonates it at its natural frequency and raises its effective inductance at any lower frequency. These Type 940 Decade Inductors have been calibrated at their minimum or zero frequency values. If necessary, their effective inductance at any operating frequency may be computed from the equation:

$$L = \frac{L_0}{1 - \omega^2 L_0 C_0} \qquad (5)$$

Appropriate values for the distributed capacitance C_0 are indicated in the specifications below.



D-C Resistance and Zero Inductance Values

Each of the toroidal inductors was wound with the minimum resistance practicable. The 1, 2, and 5 millihenry toroids, as wound, have about 60 ohms per henry, while the higher values have

Figure 4. Variation of the coefficients β and γ used in Equations 2, 3, and 4.

about 44 ohms per henry. The switch and connector resistance of each TYPE 940 Decade is about 30 milliohms, of which only 4 milliohms is actual contact resistance and subject to possible variation. These 30 milliohms are insignificant in the higher decade units, but they do appreciably reduce the low frequency Q values of the TYPE 940-A Decade, especially when this lowest decade is used *alone* in the TYPE 1490 Assemblies. The zero-setting resistance of either TYPE 1490 Assembly amounts to 30 milliohms per decade plus 30 milliohms for the internal wiring.

Each TYPE 940 Decade has a zero-setting inductance of 0.13 microhenrys; the zero-setting inductance of the TYPE 1490 Assemblies is 0.31 microhenrys per decade.

Storage and Dissipation Factors — Basic Theory

The utility of an inductor at any frequency and operating level is established by its storage factor Q, or by its dissipation factor D, which is the reciprocal of Q. The following analysis is an expansion of an earlier paper[3] by two of the author's colleagues. In an inductor having a ferromagnetic core, the magnitudes of Q and D are dependent upon two fundamental types of internal loss — core or magnetic loss, which is a function solely of the core used, and winding loss, which depends solely on the winding applied to the core. Magnetic loss, in turn, has three components — residual loss, hysteresis loss, and eddy current loss. Winding loss, likewise, has three components — copper loss, dielectric loss in the insulation of the windings and its environs, and skin-effect loss due to eddy currents induced in the windings. It can be shown that these six component losses may best be combined in terms of the sum of the corresponding dissipation factors:

$$D = D_m + D_w = (D_r + D_h + D_e) + (D_c + D_d + D_s) \quad (6)$$

The residual dissipation factor D_r is proportional to the effective permeability μ' of the core and is independent of the frequency. At low induction levels where Rayleigh's law holds and α in Equation (1) is constant, the hysteresis factor D_h is independent of the frequency f and is proportional to H. The eddy current factor D_e is proportional to the product $\mu' f$.

The copper-loss dissipation factor D_c is defined as the ratio of the d-c resistance R' to the reactance of the inductor and is, therefore, inversely proportional to f and becomes the predominant component of D_w at low frequencies. The dielectric loss factor D_d is the major component of D_w at high frequencies, since it is proportional to the square of

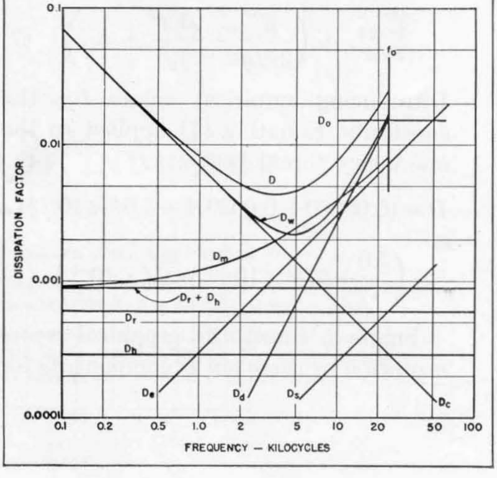


Figure 5. Evolution of the D curve for one henry toroid energized at 100 millioersteds.

To obtain D_m curve add ordinates of lines D_r, D_h and D_e.

To obtain D_w curve add ordinates of lines D_c, D_d and D_s.

To obtain final D curve add ordinates of D_m and D_w curves.

[3] McElroy and Field, "How Good is an Iron-cored Coil?" *General Radio Experimenter*, March, 1942.

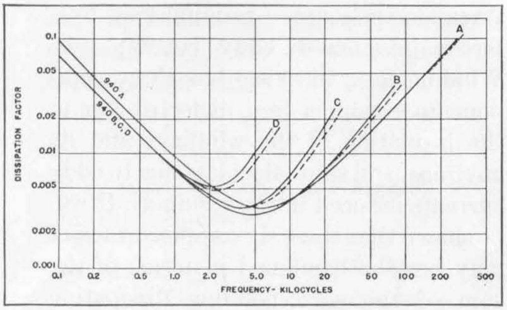


Figure 6. *D* curves for the full value of each Type 940 Inductor taken at initial μ. Dashed curves correspond to use with chassis floating.

the frequency. D_d can be evaluated in terms of the natural frequency f_o and D_o, which is the value of D_d at f_o. (D_o, in turn, can be considered to be independent of the operating frequency.) Finally, the dissipation factor D_s due to skin effect is proportional to the frequency and usually can be made insignificant by replacing large diameter wire with litz wire (with some increase in D_c). This was done in the 1, 2, and 5 millihenry toroids.

Substituting these six factors, in sequence, into (6), we have Equation (7) in which c, b, k_1, and k_2 are appropriate constants. Note that only D_h depends directly on the operating level and hence vanishes at initial permeability.

$$D = \left(\frac{c\mu}{2\pi} + bH + k_1\mu' f\right) + \left(\frac{R'}{2\pi Lf} + \frac{D_o f^2}{f_o^{\,2}} + k_2 f\right) \quad (7)$$

Introducing empirical values for the constants, Equation (7) applied to the one henry toroid becomes:

$$D = (0.00060 + 0.0029H + 3.0f \times 10^{-7}) + \left(\frac{7.0}{f} + 27f^2 \times 10^{-12} + 25f \times 10^{-9}\right) \quad (8)$$

Figure 5 shows the graphical representation of these six D components for the one henry toroid and their progressive summation in terms of D_m and D_w. D_h was evaluated at an arbitrary level of 100 millioersteds produced by a current of 330 microamperes.

We thus see that the reduction of eddy currents by a fine subdivision of the ferromagnetic material, together with its small hysteresis loss, permits the low dissipation factors indicated in Figure 6 to be obtained in these high quality inductors. These Figure 6 data were obtained close to initial permeability, where D_h becomes negligible, and show clearly the effect of displacing the D_d line to the left as the values of inductance are increased.

Safe Operating Limits

On the assumption that one of these toroidal windings can dissipate two watts without detrimental temperature rise, the r-m-s current values designated as I_2 in the specifications below were obtained. Such currents, however, would materially lower the inductance below initial values. To avoid any possible "magnetic memory" modification of L_o, large currents should be reduced progressively, rather than by a sudden interruption of the circuit.

In addition, it should be borne in mind that, if these high Q inductors are resonated by tuning with external series capacitance, the voltages developed across them may substantially exceed that of the circuit generator. A safe limit may be taken as 500 volts rms for any fixed position of the inductor switch. To prevent detrimental arcing at the switch contacts, the voltage on any decade unit should not exceed 150 volts rms when the switches are manipulated.

Mr. R. F. Field collaborated in securing the data quoted in this article.

— Horatio W. Lamson

TYPE 940 DECADE INDUCTOR UNIT

SPECIFICATIONS

Accuracy: Each unit is adjusted so that its inductance at zero frequency and initial permeability will be the nominal value within the accuracy tolerance given in the following table:

Inductance per step	1 mh	10 mh	100 mh	1 h
Accuracy	±2%	±1%	±0.5%	±0.25%

Frequency Characteristics: See "Frequency Correction," page 4. Typical values for the distributed capacitance C_0 of the TYPE 940-A Decade Inductor Unit are as follows:

Step	1	2	3	4	5	6	7	8	9	10
C_0 ($\mu\mu$f); Chassis tied to Low Terminal	90	60	50	50	50	45	40	37	35	35
C_0 ($\mu\mu$f); Chassis Floating	45	45	35	35	50	40	35	32	30	25

For the TYPES 940-B, -C, and -D the above values should be multiplied by the factors 1.1, 1.25, and 1.5 respectively.

Dissipation Factor: Figure 4 shows the variation of the dissipation factor $D = 1/Q$ with frequency for the full value of each inductor. It will be seen that maximum storage factor Q values between 200 and 330 are obtained at frequencies between 2 and 5 kc.

Temperature Coefficient: The temperature coefficient of inductance is about –24 parts per million per degree Centigrade. See Figure 3.

Maximum Voltage: The maximum r-m-s voltage for which the units are insulated is 500 volts. The switch will break the circuit at 500 volts if turned rapidly to the new setting, but voltages above 150 may cause destructive arcing if the switch is set between detent positions.

Current Characteristics and Maximum Current Ratings: The core permeability and the inductance value of each toroid are raised 0.1% by the application of 1.22 ampere turns. The corresponding r-m-s current values I_1 for each of the toroids are listed below, together with the r-m-s current values I_2 corresponding to a safe heat dissipation of two watts per toroid.

Inductor	*Toroid*	I_1 (ma) for 0.1% increase	I_2 (amp)
940-A	1 mh	15.6	7.2
940-A	2 mh	11.0	5.2
940-A	5 mh	7.0	3.0
940-B	10 mh	4.9	2.3
940-B	20 mh	3.5	1.7
940-B	50 mh	2.2	1.0
940-C	100 mh	1.56	0.72
940-C	200 mh	1.10	0.52
940-C	500 mh	0.70	0.30
940-D	1 h	0.49	0.23
940-D	2 h	0.35	0.17
940-D	5 h	0.22	0.10

Currents of twice the I_1 values will produce 0.2% increase in inductance; 5.4 I_1 gives 0.5% increase in inductance; 14.6 I_1 gives 1% increase in inductance; while 43.4 I_1 gives a maximum increase (2%) in inductance. Still larger currents will decrease the inductance progressively, the error being zero at about 108 I_1 and negative at larger values.

Terminals: Soldering lugs are provided.

Mounting: Each decade is complete with dial plate, knob, and mounting screws.

Dimensions: (Width) 7¼ x (height) 3½ x (depth behind panel) 3¼ inches, over-all.

Net Weight: 3½ pounds.

Type	*Inductance*	*Code Word*	*Price*
940-A	**0.01 h in 0.001 h steps**	INDUCTOANT	**$62.00**
940-B	**0.1 h in 0.01 h steps**	INDUCTOBOY	**56.00**
940-C	**1 h in 0.1 h steps**	INDUCTOCAT	**62.00**
940-D	**10 h in 1 h steps**	INDUCTODOG	**70.00**

TYPE 1490 DECADE INDUCTOR

SPECIFICATIONS

Frequency Characteristics: In determining the correction factor w^2C_0L use the C_0 value corresponding to the largest decade unit actually in circuit. For each larger decade unit not in circuit add 100$\mu\mu$f if the inductor is grounded to the panel or add 20$\mu\mu$f if the inductor is not grounded to the panel.

Terminals: Jack-top binding posts.

Mounting: The decades are mounted on an aluminum panel in a metal cabinet.

Dimensions: 1490-A 12¾ x 7¾ x 5½ inches over-all height; 1490-B 16½ x 7¾ x 5½ inches over-all height.

Net Weight: TYPE 1490-A, 15 pounds; TYPE 1490-B, 19 pounds.

Other specifications are identical with those for the TYPE 940 Decade Inductor Units.

Type	*Inductance*	*Code Word*	*Price*
1490-A	**1.11 h, total, in steps of 0.001 h**	CLUMP	**$220.00**
1490-B	**11.11 h, total, in steps of 0.001 h**	COACH	**285.00**

MISCELLANY

RECENT VISITORS to our laboratories:

From England: Mr. R. L. Smith-Rose, Superintendent, Radio Division, Department of Scientific and Industrial Research, London; Mr. J. F. Coales, Director, Research Laboratories, Elliot Brothers (London) Ltd., London; and Mr. R. G. Clark, Consulting Engineer, Epsom, Surrey.

From Spain: Dr. A. Gurvis, Technical Manager, and Mr. Domenech, Commercial Manager, both of Iberia Radio, Barcelona; and Dr. A. A. Pascucci, Research Section Director, Radio Hispano Suiza, Barcelona.

From France: Mr. Paul Fabricant, of Radiophon, Paris, Distributors of General Radio products in France and the French Possessions.

From Denmark: Mr. O. Lund, Communication Laboratory, Royal Technical College, Copenhagen; Mr. Viggo Kjaer, Manager, Brüel and Kjaer, Copenhagen.

From China: Mr. F. C. Chien, Chief Engineer, Central Broadcasting Station, Nanking.

From Italy: Professor Valentino Zerbini, Chief of Magnetic Section, Institute Elettrotecnico Nazionale "G. Ferraris," Torino.

From Canada: Professor B. de F. Bayly, of the University of Toronto. Professor Bayly is head of Bayly Engineering, Ltd., Oshawa, Ontario, who handle repairs of General Radio instruments in Canada.

VACATION — During the weeks of July 25 and August 1 most of our employees will be vacationing. Manufacturing departments will be closed, and other departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

MEASURING NOISE LEVELS ON FREQUENCY-MODULATED TRANSMITTERS

Also IN THIS ISSUE

●**THE** "Standards of Good Engineering Practice Concerning F-M Broadcast Stations" impose certain minimum noise-level requirements on frequency-modulated transmitters. Both f-m and a-m noise levels must be held below specified limits. Moreover, it is now required that these tests be made on an annual basis, at least once during the four months' period preceding the station license renewal.

In the past, the evaluation of noise level might be limited to a single set of measurements made when the transmitter was first installed and operated. The practicability of repeat measurements was largely a matter of balancing the cost of a distortion and noise meter against the desire for superior quality. New FCC requirements, however, make it desirable to have the necessary measuring equipment available in the station for the routine inspection of the transmitter characteristics.

F-M NOISE LEVEL

Measurements of the f-m noise level are usually made by applying

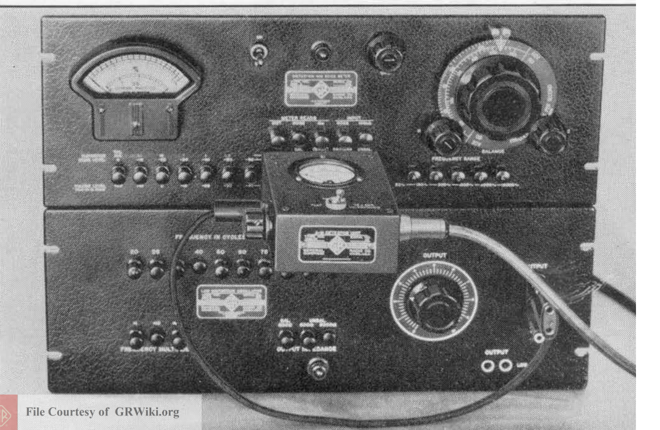


Figure 1. View of the Type 1932-P1 A-M Detector Unit plugged into the panel jacks of a Type 1932-A Distortion and Noise Meter. Below the Distortion and Noise Meter is a Type 1301-A Low-Distortion Oscillator.

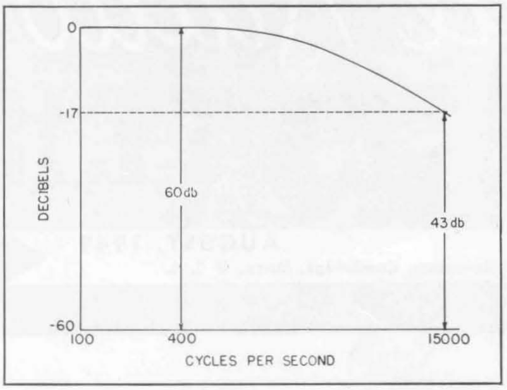


Figure 2. Effect of the de-emphasis characteristic on noise and distortion measurements with constant modulation percentage.

the audio output derived from an F-M modulation monitor to a conventional distortion and noise meter. The TYPES 1170-A F-M Monitor[1] and TYPE 1932-A Distortion and Noise Meter[2] have been previously described for this purpose.

The F-M Monitor provides a very linear f-m detector and de-emphasized audio output circuit. The Distortion and Noise Meter is an audio-frequency device exclusively and measures the distortion and noise characteristics of an audio signal. Measurements are made at a reference of 400 cycles, 100 per cent modulation.

It is important to recognize that the reference frequency must also be given, because of the de-emphasis circuit within the measuring equipment, which results in a decrease in audio output at high modulation frequencies for a constant percentage of modulation. The over-all transmission system from microphone to receiver output is flat, because of the canceling effects of pre-emphasis in the transmitter and de-emphasis within the receiver. However, when the transmitter percentage modulation is held constant, rather than its audio input level, the de-emphasis results in less audio output at the higher audio frequencies.

As an example, consider a typical case in which the power line hum components are the major source of noise. If the reference frequency is 400 cycles, the results might be, say, −60 db. Should the measurement be referred to 15,000 cycles, the same conditions would give an indication of only −43 db, as shown in Figure 2.

It is also interesting to note that this same effect will influence the results obtained in distortion measurements. Take for example, the case of a 60 db noise level below the stated reference of 400 cycles, 100% modulation. Most distortion and noise meters currently used operate upon the principle of removing the fundamental audio component only and indicating the remaining components above and below the fundamental, as distortion. Thus the 60 db noise level at 400 cycles would produce an effective minimum distortion reading of 0.1% on the meter, since 60 db corresponds to a voltage ratio of 1:0.001. Likewise, the same system noise level would result in a minimum distortion reading of 0.7% at 15,000 cycles, since 43 db corresponds to a voltage ratio of 1:0.007.

A-M NOISE LEVEL

The amplitude-modulation noise level has largely been the concern of the transmitter design engineer in the past, but it is now necessary for the transmitter operating engineer to become familiar with its measurement. The demodulation system, shown in Figure 3, uses a conventional linear rectifier and r-f filter as is usual in a-m practice, but there are two important differences — (1) there is no longer an available reference modulation to calibrate the system,

[1] C. A. Cady, "Type 1170-A F-M Monitor for Broadcast and Television Services," *Experimenter*, XXII, 5, October, 1947.
[2] Frank D. Lewis, "Distortion Measurement in the Broadcasting Station," *Experimenter*, XXIV, 1, June, 1949.

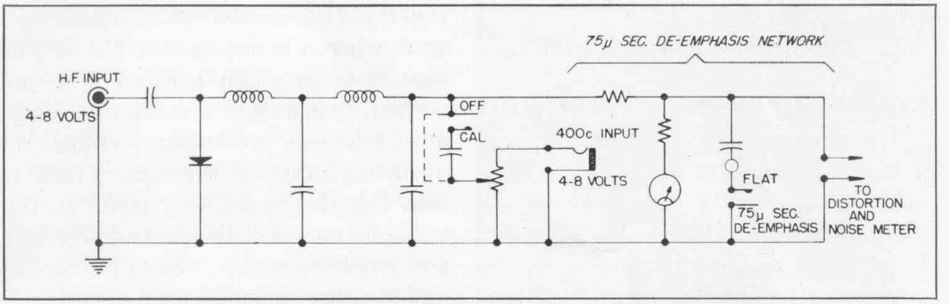


Figure 3. Circuit of the Type 1932-A Distortion and Noise Meter.

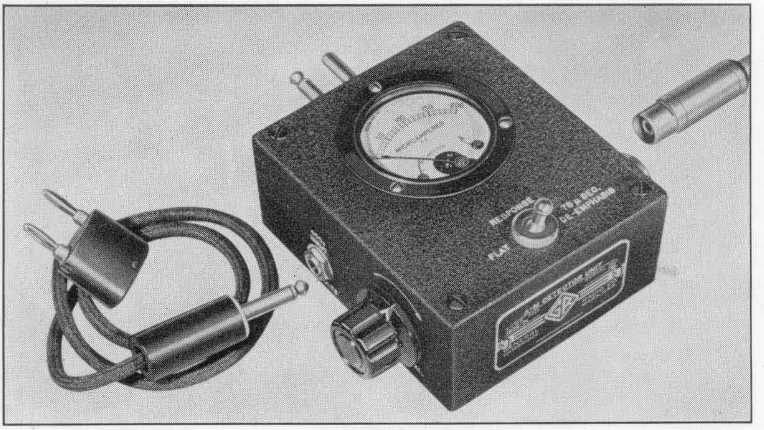
and (2) a 75 μ-second, de-emphasis network is specified by the FCC in the audio measurement device (to match the receiver characteristic).

Since the noise modulation is inherently a very low modulation percentage, certain of the problems associated with linear detector design are removed, such as negative peak clipping at high modulation frequencies. We do, however, have to provide for an external audio calibrating voltage which can be established at a level equivalent to 100% amplitude modulation. This is accomplished by using the d-c output of the rectifier as a standard of comparison. Connecting an external audio signal to the detector and establishing an arbitrary reference level as noted by the rectified dc, and at the same time setting up the noise meter to read full scale, establishes the first reference point. When the inserted audio signal is removed and replaced by the transmitter carrier frequency and the r-f level is adjusted to give the same d-c rectified current as before, the noise meter will then read the noise level directly. The change in rectifier efficiency between the audio test frequency and the transmitter carrier frequency is compensated for, since the average rectifier dc is maintained constant in each case.

An r-f filter, following the detector, isolates r-f components from the noise meter. The 75 μ-second de-emphasis network is added to give the desired response characteristics.

The r-f input circuit can be coupled directly into a low impedance transmission line, thus avoiding the limitations of tuned circuits upon the r-f bandwidth and the need for adjustments. Most transmitter monitoring outputs are adequate to provide 4 to 8 volts for operating the crystal rectifier. This voltage

Figure 4. Close-up view of the A-M Detector Unit. The coaxial connector at the right is supplied with the unit; the cord, plug and jack at the left are not.



range is a compromise between detector linearity and over-all sensitivity.

TYPE 1932-P1 A-M DETECTOR UNIT

The detector unit, arranged in a convenient plug-in form, is shown in Figure 4. It plugs directly into jacks on the panel of the TYPE 1932-A Distortion and Noise Meter. Direct connection to the r-f monitoring line is provided by means of a coaxial jack on the right side. An audio input jack and a convenient amplitude control and disconnect switch are provided on the left side. The diode-current microammeter is mounted in an easily viewed position at the top of the unit, together with a switch for removing the 75 μ-second de-emphasis network when it is not desired. No r-f gain control is provided because it is not needed. It is merely necessary to accept any reference r-f signal within the operating range of the meter, then to establish the audio level equal to this value by means of the control provided, and finally to reinsert the r-f connection and measure the noise level directly.

The plug-in construction is convenient and avoids unnecessary duplication of facilities, particularly when the distortion and noise meter is to be used with several transmitters, as in stations operating A-M, F-M, and TV transmitters.

— C. A. CADY

SPECIFICATIONS

R-F Input:

50 — 220 Mc.

4 to 8 volts required, from low-impedance line.

Type 774-G Connector.

Audio Input:

400 cycles.

4 to 8 volts required; internal potentiometer is provided.

Input impedance = 1000 Ω.

Standard single-contact telephone-jack connector.

Audio Output:

30 — 30,000 cycles ± 1 db; or 75 μsec de-emphasis characteristic.

1 to 1.5 volts, into 100 kΩ load.

Plugs to fit standard W. E. panel jacks, on Type 1932-A Distortion and Noise Meter are provided.

Accessories:

1 Type 774-M Cable Jack.

Mounting:

Black wrinkle-finish case.

Dimensions:

5¼ x 6 x 2½ inches, overall.

Net Weight:

1½ pounds.

Type		*Code Word*	*Price*
1932-P1	**A-M Detector Unit**	AMDET	**$55.00**

THE VERSATILE VOLTAGE DIVIDER

PART III

EXAMPLES IN GENERAL RADIO INSTRUMENTS

Many specialized voltage dividers have been designed and manufactured for use in various of our instruments.

1. **CRL Dials for Bridges, etc.** One of the most widely used items is a TYPE 433-LC Voltage Divider (L for logarithmic, C for compensating mechanism) used as a rheostat in several alternating-current bridges, including TYPES 625-A, 650-A, 740-B, 740-BG, and 1611-A. The 20-db logarithmic feature is not used as such, since there is no extension resistor. The mandrel is used only to spread the scale at the low end in order to make percentage accuracy more nearly the same throughout the dial.

The dials are etched to a curve which

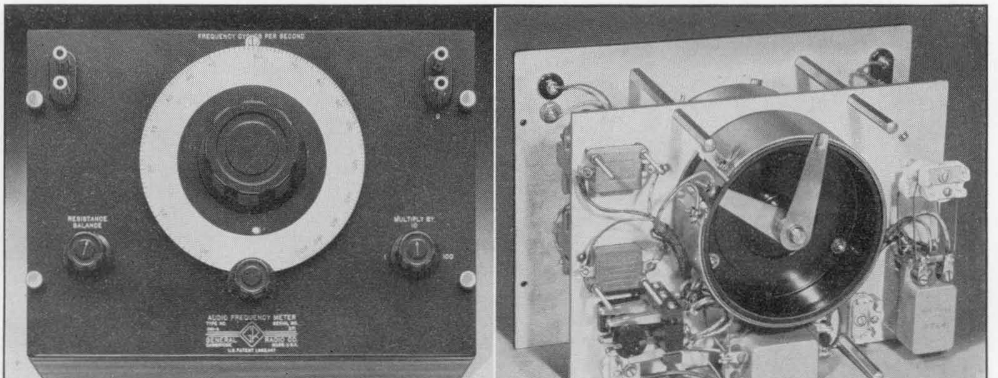
represents the average of a number of voltage dividers in production. It is a fairly simple matter to track the voltage divider to the scale by using a screw driver on the adjusting screws of the compensating mechanism. A d-c Wheatstone bridge is simply set for a resistance value corresponding to the then dial setting and the compensating mechanism adjusted until the bridge balances.

2. **Wien Bridge.** Two voltage dividers very similar to that described under "1" but having a different resistance value and being ganged together back-to-back are employed in our TYPE 1141-A Frequency Meter (Wien-bridge type) for continuous frequency adjustment, while the bridge capacitors are switched to provide decade steps. For various reasons the compensating mechanism is not included, and so each instrument is hand-calibrated. Techniques have been worked out for engraving a complete set of marks on the frequency scale distributed according to a smooth curve but starting from a minimum number of actually calibrated and marked points on the scales. In this instrument, extension resistors are employed, the dial covers a range a little over ten to one and does not go up to infinity, and the accuracy of setting is practically uniform throughout the dial.

Figure 11. Panel view of the Type 650-A Impedance Bridge. The logarithmic rheostat controlled by the large dial was shown in Figure 2, Part I, of this article.

3. **Twin-T R-C Networks.** Our TYPES 760-A and 762-A Sound and Vibration Analyzers use R-C twin-T networks for frequency determination. Capacitors are shifted for stepping multipliers of three and ten, while the continuous adjustment therebetween is afforded by three ganged voltage dividers operating as rheostats. One of these voltage dividers is one-half the resistance of the other

Figure 12. Panel (left) and interior (right) views of the Type 1141-A Audio Frequency Meter.



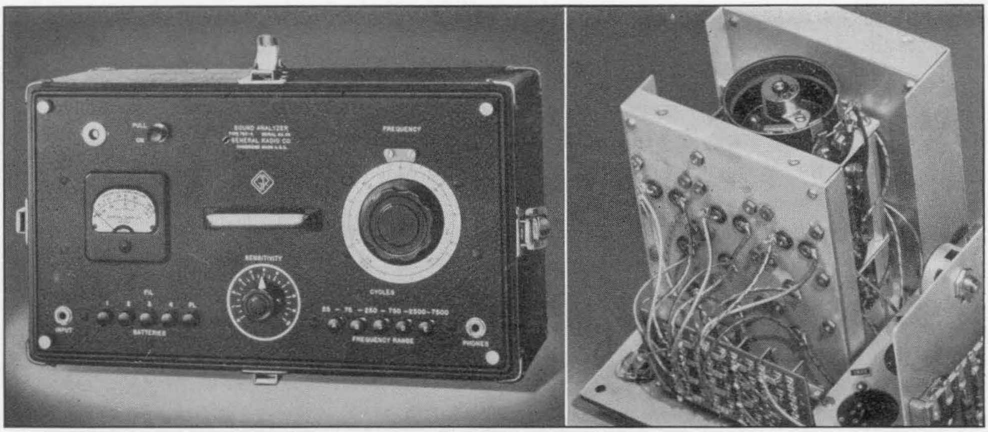


Figure 13. Panel view (left) and portion of interior of Type 760-A Sound Analyzer. In the interior view at the right, one unit of the four-gang voltage divider can be seen.

two. Close tracking is important if the instruments are to function properly. It has been found that the desired closeness of tracking is not easy to obtain if the third or one-half-resistance unit is wound using a different size of wire from the other two. Experience has shown that it costs less in the end to make the half-resistance unit by connecting in parallel two full-resistance units. Accordingly, four voltage dividers are ganged and driven by a single steel-cored phenolic shaft.

The trapezoidal mandrels have a straight taper with a ratio of about 2½ between extreme widths. The curve shape is, accordingly, a portion of a parabola. In manufacturing these four-gang voltage dividers, the mandrel shapes and thicknesses are closely controlled, the concentricity and dimensions of the bases are assured, the winding is carefully controlled, and each group of four associated units is carefully selected from among a large production quantity for tracking uniformity.

EXAMPLES OF SPECIAL UNITS FOR CUSTOMERS

With the factors mentioned earlier under the heading of Economics taken into account, there have been many

Figure 14. Panel view (left) of a Western Electric detector used in checking coils. The four-gang rheostat controlled by the TUNING dial is shown at the right.

special voltage dividers manufactured for our customers. A few examples may prove interesting:

1. **Twin-T R-C Networks.** In the manufacture of coils of many sorts for use in the nation-wide telephone system, measuring equipment is used for which hyper-accurate ganged rheostats are needed. These are similar to the ones just described for use in our analyzers, but are held to closer tracking tolerances and have some special features desired by the customer, such as pigtails in parallel with the sliding center contacts, for instance. Pigtails have not been necessary on the ganged resistors for our analyzers, and could not be used anyhow, since as a convenience feature there are no stops provided and the shaft can be rotated continuously.

2. **Vacuum-Tube Checker.** The Hickok Electrical Instrument Company desired a precision rheostat which should have a resistance-rotation curve in which the resistance would be proportional to the five-thirds power of the rotation. If the rheostat were so made, the dial would have numbers, representing "C" bias of the tube, evenly spaced. If the rheostats could be made accurately like one another, this dial could be electrochemically etched with consequent saving in calibration time.

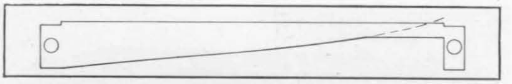
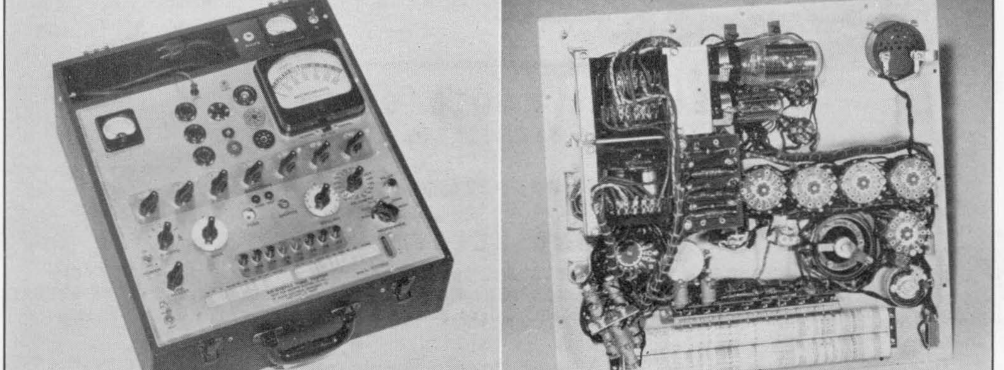


Figure 15. Mandrel shape used for the "C"-bias rheostat in the tube checker of Figure 16.

To meet the five-thirds power curve, the lengths of the turns of wire on the rheostat should vary according to the two-thirds power of the rotation. This, unfortunately, would mean that the width of a mandrel of a finite thickness would be negative at zero rotation. Accordingly, the shape had to depart from the theoretical for about the first fifth of the rotation. This departure was accounted for in the etched scale, making it somewhat crowded near zero. Cuts of a modified instrument and of the special voltage divider with the shaped mandrel are shown. Figure 15 shows the actual mandrel shape employed, the dotted line showing what the shape would have been if nothing governed it but the mathematics.

3. **Air-Brake Test Set.** The problem of braking a modern high-speed passenger train is not a simple one. It should be possible to apply the brakes to any desired degree, having a servo-mechanism to assist in that application, and there should be safety features to assure that an emergency braking system will take over if the servo system fails.

Figure 16. Panel view (left) and interior (right) of the vacuum-tube checker. The "C"-bias rheostat is near the lower right-hand corner in the interior view.



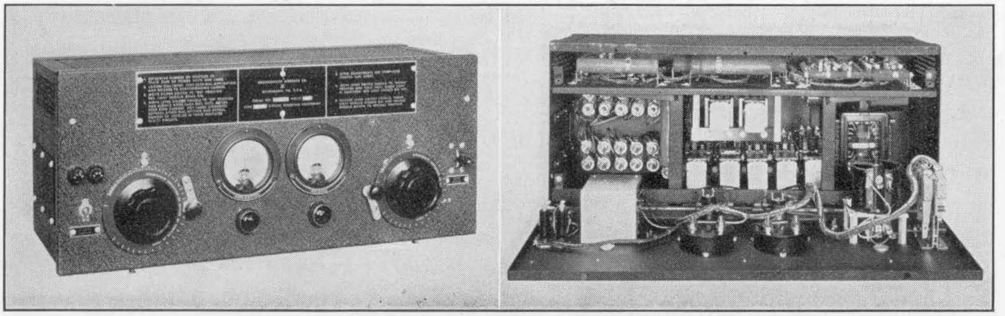


Figure 17. Panel and interior views of the air-brake test set. The dials control identical rheostats, one of which can be seen at the right in the interior view, ganged with another, smaller, rheostat.

As part of this complete braking system, Westinghouse Air Brake Company of Wilmerding, Pennsylvania, designed a Wheatstone-bridge-type device which periodically checks to see whether the brakes on all of the cars are working. This system has been described in the technical literature.[1, 2]

Each car contains a solenoid associated with the braking mechanism. In a long train these solenoids are connected in parallel and form one (the unknown) arm of the bridge. The other, or variable, arm is the special rheostat manufactured here. Its etched metal scale is approximately evenly divided, with the divisions numbered to correspond to the number of cars in the train. The resistance must vary inversely with the rotation, then.

It was soon discovered that the slope at the wide end was too large and the width at the narrow end too small to be manufacturable. However, a suitable compromise was reached in which the rheostat mandrel was curved for about 80% of the rotation and parallel-sided for the remaining 20%. On this straight portion, two different wire sizes were used, giving a dog-leg approximation to a mathematical curve. Figure 18 shows the shape of the mandrel employed. The rheostat is shown in the interior view of the circuit-checking equipment. The two dials are associated with two like rheostats, since each equipment actually contains two operating Wheatstone bridges as well as a number of relays and other circuit elements.

—P. K. McElroy

[1] C. M. Hines, "A Unique Application of the Wheatstone Bridge to High-Speed Train Braking," A.I.E.E. Technical Paper 48-53, December, 1947.

[2] Fuller description of this type brake in previous paper.

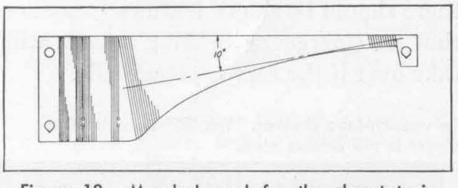


Figure 18. Mandrel used for the rheostats in the air-brake test set.

THE General Radio EXPERIMENTER

VOLUME XXIV No. 4 SEPTEMBER, 1949

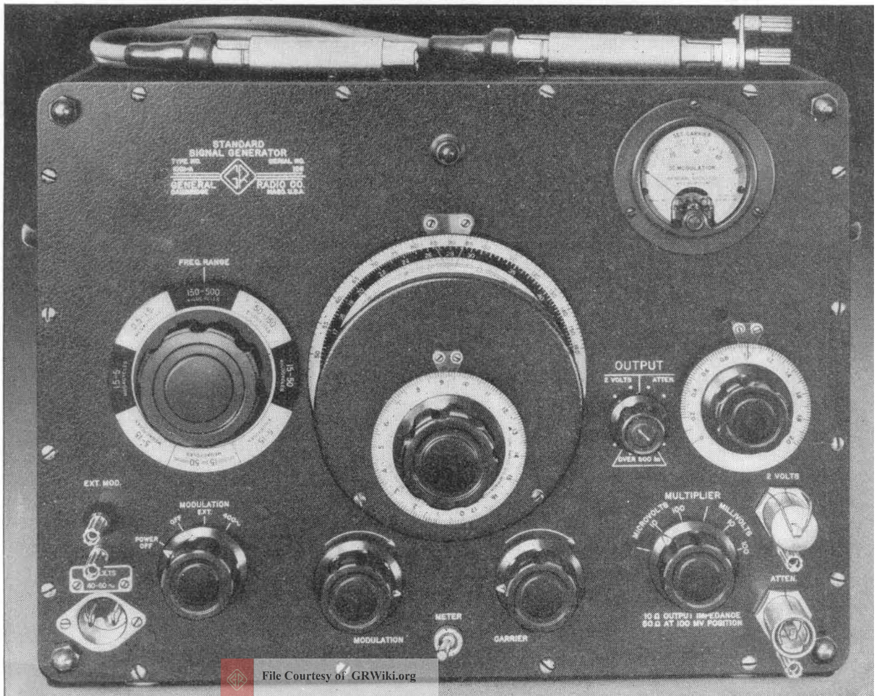
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

GENERAL-PURPOSE A-M STANDARD-SIGNAL GENERATOR

A NEW general-purpose A–M standard-signal generator is now in production, superseding the Type 605, which was discontinued some time ago. The new generator, Type 1001–A, embodies a number of features of design and construction that result in performance characteristics that are greatly improved over those of its predecessor. Among the specific improvements are higher output voltage, wider frequency range, lower leakage, and a better output system.

The Type 1001–A Standard-Signal Generator covers carrier-frequencies from five kilocycles to fifty megacycles in eight logarithmic direct-reading ranges. It can be amplitude-modulated up to 80%

Figure 1. Panel view of the Standard-Signal Generator. Output cable and other accessories are shown on the top of the cabinet.



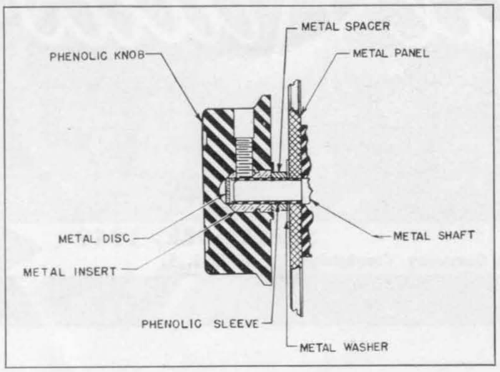


Figure 2. Method of shielding a shaft that projects through the panel. The metal insert of the knob, insulated from the shaft by a phenolic sleeve, is grounded to the panel through a metal washer.

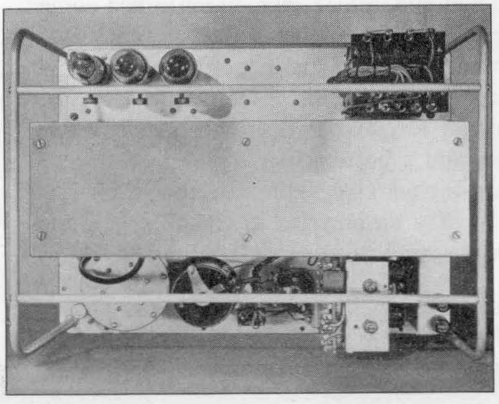
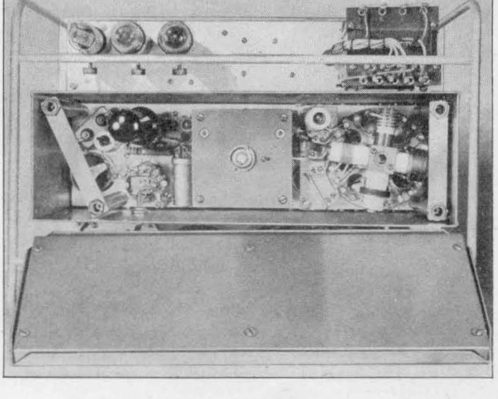


Figure 3. Interior view of the generator. The carrier-frequency compartment is in the center.

Figure 4. Rear view with cover removed from carrier-frequency compartment. The double cover is several hundred times as effective a shield as is a single one.



either at 400 cycles by the internal source or over the 20-15,000 cycle audio spectrum by an external source. The open-circuit output voltage at the attenuator jack can be adjusted from less than a tenth of a microvolt to 200 millivolts, with the smallest calibrated division at 0.1 microvolt. Two-volts output is available at a second jack. The generator can be operated from any 115- or 230-volt power line of 40- to 60-cycle frequency. Figure 1 is a panel view and Figure 3 is a rear view with cabinet removed.

Shielding

An outstanding feature of the generator is its freedom from leakage and stray fields. This has been achieved by enclosing all carrier-frequency circuits in a completely shielded compartment, which eliminates induced circulating currents and ground-return currents in the front panel. All leads entering the compartment are well filtered by resistance-capacitance networks using through-type capacitors. The all-metal cabinet and the compartment within it provide a very effective double-shield system.

Shafts extending through the panel from the carrier-frequency compartment, whether made of metal or of dielectric material, are a potential source of leakage. Metal shafts act as antennas and dielectric shafts behave as waveguides. Grounding the shafts at the front panel helps to reduce leakage, but for really effective shaft shielding it is necessary to enclose each shaft end that extends beyond the panel in a coaxial grounded shield. The shield around a metal shaft must be insulated from it. In the TYPE 1001-A Generator the metal inserts of the knobs are used as shields, as shown in Figure 2. They are insulated from the metal shafts by phenolic sleeves and grounded by means of spring washers to the front panel.

The carrier-frequency compartment is a deep box with a flat cover. To avoid a multiplicity of screws for good contact, a rather unusual, but very effective, design was devised. The cover is made of two pieces with the inner and outer cover sections insulated from each other. The sides of each cover section make spring contact to the inner and outer walls respectively of the compartment, thus providing a shield within a shield. The double cover is several hundred times as effective a shield as is a single cover, yet it is easily removed, as shown in Figure 4, for access to all the tubes and most of the components in the compartment.

To facilitate testing and servicing, the sub-panel in the carrier-frequency compartment can be taken out relatively easily. All circuit components are then completely accessible as can be seen from Figure 5. A long connecting cable permits operation of the equipment in this "dissected" condition.

Oscillator

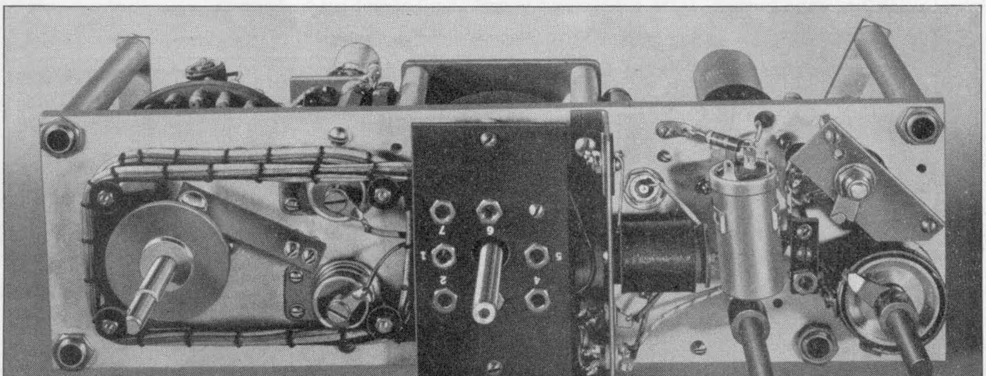
The basic circuit arrangement of the Type 1001–A Generator consists of a Hartley-type carrier oscillator followed by a modulated amplifier, a carrier voltmeter, and an attenuator system. The schematic is given in Figure 7.

The Hartley-type oscillator has somewhat better high-frequency performance than that of the tuned-plate circuit used in the Type 605, and the coil structure is simpler. It uses a newly developed, insulated-rotor tuning capacitor, which has soldered plates, shaped for logarithmic frequency calibration, sturdy end plates, and ball bearings to avoid backlash.

The eight carrier-frequency oscillator coils are mounted on a turret-like disc, which places the active coil, as selected, close to the terminals of the tuning capacitor and of the 6C4-type miniature triode oscillator tube. Because coils are mounted on both sides of the disc, the turret is only four inches in diameter.

Considerable attention was devoted to the design of the coil-switching mechanism to obtain low contact-resistance which is essential for reliable operation at high frequencies. Contact is made between a three-tined blade and a cylindrical surface. This construction ensures at least a three-point contact. The contact springs are ¾-inch long and are pre-loaded to obtain

Figure 5. Front view of the oscillator assembly. Connections to other circuits in the generator are made through the jack plate shown in the center. For servicing, the jack plate, which connects through the servicing cable shown at the right, can be detached and plugged into the generator chassis.



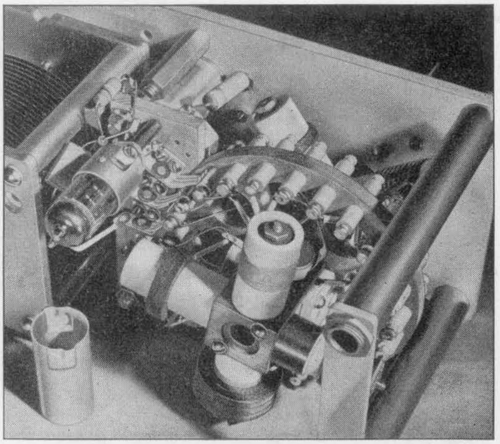


Figure 6. Close-up of the coil turret and switching mechanism. The switch blades are shown just to the right of the oscillator tube. Part of the tuning capacitor can be seen at the left.

pressure which is independent of minor misalignments. Figure 6 shows the coil turret and switch in detail.

Amplifier

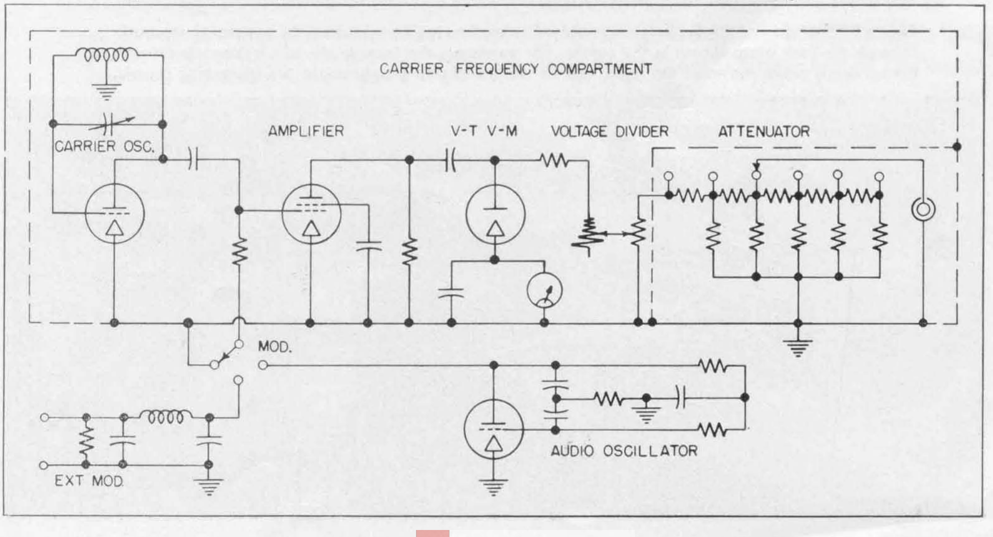
The carrier oscillator is followed by a modulated, untuned, amplifier stage using a 6L6-type beam-power-amplifier tube. More output could be obtained by using a tuned amplifier, but only at a considerable increase in cost. Similarly, grid modulation, which gives good performance to about 80% modulation, was chosen, rather than the inherently superior plate modulation, to avoid audio power amplification with its more costly power supply requirements. The small internal 400-cycle oscillator easily provides the voltage required for 80% modulation, and the external audio source need supply only 36 milliwatts.

Output System

The plate load of the modulated aperiodic amplifier is the output system of the signal generator; it consists of a vacuum-tube voltmeter, a voltage divider, and a six-step ladder-type resistance attenuator.

The d-c plate current of the output tube is about 40 milliamperes, and the carrier frequency component of plate current is limited to about 4 milliamperes to assure low distortion under modulation. The input impedance of the attenuator system is 50 ohms, and the maximum attenuator output is therefore 0.2 volt. Since voltage at this low level cannot be easily measured, resistance is connected in series with the attenuator system to increase the voltage at the carrier voltmeter to 1.6 volts, and also to make available a constant 2 volts output at another jack.

Figure 7. Elementary schematic circuit diagram of the Type 1001–A Standard-Signal Generator.



The output voltage is adjusted by means of the carrier-oscillator plate-supply control. The correct value is indicated by a reference line on the panel meter. A calibrated voltage divider provides continuous adjustment of output between the decade steps of the attenuator. The voltage-divider system was adopted in preference to the more obvious calibrated voltmeter method since it is difficult to obtain a reliable voltmeter calibration over a ten-to-one range at low voltage levels.

The voltage divider consists of two rheostats on the same shaft. They form a modified T-network and maintain to a constant value the effective load in the amplifier plate circuit. One of the rheostats is linear; the other is tapered; and both have non-inductive Ayrton-Perry windings. To maintain the accuracy of the system up to the highest output frequencies, the residual phase angle in the voltage divider is duplicated in the series resistor.

The ladder network contains a series and a shunt resistor at each attenuator step. The two resistors are wound on a common card of 10-mil mica. To assure correct attenuation at all frequencies, the phase angles of the two resistors in a series-shunt pair must be the same; various wire sizes and winding methods have been selected to assure the correct phase-angle match.

The mica cards are mounted in shielded segments of the cast attenuator housing (Figure 8), which contains the attenuator switch contacts. Complete shielding is necessary to reduce the attenuator input voltage to an accurate output of 0.1 microvolt. Over-all attenuation in this casting is one hundred thousand to one, and in the complete attenuator system it is sixteen million to one.

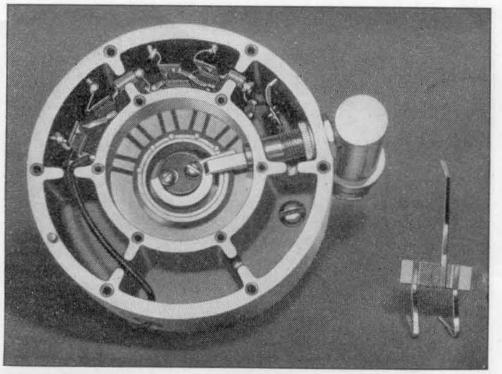


Figure 8. View of the casting that houses the MULTIPLIER network. One of the mica cards, with a series and a shunt element of the ladder network wound on it, is shown at the right.

The voltage appearing at the attenuator jack is indicated by the setting of the voltage-divider dial and of the attenuator MULTIPLIER. The output impedance is ten ohms for all but the 100 MILLIVOLTS setting of the MULTIPLIER where it is increased to 50 ohms. To increase the flexibility of the equipment, the output cable and terminations are supplied as separate items that may be used as demanded by the particular application. These accessories include a doubly shielded 50-ohm cable, a 50-ohm termination unit, and a 40-ohm series unit to provide, when need be, a 50-ohm output impedance at all MULTIPLIER settings. Additional accessories not supplied as standard equipment with the TYPE 1001–A Signal Generator include the TYPE 1000-P10 Test Loop and the TYPE 1000-P3 Voltage Divider, which provide two methods for testing loop-type radio receivers, and the TYPE 1000-P4 Standard Dummy Antenna for testing receivers designed for use with conventional antennas. These accessories are shown schematically in Figure 9. The generator output terminals as well as the accessories are all designed around the new

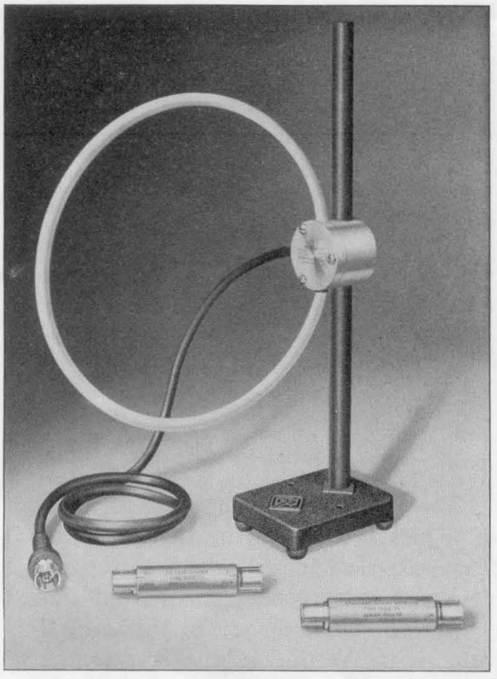


Figure 10. View of the Type 1000–P10 Test Loop, the Type 1000–P3 Voltage Divider, and the Type 1000–P4 Standard Dummy Antenna.

874-type coaxial system[1] where all connectors are identical, and plug-and-jack combinations are completely avoided.

[1]W. R. Thurston, "A Radically New Coaxial Connector for the Laboratory," *General Radio Experimenter*, Vol. XXIII, No. 5, October, 1948.

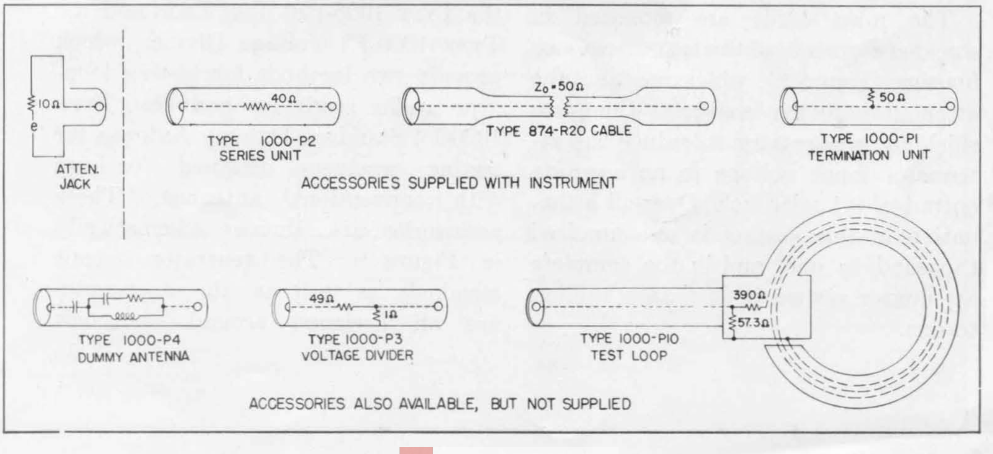
Other Circuits

The remainder of the circuits used in the Type 1001–A Standard-Signal Generator are conventional and need no elaboration. The plate supply is regulated where necessary. Because a balanced diode circuit is used, the heater of the carrier vacuum-tube voltmeter tube does not require regulation. The 400-cycle audio oscillator is of the R-C type. The modulation voltmeter uses a pair of 1N34-type germanium crystals in a balanced, full-wave, voltmeter circuit.

Frequency Dial

There are three frequency calibrations on the main frequency dial, and they have been marked clearly to correspond with the ranges of the frequency selector switch. One of the frequency calibrations is used for the 5- to 15-kc, 50- to 150-kc, 0.5- to 1.5-Mc, and 5- to 15-Mc ranges. The dial calibration and the frequency range sectors have dark symbols against a light background for easy identification. A second frequency calibration is used for the 15- to 50-kc, 150- to 500-kc, and 1.5- to 5-Mc ranges; light symbols against a dark background are used here to dis-

Figure 9. Schematics of the output accessories supplied and of other accessories available. Various combinations of these elements can be used. For a review of the output characteristics of signal generators under various conditions of termination, see Arnold Peterson, "Output Systems of Signal Generators," *General Radio Experimenter*, Vol. XXI, No. 1, June, 1946.



tinguish at a glance from the other frequency ranges. The highest frequency range (15 to 50 Mc) does not cover the full 180° rotation of the dial; it is identified at both the frequency dial calibration and the selector switch by a pair of parallel lines etched between the numerals.

The gear-drive mechanism is identical with that of the General Radio TYPE 908 Dial. About seven and a half turns of the vernier dial rotate the main dial over its total range. Since the calibrations for all but the 15- to 50- Mc range are logarithmic, the vernier dial indicates directly in per cent frequency change for small frequency increments. Each division of the vernier dial corresponds to a 0.1% change in frequency for all frequencies below 15 Mc.

Cabinet

The instrument is housed in an all-aluminum welded cabinet for light weight, low cost, good shielding, and pleasing appearance. A compartment is provided in the cabinet top for storing the output cable and the other standard accessories.

— A. G. BOUSQUET

SPECIFICATIONS

Carrier-Frequency Range: 5 kilocycles to 50 megacycles covered in eight direct-reading ranges as follows: 5 to 15 kc, 15 to 50 kc, 50 to 150 kc, 150 to 500 kc, 0.5 to 1.5 Mc, 1.5 to 5 Mc, 5 to 15 Mc, and 15 to 50 Mc.

Frequency Calibration: Logarithmic up to 15 Mc, departing slightly from the logarithmic scale at higher frequencies. Accuracy, ±1%.

Incremental-Frequency Dial: Frequency increment is 0.1% per dial division, at frequencies up to 15 Mc.

Frequency Stability: Warm-up drift is of the order of 0.25% in 24 hours. Half the maximum drift is reached in 1½ hours; 95% of maximum in four hours. Carrier shift with 80% modulation is 20 parts per million, or less.

Output Voltage Range: Open-circuit output voltage at the attenuator jack is continuously adjustable from 0.1 microvolt to 200 millivolts. With output cable terminated at both ends, output voltage is continuously adjustable from 0.05 microvolt to 100 millivolts. Open-circuit output voltage at the 2 VOLTS panel jack is measured directly by the output meter and is 2 volts if the meter is set to the reference mark. This voltage is available up to at least 15 Mc.

Output Impedance:* Output impedance at the attenuator jack is 10 ohms (50 ohms when the series unit is used) except for the highest output position of the attenuator, where it is 50 ohms.

Output impedance at the end of the terminated cable is 25 ohms. Output impedance at the 2 VOLTS panel jack is about 300 ohms.

An output impedance of one ohm (with output voltage reduced 100:1) can be obtained with the TYPE 1000–P3 Voltage Divider, a standard (IRE) test impedance with the TYPE 1000–P4 Dummy Antenna, and a known induction field with the TYPE 1000–P10 Test Loop (see price list below).

*See "Output Systems of Signal Generators," *General Radio Experimenter*, Volume XXI, Number 1, June, 1946.

Accuracy of Output Voltages: At frequencies below 10 Mc, when the output dial is set at about full scale or at about one-tenth full scale, the output voltage is correctly indicated to $\pm(6\% + 0.1\ \mu v)$. With the output dial set in the mid-scale region, the error may be greater or smaller by 4%. At frequencies above 10 Mc, when the output dial is set at about full scale, the output voltage is correctly indicated to an accuracy of $\pm(10\% + 0.3\ \mu v)$ and the error may be as much as 10% larger or smaller at other output dial settings.

The accuracy of the open-circuit output voltage at the 2 VOLTS panel jack is ±3% up to 15 megacycles.

Amplitude Modulation: Adjustable from zero to 80%. Modulation percentage is indicated on the panel meter and is accurate within ±10% of the indicated value, with a possible additional error of 2% in modulation level.

The external modulation characteristic is flat within ±1 decibel from 20 cycles to 15 kilocycles. To provide 80% modulation, the external audio oscillator must supply 12 volts into a 4000-ohm load (36 milliwatts).

Incidental Frequency Modulation: At 80% amplitude modulation, the incidental frequency modulation varies from about 10 to 100 parts per million over each carrier-frequency range except for the highest frequency range (15 to 50 Mc) where it may be three times as great. At lower modulation percentages, frequency modulation is approximately proportional to modulation percentage.

Carrier Distortion: Of the order of 5% on all except the lowest range, where it may increase rapidly, reaching 12% at 5 kc.

Envelope Distortion: About 6% at 80% amplitude modulation.

Noise Level: Carrier noise level corresponds to about 0.1% modulation.

Leakage: Stray fields are substantially less than one microvolt per meter two feet from the generator.

Terminals: TYPE 874 Coaxial Terminals are provided for the attenuator output and for the constant 2-volt output.

Power Supply: 105 to 125 (or 210 to 250) volts, 40 to 60 cycles. Power input is approximately 65 watts at 115 volts.

Tubes: Supplied with the instrument.

1 — 6C4	1 — 5Y3-GT
1 — 6L6	2 — OC3/VR105
1 — 6AL5	1 — 6SN7-GT

Accessories Supplied: TYPE 874-R20 3-foot Coaxial Cable, TYPE 1000-P1 50-ohm Termination Unit, TYPE 1000-P2 40-ohm Series Unit, TYPE 874-Q2 Adaptor, TYPE 1000-215 Adjustment Tool, and a power cord.

Other Accessories Available: Not supplied but available on order are the TYPE 1000-P3 Voltage Divider, the TYPE 1000-P4 Standard Dummy Antenna, and the TYPE 1000-P10 Test Loop.

Mounting: The instrument is assembled on an aluminum panel finished in black crackle lacquer and mounted in an aluminum cabinet with a black wrinkle finish. The cabinet is provided with carrying handles. A recessed compartment is built into the top of the cabinet for storing the accessories.

Dimensions: (Height) 14⅜ × (width) 20¼ × (depth) 10$\frac{9}{16}$ inches over-all.

Net Weight: 52 pounds.

Type		*Code Word*	*Price*
1001-A	**Standard-Signal Generator**	ARGUS	**$595.00**
1000-P3	**100:1 Voltage Divider**	ARMOR	**15.00**
1000-P4	**Standard Dummy Antenna**	ARROW	**15.00**
1000-P10	**Test Loop**	ARRAY	**30.00**

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THE General Radio EXPERIMENTER

VOLUME XXIV No. 5 OCTOBER, 1949

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A SMALLER VARIAC SPEED CONTROL

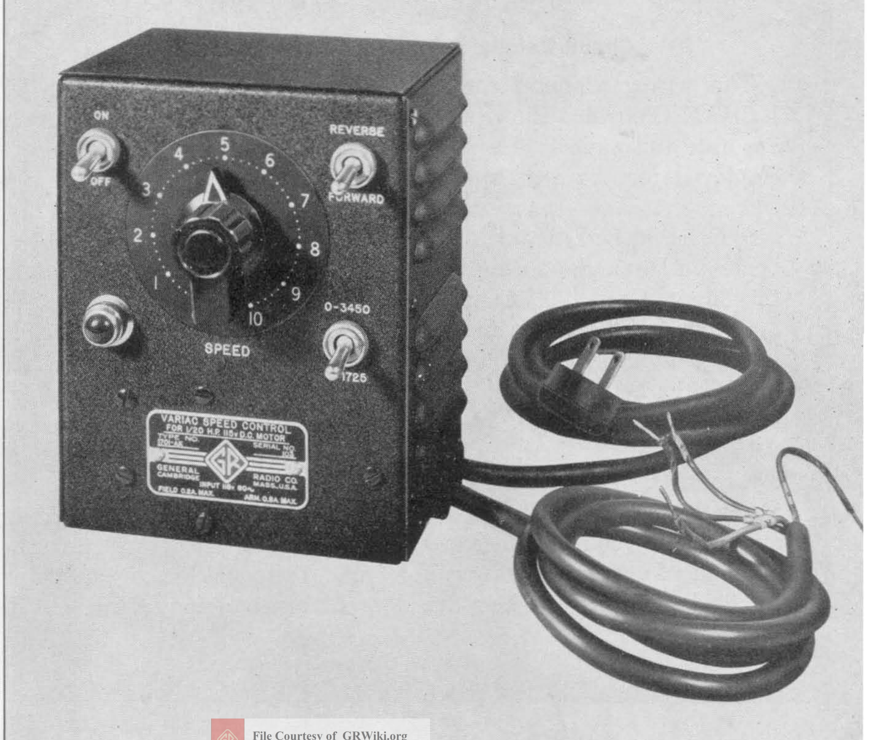
Also IN THIS ISSUE

Introduction

In the April issue of the *Experimenter*, the Type 1700 Variac Speed Controls* were described for operation of shunt motors having ratings up to ⅓ h.p. The Type 1701 Controls are now offered for applications requiring up to about $\frac{1}{15}$ h.p. output. A very compact design has been achieved by employing miniature selenium rectifiers instead of the full-wave gas rectifier used in the Type 1700 Control. The selenium rectifiers also

*W. N. Tuttle, "Variac Motor Speed Controls," *General Radio Experimenter*, April, 1949.

Figure 1. Panel view of the Type 1701-AK Variac Speed Control.



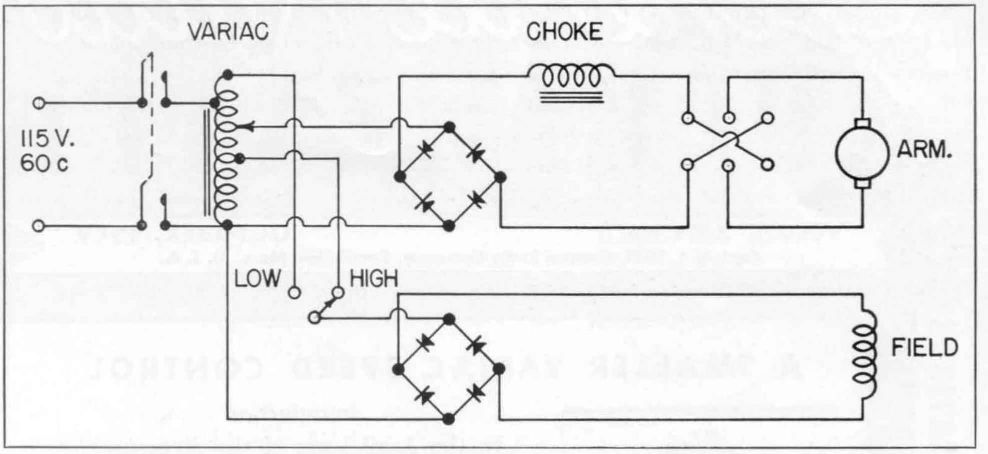


Figure 2. Circuit of Type 1701-AK Speed Control. Circuit of Type 1701-AU is similar but furnishes the field supply at a lower voltage and has only a single speed range.

permit considerable circuit simplification and reduction in cost and eliminate the need for a time delay when the unit is first turned on. Two types are offered. The Type 1701-AK is for shunt motors of standard design. The Type 1701-AU is for series or universal motors converted by reconnection for operation at constant field excitation.

Circuit Details

The wiring diagram for the Type 1701-AK Control is shown in Figure 2. Separate full-wave bridge rectifiers are employed for the armature and field. The adjustable output voltage of the Variac feeds the armature through one of the bridges and a choke, which, as in the larger Type 1700 Controls, serves both to reduce the ripple and to improve the regulation. Fixed taps on the Variac furnish the field excitation through the second rectifier bridge. Normally the field is left fully excited, and the speed is controlled by adjustment of the armature voltage from zero to maximum. For applications requiring increased maximum speed at reduced torque, however, the field excitation can be reduced by a two-position speed-range switch. The line power switch serves as the motor start and stop switch, because the selenium rectifiers are ready for instant operation without warm up.

Construction

The general appearance of the control is shown in the photograph, Figure 1.

The cabinet is 6⅞ inches high, 5¼ inches wide, and 3⅝ inches deep. The louvers make the width ½ inch greater overall, and the knobs and switches add about ⅞ inch to the depth. Ventilation is entirely through the side louvers, so the cabinet can rest on its base and the control can be operated conveniently on a laboratory bench without being permanently installed. Further to facilitate laboratory use, and to simplify installation, the power cord and a four-conductor motor cord are permanently attached to the control.

Figure 3 shows the internal construction and the method of attachment of the cover. The base is integral with the panel. The cords are attached to the base, and the cover is notched so that it can be removed without disturbing the wiring. This construction permits two alternative methods of mounting in permanent installations. Either the control can be mounted through its base and the cover left free, or the cover can be permanently mounted on a vertical surface through holes in its back and the control in turn attached to the cover. The latter arrangement makes it possible to remove a unit with its connecting cords for servicing by taking out only the small screws attaching it to the cover.

Performance

The internal resistance of the armature supply circuit is very low, about 12 ohms compared with the armature resistance of about 42 ohms. Hence, at base speed, the regulation is only slightly greater than when the motor is operated directly from a d-c line. Families of speed-torque curves for the high and low speed ranges of the control are shown in Figure 4. As with motors operated from the larger Type 1700 Variac Speed Controls, the rise in speed between full load and no load is the same at all speed settings, so the regulation expressed as a percentage of the full-load speed is inversely proportional to the speed setting. The r.p.m. rise is about 470 and 680 r.p.m. for the low and high speed ranges, or about 27 per cent and 20 per cent, respectively, at the maximum speed setting for each range. This compares favorably with the performance of the larger Type 1700 Controls, the difference being largely in the inherently poorer regulation of the smaller motor.

The Type 1701-AU Control for Converted Universal Motors

This model of the control makes it possible to obtain adjustable constant-speed operation from a motor of the

Figure 3. Interior view of control.

series or universal type by separately exciting the field at the voltage normally appearing across it at full load in the series connection and applying an adjustable voltage to the armature alone. The performance is exactly the same as for a shunt motor, but the field excitation is supplied at lower voltage and higher current.

The reasons for supplying this model of the control are that universal motors are widely available in a large number of types, are relatively inexpensive, and run at high efficiency. They are the only motors generally available for operation at speeds up to 10,000 r.p.m. and higher, and they are very compact for a given power output. Another consideration is that with this control various types of equipment run by universal motors can be modified for operation at adjustable constant speed without changing the motor. Finally, because of the high speeds available, operation on a constant torque basis is possible over an extremely wide range of speeds, up to 50:1 or even 100:1. The only disadvantages of any consequence in the universal motor appear to be that the high operating speed causes greater brush and bearing wear, and that for some applications a relatively high gear or pulley reduction ratio must be employed.

It is clear that with d-c operation under steady load conditions the motor will perform identically whether the field and armature are connected in series or separately excited at the same voltages. One motor tested, for example, had a rating of 1/15 h.p. at 5000 r.p.m., 1.25 amperes, and 115 volts. The field resistance was 12.5 ohms, so the field voltage at full load was 15.6 volts and the armature voltage 99.4 volts in the usual series connection. When these voltages were supplied separately to the armature and field, operation at rated load was unaffected, but the speed, instead of varying widely with the load, was maintained within close limits. The

Figure 4. Speed-torque curves for 1/20 h.p. shunt motor with Type 1701-AK Control for the high and low speed ranges.

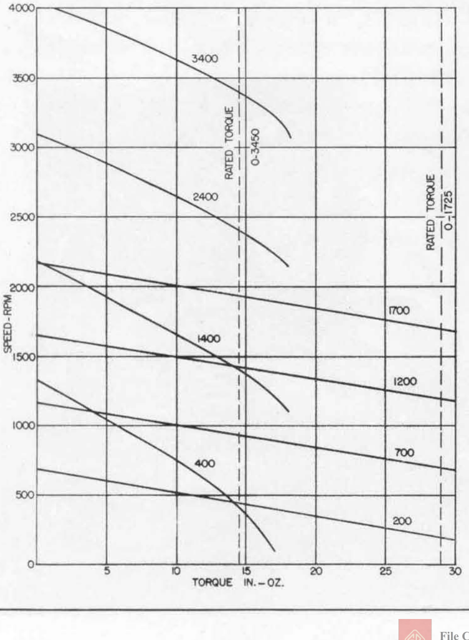
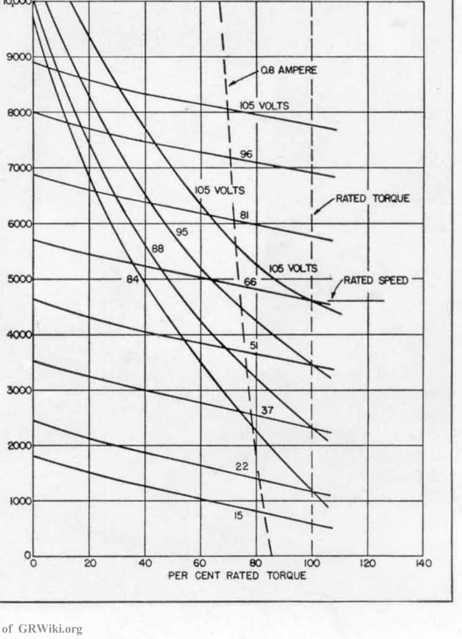


Figure 5. Speed-torque curves for 1/15 h.p. converted universal motor used with Type 1701-AU Control compared with a-c operation of the motor.



very high starting torque of the series connection must be given up, on the other hand, for the relatively lower starting capabilities of the shunt motor. When, as in the Type 1701 Control, the armature voltage is adjusted to set the speed, however, heavy loads can be started without difficulty by turning up the speed control.

An important feature of the Type 1701-AU Control is that it takes advantage of the greatly improved performance of a universal motor on dc in comparison with the usual operation on ac. Greater power output can be obtained with a motor of given size, the efficiency is higher, and commutation is very much better. With a-c operation, the brushes must be set off neutral for the best commutation, so that motors for reversing service are not entirely satisfactory. When motors are operated on dc, as with the Type 1701 Control, excellent reversing characteristics are obtained.

Figure 5 illustrates the comparative performance of a 1/15 h.p. universal motor working on adjustable a-c voltage from a Variac, and working on dc with fixed field excitation and adjustable armature voltage obtained from the Type 1701 Control. This motor is suitable for use with the control, although its rated current for a-c operation, 1.25 amperes, is considerably greater than the maximum continuous current, 0.8 ampere, which can be provided by the control. This is because on dc, even with 105 volts applied and with a load of rated torque, the armature current is only about 1 ampere and the speed is about 70 per cent greater than the rated speed for a-c operation. The 0.8 ampere current limit of the control is shown by a dashed line. It is seen that this current will provide 80 per cent of rated torque at 8000 r.p.m. instead of the rated 4600 r.p.m. The combination of the control with this motor, then, will provide continuously about 40 per cent more than the motor rated power, or about 1/11 h.p. instead of 1/15 h.p. Because of these characteristics, considerably increased output can be obtained from a given universal motor when used with the Type 1701-AU Control wherever operation at increased speed and somewhat reduced torque can be provided for. Even without exceeding the rated speed, about 75 per cent of rated torque, or 1/20 h.p., can be obtained from this combination without exceeding the continuous duty rating of the control.

The dashed characteristics show the comparative performance of the motor run in the series connection from adjustable a-c voltage. The usual inverse speed-torque characteristic contrasts greatly with the constant-speed characteristics obtained on dc with separate field excitation. Corresponding operating voltages are also marked on the curves. The great improvement in both regulation and efficiency is apparent.

— W. N. Tuttle

SPECIFICATIONS

	Type 1701-AK		*Type 1701-AU*	
Supply Frequency	60 c	50 c	60 c	50 c
Supply Voltage	105–125 v	105–120 v	105–125 v	105–120 v
D-C Output Armature Voltage	0–115 v		0–115 v	
D-C Output Armature Current	0.8 a. max.		0.8 a. max.	
D-C Output Field Voltage	38 v, 115 v		16 v	
D-C Output Field Current	0.2 a.		1.0 a.	

Speed Range: Motor rated speed down to zero at constant torque. A working range of 30:1 can be satisfactorily employed with the TYPE 1701-AK Control and up to 50:1 or more when the TYPE 1701-AU Control is used with a converted universal motor having a speed rating of 5000 r.p.m. or higher. Two speed ranges, one up to rated speed and one at reduced field excitation up to approximately twice rated speed, are provided in the TYPE 1701-AK Control. Only a single range is provided in the TYPE 1701-AU Control because of the higher rated speeds of universal motors.

Motor: The TYPE 1701-AK Control can be used with any 1/20 h.p. 115-volt d-c shunt motor or with a 1/15 h.p. motor when the current consumption is within the rating of the control. Speed ranges marked on the panel are for motors having a base speed of 1725 r.p.m. and reduced field operation up to 3450 r.p.m. as provided by Bodine Motor Model NSH-33 listed below.

The TYPE 1701-AU Control can be used with 1/20, 1/18, or 1/15 h.p. universal motors when the current consumption is within the rating of the control. When operating at rated current, such motors will furnish rated torque at up to 150 per cent or more of rated speed, giving output power substantially greater than the rating. Motors of the four-wire reversible type can be used without modification. Uni-directional motors must be provided with separate field leads. Bodine type NSE-12 motors 1/18 h.p., 5000 r.p.m., for reversing service are stocked as listed below. Motors of other ratings or with built-in gear reduction can be obtained from the manufacturer.

Overload Protection: No protection for starting load or momentary overload is required. A slow-blow fuse is provided in the TYPE 1701-AU Control only as a protection against damage from stalling when starting an excessively heavy load.

Reversal: Motors with brushes set on neutral give excellent reversing performance with either control. Sparking at the commutator may occur if it is attempted to reverse motors having brushes set for a single direction of rotation.

Mounting and Wiring: The control can be mounted either through the bottom or the back and can be used unmounted on a laboratory bench. Mounting must permit ventilation through the side louvers. A 5½ foot power cord and a 3½ foot four-conductor motor cord are permanently attached to the control.

Dimensions: Height 6 13/16 inches, width 5 11/16 inches, depth 4⅝ inches overall.

Weight: Six pounds for either model.

Type		*Code Word*	*Price*
1701-AK	**Variac† Speed Control,** 115 v, 50-60 c.p.s., for D-C Shunt Motor	WINDY	**$65.00**
1701-AU	**Variac† Speed Control,** 115 v, 50-60 c.p.s., for Converted Universal Motor	WEARY	**65.00**
MOD-1	**Bodine Model NSH-33** Sleeve-Bearing D-C Shunt Motor, 1/20 h.p., 1750 r.p.m., for use with TYPE 1701-AK Control	MOTOR*	**24.50**
MOD-4	**Bodine Model NSE-12** Sleeve-Bearing Reversible Universal Motor, 1/18 h.p., 5000 r.p.m., for use with TYPE 1701-AU Control	MOTOR*	**14.26**

*To order speed control with motor, use compound code word, WINDYMOTOR or WEARYMOTOR.
†Trademark registered in U.S.A. U.S. Patent No. 2,009,013.

RETURNING INSTRUMENTS FOR REPAIR

When General Radio instruments are returned to the Service Department for repair or reconditioning, the time consumed in handling the job can be held to a minimum if the procedure outlined here is followed.

Before returning an instrument for any reason, write to the Service Department, stating the reason for return, and giving the type and serial numbers. Shipping instructions, where necessary, and a Returned Material Tag, will then be furnished by the Service Department. Do not ship equipment to our plant without first obtaining instructions. Unauthorized shipments are made at the owner's risk. We cannot accept responsibility for them.

When the return is to be made for repair, please give us complete information on the observed defects: their nature, symptoms, etc., as well as a sketch of the external circuits to which it is connected. When we have all this information, we can often diagnose the trouble and correct it by furnishing a replacement part.

Often instruments have been returned with no greater trouble than a blown fuse or deteriorated vacuum tube. Occasionally equipment has been returned in first-class condition because the operating instructions supplied with it had not been followed, or possibly were not fully understood. Frequently what appears to be unsatisfactory performance can be traced to the external circuit with which the instrument is being used.

Even when equipment must be returned for repairs, a detailed statement of the trouble may be very helpful. Analysis of this information sometimes shows that the trouble is caused by a single defective component which can be easily replaced. Our laboratory will know what condition needs correction, and no time will be lost in making extra preliminary checks.

The letter or purchase order authorizing necessary work to an instrument should always be mailed so as to arrive before the shipment. The *Returned Material Tag* should always be fastened to the instrument when shipment is made. If this is not done, serious delays will result, as in some cases we would have no way of knowing by whom the instrument was shipped.

In accordance with the procedure of their purchasing divisions, some of our customers request a quotation to cover the cost of reconditioning equipment. It is our practice to submit an estimate based on records of previous charges for equipment of the same type and age. This estimate is not a definite quotation, but is the form of minimum and maximum prices.

We have found it necessary to follow this plan rather than to test a returned instrument completely and then to quote an exact charge, which would inevitably be in excess of what the customer expected because of the laboratory time required for testing. Since repair charges depend upon the cost of the labor and material involved, a considerable saving can thus be made in the repair charge.

If, upon inspection of a returned instrument, it is found that the cost of reconditioning will be in excess of normal charges, the customer is advised of the maximum cost, and no work is done until a reply is received.

In reconditioning a returned instrument we clean it thoroughly; check and resolder any connections that may have weakened; replace or repair any component parts that have become worn, deteriorated, or damaged; tighten all assembly and mounting screws; clean the panel and polish the cabinet.

It is then sent to the laboratory for final test and recalibration. The repaired instrument must pass the same test as a new instrument. If an obsolete type, it is tested under the specifications that were used when it passed through the laboratory originally. Because of the careful and complete reconditioning in our shop and laboratory, we are able to guarantee the instrument for one year, tubes and batteries excepted. This guarantee is identical to that which applied when the instrument was originally sold.

— H. H. Dawes

MISCELLANY

Recent Visitors to General Radio—Mr. A. Bruaux, Ateliers de Constructions Electriques, Charleroi, Belgium; Mr. P. L. Jain, Jubbulpore, C.P., India; Mr. Arun Prasad, Bangalore, South India; Dr. R. A. Smith, Telecommunication Research Establishment, Great Malvern, England; Dr. H. Van Dijk, Kamerlingh-Onnes Laboratory, Leiden, Holland; and Mr. Gunnar Hammerik of Maskin-Aktieselskapet Zeta, Oslo, sales representatives for General Radio products in Norway.

Papers — by Ivan G. Easton, Engineer, "Amplifier and System Measurements," tenth lecture in the Spring Educational Series of the Audio Engineering Society, New York, May 19.

— by Arnold P. G. Peterson, Engineer, "The Measurement of Non-Linear Distortion," at the Pacific Coast Convention of the I.R.E., San Francisco, and at a meeting of the Seattle Section of the I.R.E.

In Denmark, we have been represented for the past year by Mogens Bang and Company, Copenhagen/Skordsborg. Our friends in Denmark will be glad to learn that, effective October 1, Mogens Bang and Company will be our exclusive representatives in Denmark.

Credits — Design and development of the TYPE 1001-A Standard-Signal Generator, described in our September issue, was carried out under the supervision of Eduard Karplus. Development engineer was A. G. Bousquet, author of the descriptive article.

Erratum

It has been brought to our attention that the caption of Figure 3 on page 3 of the August, 1949, *Experimenter* is incorrect. The caption should be "Circuit of the TYPE 1931-P1 A-M Detector Unit."

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THE General Radio EXPERIMENTER

VOLUME XXIV No. 6 NOVEMBER, 1949

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

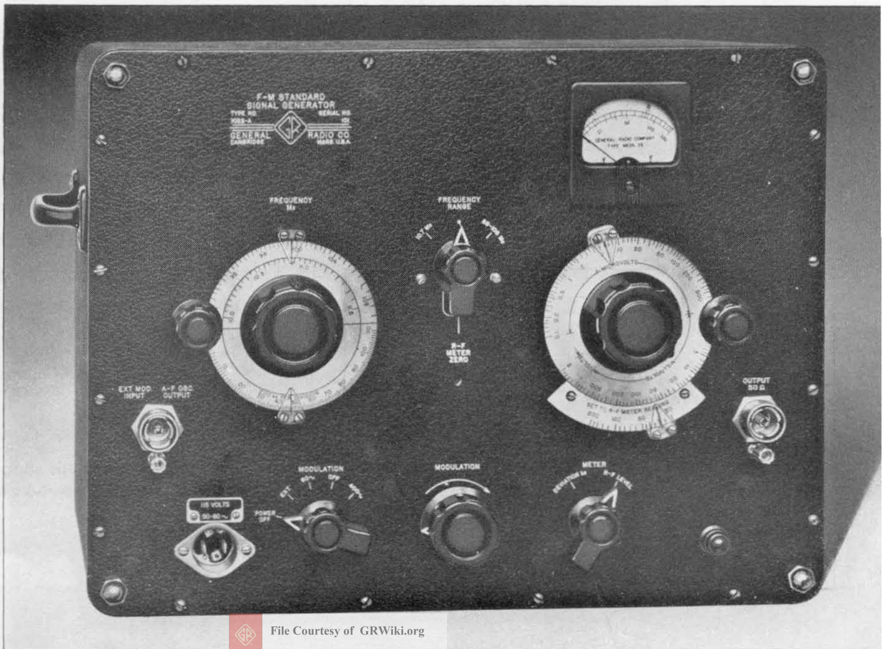
A SIMPLE STANDARD-SIGNAL GENERATOR FOR F-M BROADCAST USE

Also
IN THIS ISSUE

● **TO SUPPLEMENT** the TYPE 1001-A general-purpose a-m standard-signal generator announced in the September, 1949, *Experimenter*, an f-m standard-signal generator, specifically intended for measurements on f-m broadcast receivers, is now available.

The TYPE 1022-A F-M Standard-Signal Generator has been designed to provide first-class performance at a moderate price. Every effort has been made to use simple, direct methods in the design, and only those features necessary for measurements of f-m broadcast receivers have been included.

Figure 1. Panel view of the Type 1022-A F-M Standard-Signal Generator.



The instrument comprises an oscillator, covering the frequency ranges of 88-108 Mc and 10.7 Mc ±10%, and a reactance-tube modulator, providing deviations up to ±200 kc. The output voltage is obtained through a mutual-inductance-type attenuator and can be adjusted over a range from 0.1 μv to 1 volt on the 88-108 Mc range, and from 0.1 μv to 0.25 v on the 10.7-Mc range. The output impedance is 50 ohms resistive, constant over the tuning range.

The TYPE 1000-P5 Transformer described in an accompanying article can be plugged into the TYPE 874-P Output Jack to convert the 50-ohm unbalanced output system to 300 ohms balanced.

GENERAL FEATURES

The direct use of the r-f oscillator eliminates difficulties with spurious beats, or "birdies," that cause trouble in beat-type systems. The restricted tuning range opens up the tuning scale and facilitates precise frequency settings. For easy interpolation on the 88-108 Mc band, an auxiliary scale on the main tuning dial is marked in 200-kc intervals. On the 10.7 Mc range, this same scale provides intervals of approximately 20 kc.

The modulation system is flat from 20~ to 15 kc, and the instrument can therefore be modulated, from an external source, with any frequency that is of interest in designing f-m receivers. Fixed internal modulating frequencies of 60~ (line frequency) and 400~ are provided. When these are used, the modulation voltage appears at the external modulation binding posts to drive the horizontal plates of a cathode-ray oscillograph for sweep-generator applications. Deviation is indicated directly on a panel meter whose quasi-logarithmic scale spreads the readings at small deflections, so that good accuracy is obtained in reading small deviations as well as large.

Shielding is excellent. All the r-f circuits are contained within one casting, which is closed with a tight-fitting cover. All leads entering the casting are carefully filtered, and the amount of leakage from the assembly is so small that the extra attenuation provided by the panel and aluminum cabinet reduces the external leakage below the noise level. The testing specification on leakage, in fact, calls for no measurable signal to be detected on a high-sensitivity f-m receiver.

No provision for amplitude modulation is incorporated in the TYPE 1022-A itself. The TYPE 1023-A Amplitude Modulator, described in the accompanying article, was therefore designed to be used in conjunction with the signal generator for a-m tests.

Several of the circuits and design features, which contribute to the good performance and simplicity of the instrument, are unconventional and worthy of mention.

R-F OSCILLATOR

The oscillator circuit, shown in Figure 2, is based on the series-tuned circuit described by Clapp.[1] It was chosen both

[1] J. K. Clapp, "An Inductance-Capacitance Oscillator of Unusual Frequency Stability," *Proceedings of the I.R.E.*, March, 1948.

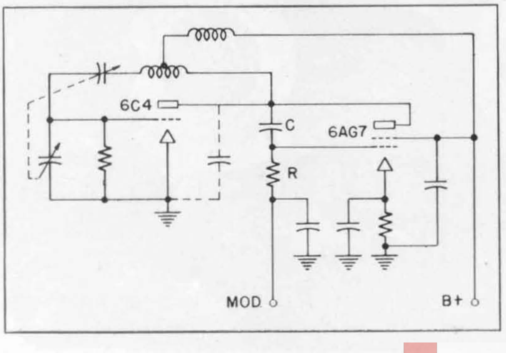


Figure 2. Elementary schematic diagram of the oscillator and reactance-tube circuits.

because it is inherently a stable circuit and because it gives a minimum change of deviation with the oscillator frequency.

Two tuning inductors, for the two frequency ranges provided, are mounted on a turret switch. For the particular frequency range selected, the appropriate inductor is moved to a position in which connections to the oscillator circuit are made and proper magnetic coupling to the mutual-inductance-type attenuator is established. The tuning capacitor has two sections, one connected in series with the inductor, between plate and grid, for tuning, and another connected from grid to ground to maintain proper feedback to provide constant output over the tuning range. The fixed capacitance between plate and ground, that completes the oscillator circuit, is provided by the capacitance component of the reactance-tube-modulator admittance and the plate-to-ground capacitance of the oscillator triode.

The circuit shown yields a deviation that ideally would vary inversely as the carrier frequency. This is not a very rapid variation, and could be compensated readily by a conventional ganged volume control in the modulation circuit. The departures from ideal behavior, however, have been put to good use in eliminating even this mechanical complication. It was found that the type of tube used for the reactance modulator tended to resonate in the 88-108 Mc range, with a consequent increase in effective input capacitance with frequency. Over this relatively narrow frequency range it was therefore found possible to maintain substantially constant deviation, without ganged controls, by proper choice of components, lead lengths, and mechanical layout.

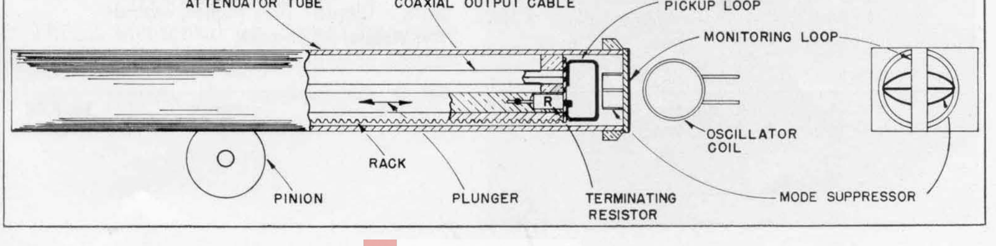
Over the 10.7 Mc band the deviation varies inversely as the carrier frequency but this variation is of less importance because the 10.7-Mc RMA standard intermediate frequency is in such wide use. The resistive element of the reactance-tube phase-splitting circuit is automatically switched with the tuning inductors to produce the same deviation at 10.7 as that maintained over the 88-108 Mc band.

OUTPUT SYSTEM

The mutual-inductance-type attenuator is magnetically coupled to the selected oscillator coil. A monitoring loop, placed directly across the attenuator mouth, samples the magnetic field at that point, and the induced voltage, rectified by a diode voltmeter circuit, actuates the panel meter. A mode suppressor, also located at this point, rejects unwanted components of the magnetic field and supports, in its vicinity, only the TE 1-1 mode that attenuates down a waveguide of circular cross section at the rate of 32 db/diameter.

The field that excites the monitoring loop is therefore of the same character as that which excites the attenuator pickup loop, and a true measure of output voltage, under all conditions, is given by the meter reading and the posi-

Figure 3. Cutaway view of the attenuator and termination.



tion of the attenuator plunger. The plunger slides within the attenuator tube and incorporates a well, in which a 50-ohm terminating resistor is mounted. This resistor is connected to an output cable of 50 ohms characteristic impedance by the pickup loop, which is carefully proportioned to act as a π-type artificial-line section of the same characteristic impedance.

A completely smooth termination system ideally results from this combination and, since the system was originally designed for operation at frequencies up to 500 Mc, the departure from perfection at lower frequencies is principally the ±2% tolerance of the terminating resistor itself.

For standardizing the attenuator dial in terms of the meter reading, use is made of the adjustable index and auxiliary scale illustrated in Figure 1. When the adjustable index is set on this scale to agree with the meter reading, the dial index moves with it to assume the proper position for the indicated level of magnetic field at the attenuator mouth, and the dial then reads directly in open-circuit output voltage. The quasi-logarithmic meter scale indicates both the 0.25 volt level at 10.7 Mc and the 1-volt level over the 88-108 Mc band well upscale to make possible precise settings on both frequency bands. Changes of output over each band are quite small and minor readjustment of the index as the frequency is varied is generally found necessary only when measurements of the highest accuracy are required.

—D. B. Sinclair

SPECIFICATIONS

Carrier Frequency Range: 10-11.5 megacycles and 88-108 megacycles in two ranges.

Frequency Calibration: The dial is adjusted to better than ± 0.25% at all points.

Frequency Stability: *Instantaneous Stability* (F-M Noise Level) — more than 50 db below 75 kc deviation. *Slow Drift* — less than 0.005% after first 20 minutes of operation.

Open-Circuit Output Voltage: 88 to 108 Mc range — less than 0.1 microvolt to more than 1 volt; 10.7 Mc — less than 0.1 microvolt to approximately 0.25 volt.

Output Impedance: 50 ohms nominal; actual $(50 + j0) \pm (3 + j2)$.

Maximum Output Voltmeter Error: ±10% when zero is correctly set.

Maximum Attenuator Error: ±2% at minimum attenuation, increasing linearly to ±5% at maximum attenuation.

Leakage: Cannot be detected on high-sensitivity, commercial f-m receivers.

Frequency Modulation: 0-200 kc deviation.

Internal Modulation Frequencies: Line frequency and 400 cycles.

External Modulation: 20 c to 15 kc; approximately 7 volts at 0.5 megohm are required.

Distortion: At 400-cycle modulation, less than 3% at 75 kc deviation; less than 10% at 200 kc deviation.

Incidental Amplitude Modulation: Less than 5%.

Accuracy of Indication:

Variation of Deviation Carrier Frequency: 88- to 108-megacycle range, ±5%; 10.7-megacycle range, approximately inversely proportional to carrier frequency.

Variation with Modulation Frequency: ±2% 20 c to 2 kc; ±10%, 2 kc to 15 kc.

Meter Error: ±2 kc, maximum.

Power Supply: 110-130 or 220-260 volts, 50-60 cycles.

Power Input: Approximately 50 watts.

Tubes:

1—6C4	1—6AG7	1—6SL7	1—6AL5
1—2050	1—6AQ6	1—6H6	1—991

Accessories Supplied:

1—874-R20 50-Ω Output Cable
1—Power Cord
1—874-C Cable Connector

Other Accessories Available: Type 1000-P5 Transformer (50 Ω unbalanced to 300 Ω balanced), Type 1000-P1 Termination Unit (50 Ω).

Terminals: Output and external modulation terminals are Type 874 Coaxial Connectors.

Mounting Dimensions: (Height) 13⅝ x (width) 20¼ x (depth) 10⅝ inches, overall.

Net Weight: 35 pounds.

Type		*Code Word*	*Price*
1022-A	**F-M Standard Signal Generator***	ABIDE	**$625.00**

*U. S. Patent No. 2,125,816.

A VERSATILE AMPLITUDE MODULATOR FOR V-H-F STANDARD-SIGNAL GENERATORS

Although designed particularly for use with the TYPE 1022-A F-M Standard-Signal Generator, the TYPE 1023-A Amplitude Modulator may be used generally with standard-signal generators at frequencies between 5 Mc and 220 Mc, to produce an amplitude-modulated signal with no significant incidental fm.

GENERAL CHARACTERISTICS

The amplitude modulator consists simply of a grid-modulated aperiodic amplifier that is connected between the output of the standard-signal generator and the device under test. It is designed specifically to work out of a 50-ohm source impedance and to have a gain of 0.1, substantially flat from 10 Mc to 150 Mc and reasonably flat from 5 Mc to 220 Mc.

Modulation up to 80% is provided, either internally at the power-line frequency or from an external source from 20 to 15,000 cycles. Envelope distortion is less than 5% at 80% modulation. The gain and modulation percentage are substantially independent of r-f input voltage from 1 microvolt to 1.5 volts; at higher input voltages the gain decreases and envelope distortion increases.

The output impedance, nominally 50 ohms resistive, is $(50 + j0) \pm (5 + j4)$ from 10 Mc to 150 Mc, and the resultant voltage standing-wave ratio is less than 1.15. At higher frequencies the VSWR increases, reaching a value of about 2.0 at 220 Mc.

INCIDENTAL FM

Direct incidental fm caused by "pulling" of the oscillator frequency is almost absent because the modulation is accomplished on the output side of the standard-signal-generator attenuator. On direct comparison, a standard-signal generator, even one having a modulated amplifier following the oscillator, when modulated with the TYPE 1023-A Amplitude Modulator shows spectacularly better performance than when it is modulated with its own internal modulation system.

For the most refined measurements, however, it should be pointed out that a further source of equivalent fm arises from the phase modulation produced by changes in the input impedance of the tube over the modulation cycle. When the TYPE 1023-A Amplitude Modulator is operated from a 50-ohm source at 100 Mc, this equivalent fm only amounts to 10 cycles for 80% modulation at a 60-cycle modulating frequency. However, fm arising from phase modulation increases linearly with the modulating

Figure 1. Panel view of the Type 1023-A Amplitude Modulator.

frequency, and this equivalent fm will increase to 2500 cycles when the modulating frequency is raised to 15,000 cycles.

I-F BAND

A feature of the instrument, particularly important when it is used with the Type 1022-A F-M Standard-Signal Generator, is a second operating range that can be selected by a switch. This second range provides a gain of 10 at the 10.7 Mc, RMA standard fm-receiver intermediate frequency, with a band-width to the half-power points of ±0.6 Mc. On this range the gain and modulation percentage are substantially independent of input voltage at levels up to 0.1 volt. Output voltages up to 3 volts, however, can be obtained without serious increase in envelope distortion if some change in gain can be tolerated. The output impedance is $(50 - j2) \pm (2.5 \pm j1)$ at 10.7 Mc (a VSWR less than 1.15), and varies over the entire band within $(50 - j4) \pm (5 \pm j15)$ to produce a VSWR of less than 1.4.

GAIN STANDARDIZATION

Since the grid-modulation process involves varying the effective trans-conductance of the amplifier tube with modulating voltage, it is not feasible to stabilize the amplifier by means of negative feedback. As a consequence, some change in gain may be expected over periods of extended operation. A gain control, mounted on the panel, provides adjustment over a sufficient range to compensate for these changes and to correct for changes in gain as a result of changes in frequency or of switching ranges. When the instrument is used with a standard-signal generator having a 50-ohm output impedance, the gain can be quickly and accurately standardized by, first, connecting the receiver under test to the standard-signal-generator output directly and setting to a reference voltage; then, second, reconnecting the receiver to the output of the Type 1023-A Amplitude Modulator, resetting the standard-signal-generator attenuator to a reading 10:1 greater or 10:1 less than the original reading (for the 10-150 Mc or 10.7 Mc range, respectively) and adjusting the gain until the same receiver output is obtained.

EXAMPLES OF USE

A simple method of checking ratio-detector performance, for instance, is to use the combination of a Type 1022-A F-M Standard-Signal Generator, modulated at 400 cycles, and a Type 1023-A Amplitude Modulator, modulated at 60 cycles. With the 400-cycle modulation voltage used as horizontal deflection, and the output of the ratio detector used as vertical deflection on a cathode-ray oscilloscope, the discriminator characteristic will be displayed on the oscilloscope screen. For small amplitude-modulation percentages, no departure from the conventional pattern will be noticeable, but, as the amplitude modulation is increased, multiple patterns will begin to appear. These multiple patterns will pass through a common central point, since no significant incidental fm is introduced by the Type 1023-A Amplitude Modulator, and the fanning out at the ends will give a measure of the a-m response of the detector at the modulation percentage indicated by the panel meter. Figure 2 is a typical pattern.

For simple tests of performance of limiters or ratio detectors, the instrument gives almost ideal performance when used as described. It should be emphasized, however, that the generator is entirely satisfactory for even more refined tests where separation of f-m and a-m response is obtained by the use of sharply tuned filters, because the equivalent fm introduced by 80% modulation at 1000 cycles is only about 150 cycles, or 54 db below ±75 kc deviation.

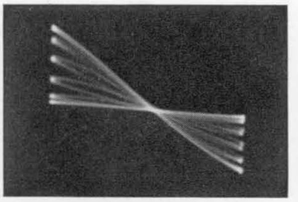


Figure 2. Typical response of a ratio detector to combined fm and am.

Owing to its very low incidental fm, the Type 1023-A Amplitude Modulator is also useful with the Type 1001-A and the Type 805-C Standard-Signal Generators. Incidental fm in these instruments, as in most a-m signal generators, is characteristically a function of the carrier frequency as well as of percentage modulation, amounting to as much as 20 kc at 50 Mc and 80% to 100% modulation, which is greater than the bandwidth of ordinary communication channels. When the Type 1023-A Amplitude Modulator is used, however, the improvement is of the order of 1000:1, and incidental fm is practically eliminated as a source of error in receiver measurements.

— D. B. Sinclair

SPECIFICATIONS

*Pass Band**	*Input Voltage Range** *(From 50-ohm source)*	*Output Impedance* *Nominal*	*VSWR*	*Output Volts*	*Gain*
10 to 150 Mc	0-1.5 v at 50 ohms	50 ohms	1.15	1/10 Input V	0.1
10.1 to 11.3 Mc	0-0.1 v at 50 ohms	50 ohms	1.4 (1.13 at 10.7 Mc)	10 Input V	10

*Instrument can be used over the range of 5 to 220 Mc, but gain will vary somewhat with frequency, and output impedance will not stay within above limits. Input voltages can be increased beyond above figures at some increase in envelope distortion and decrease in gain.

Amplitude Modulation: 0 to above 80% continuously adjustable, accurate to (5% of meter reading + 1% modulation).

Internal Modulation: At power line frequency.

External Modulation: Flat within ± 1 db from 20 c to 15 kc; approx. 5 volts into 10,000 ohms will produce 80% modulation.

Envelope Distortion: Less than 5% at 80% modulation. Decreases with the modulation percentage.

Frequency Modulation: Direct incidental fm from reaction on a low-impedance standard-signal generator is negligible. Equivalent fm from variable phase shift is of the order of 10 cycles for 80% modulation at 60 cycles and is proportional to modulating frequency and modulation percentage.

Carrier Noise Level: Better than 45 db below 80% modulation.

Leakage: At least 45 db below output signal on 10 to 150 Mc range; at least 60 db on 10.7 Mc range.

Terminals: Input and output terminals are Type 874 Coaxial Connectors.

Power Supply: 105 to 125 (or 210 to 250) volts; 50 to 60 cycles. Demand is 15 watts.

Tubes: One 6AC7 and one 6X5GT; both are supplied.

Accessories Supplied: One Type 874-R20 Patch Cord.

Other Accessories Available: Type 1000-P5 Transformer (50 ohms unbalanced to 300 ohms balanced; Type 1000-P1 Termination Unit, 50 ohms; Type 874-Q1 Adaptor (for Type N Connectors).

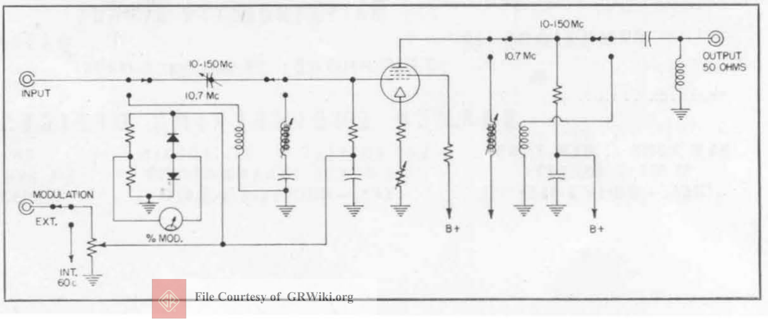


Figure 3. Elementary schematic diagram of the Amplitude Modulator.

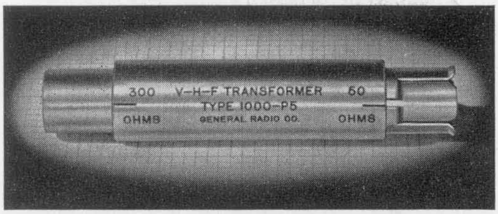
Mounting: Aluminum panel with black crackle finish; aluminum cabinet with black wrinkle finish.

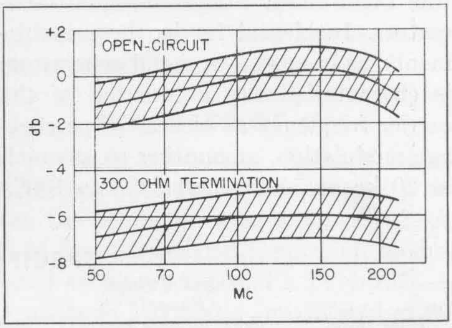
Dimensions: (Height) 14⅝ x (width) 9⅛ x (depth) 8¼ inches overall.

Net Weight: 14½ pounds.

Type		*Code Word*	*Price*
1023-A	**Amplitude Modulator**	EXULT	**$250.00**

A TRANSFORMER FOR 300-OHM BALANCED OUTPUT FROM STANDARD-SIGNAL GENERATORS





Frequency characteristic of the Type 1000-P5 V-H-F Transformer. Shaded areas show tolerances.

The TYPE 1000-P5 V-H-F Transformer is designed to plug into a standard-signal generator having a 50-ohm unbalanced output and produce an equal balanced open-circuit voltage behind a 300-ohm balanced impedance for r-f measurements of fm and tv receivers.

The transformer is mounted in a cylindrical container terminated at one end in a TYPE 874 Coaxial Connector and at the other in a socket designed to receive the Alden Type HA902P Connector for standard 300-ohm open parallel-wire line.

SPECIFICATIONS

Frequency Range: 50 Mc to 250 Mc.

Frequency Characteristic: See plot.

Accuracy: See plot.

Input Impedance: Approximately 300 ohms. Designed to work out of 50-ohm source.

Terminals: Input — General Radio TYPE 874 Coaxial Connector.
Output — Fits Alden Type HA902P Connector.

Dimensions: (Length) 4⅜ x (diameter) ⅞ inches.

Net Weight: 3½ ounces.

Type		*Code Word*	*Price*
1000-P5	**V-H-F Transformer**	ARSON	**$27.50**

GENERAL RADIO COMPANY
275 MASSACHUSETTS AVENUE
CAMBRIDGE 39 MASSACHUSETTS
TELEPHONE: TRowbridge 6-4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WOrth 2-5837

LOS ANGELES 38, CALIFORNIA
1000 NORTH SEWARD STREET
TEL.—HOllywood 9-6201

CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WAbash 2-3820

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A PRECISION ATTENUATOR HAVING A WIDE FREQUENCY RANGE

● **ONE OF THE BASIC TOOLS** in all branches of communication engineering and in many measurement techniques is the constant-impedance resistive attenuator, calibrated in decibels and designed to vary the voltage or power input into a given load. General Radio Company now offers a new series of precise attenuators, the TYPE 829 Decade Attenuator Units and the TYPE 1450 Decade Attenuators, which hold their calibration accuracy over an unusually wide frequency range.

The TYPE 829 Decade Attenuator Units can be built into speech and ultrasonic equipment, recording channels, measuring devices, etc. Each unit consists of four attenuator pads, having individual values of 1, 2, 3, and 4 units of attenuation. These pads are built into an eight-compartment "egg-crate" chassis, which permits the novel feature of bisected shielding discussed below. A steel shaft, on ball bearings, drives a series of cam-operated switches to provide integral steps of attenuation. The shaft is capable of continuous rotation, which is an advantage for certain applications. A rugged ball-and-spring detent definitely locates each of the eleven switch positions. A skirted, bar type of control knob and an etched dial plate are supplied with each decade unit.

Figure 1. Panel View of a Type 1450-HB Decade Attenuator.

TYPE 829 Decade Attenuator Units are designed for 600-ohm circuits. They are available in both T and balanced-H types and attenuation ranges of 1 db, 10 db, and 100 db. It is possible to use one side of any of the balanced-H attenuators as a T-type 300-ohm attenuator.

Also available are two non-symmetrical or tapered impedance-adjusting networks, one a T and the other a balanced-H. These tapered units are designed for matching 600 ohms to 30, 50, 75, 150, or 600 ohms (in either direction) with the minimum integral number of db insertion loss.

To obtain a wide range of adjustable attenuation in a single compact instrument, assemblies of two or three TYPE 829 Decade Attenuator Units have been mounted in cabinets to constitute the series of TYPE 1450 Decade Attenuators. These instruments are especially useful for precise power level measurements, transmission efficiency tests, gain or loss measurements on transformers, filters, amplifiers, and similar equipment, and for calibrating other attenuators.

Low-Frequency or D-C Precision

Of prime importance in a precision attenuator is the accuracy of its low-frequency, or d-c, calibration. The individual resistors in these attenuators are all calibrated to be within ±¼% of the theoretical values necessary to introduce the nominal value of attenuation when terminated with the nominal resistive load, 600 + j0. It can be shown that a 1% error in a single series resistor cannot produce more than a 0.25% deviation in the nominal db attenuation and more than a 0.5% deviation in the input impedance. Likewise, a 1% error in a single shunt resistor will produce a 0.5% deviation (or less) in the nominal db attenuation and not over a 0.343% deviation in the input impedance. Consequently, with a random distribution of positive and negative deviations of ¼% or less, the d-c error in attenuation will be well within 1%.

The zero setting resistance (switches, etc.) of one of these decade units is less than 0.15 ohm. This value gives a "zero attenuation" of 0.0011 db and augments the nominal value of any attenuator setting by the same amount.

Frequency Error in a Series of T-Pads

As the operating frequency is increased from a low value of a few kilocycles, the d-c errors of any adjustable attenuator become augmented by frequency discrimination errors due to the existence of small residual capacitances in the windings of the resistors. Residual inductances are significant only above the operating range of these TYPE 829 Attenuators.

Figure 2A shows the two switches and three resistor elements comprising a single T-pad. The blades of these switches constitute a rather large "exposure" of metal surfaces, as symbolized by the two large dots in Figure 2B

Figure 3 shows a series of three T-pads with no individual shielding. It will be seen that direct capacitance from A to C by-passes pads 1 and 2; direct capacitance from B to D by-passes pads 2 and 3; while direct capacitance from A to D by-passes pads 1, 2, and 3. The frequency discrimination produced thereby can be eliminated by enclosing each pad, with its switches, in a shielded compartment which is tied to the common side of the transmission line, as in Figure 4.

However, each individual pad is still by-passed by the direct capacitance between its input and output switches. This frequency discrimination, in turn, can be eliminated by building each pad in a bisected shielded compartment as indicated in Figure 5. Reference to Figure 6 will show that the only capacitances left to affect the high-frequency attenuation of a given pad having bisected shielding are the following unavoidable items:

(*a*) Distributed capacitance, C_1, of each series resistor.

(*b*) Distributed capacitance, C_2, of the shunt resistor.

(*c*) Direct capacitance, C_3, of each switch to the shield.

Actually, C_2 includes the body capacitance between the shield and the mid-tap portions of the series resistors, while C_3 includes the body capacitance between the shield and the switch portions of the series resistors.

The effect of C_1 will be more important in the high-attenuation pads, while that of C_2 will be more important in the low-attenuation pads.

Compensation of a T-Pad Enclosed in a Bisected Shield

With increasing frequency, the existence of the series capacitances, C_1, alone would reduce the impedance of the series elements and thereby reduce the attenuation progressively, giving the drooping characteristic *A* in Figure 7. On the other hand, the shunt capacitances, C_2 and C_3, alone would give the rising characteristic *B*. With the coexistence of all three capacitances, C_1, C_2, and C_3, these two effects tend to cancel, producing a net characteristic which is flatter to a higher frequency. Ultimately, however, either C_1 will predominate giving an *A*-type curve, or C_2 and C_3 will predominate giving a *B*-type characteristic. In all cases the input impedance will be lowered.

An *A*-type curve can be compensated into a type *C* characteristic by deliberately adding the proper small value of capacitance across the shunt resistor. Likewise a *B*-type curve can be compensated into a *D*-type characteristic by adding suitable small capacitance across each of the series resistors. In either case, the attenuation of the compensated pad will be "flatter" to higher frequency

Figure 2. Elements of a T-pad, *u* and *v* series elements, *w* shunt element.

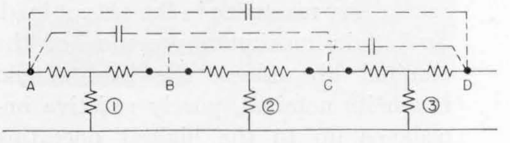


Figure 3. High-frequency cross-talk in a series of T-pads without shields.

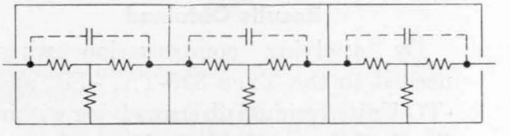


Figure 4. T-pads in single shield compartments.

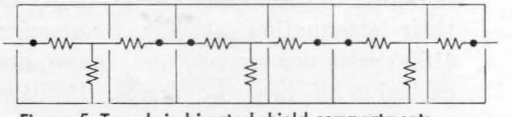


Figure 5. T-pads in bisected shield compartments.

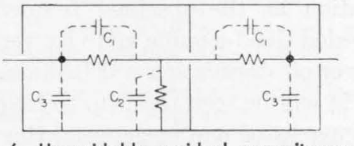


Figure 6. Unavoidable residual capacitances, T-pad with bisected shield.

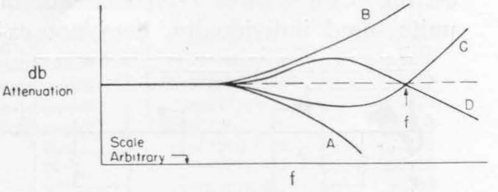


Figure 7. Extension of high frequency range by compensation.

values although the compensation can only be perfect at a certain critical frequency f'.

This compensating procedure is practical only in the range of increasing frequency where the transmission characteristic of a non-compensated pad first departs either upwards or downwards. At still higher frequencies, resonance effects due to small residual inductances produce complicated and rather erratic variations of the transmission characteristics. It should be borne in mind that the frequency characteristic of an attenuator network is modified by the existence of any reactance in the output load. To obtain maximum precision of the nominal db values, the load should retain its nominal, purely resistive impedance up to the highest operating frequency.

Results Obtained

By applying compensation when needed to the TYPE 829-TA, -TB, and -TC Units, residual db errors lying within the shaded area shown in Figure 9 were obtained. These data are in terms of their attenuation at low frequencies (100 cycles per second) and, hence, are exclusive of any d-c errors. Positive errors indicate that the actual attenuation at the specified frequency exceeded the d-c value and vice versa. The error of observation was 0.03 db.

It will be seen that, up to frequencies in excess of one megacycle, the db frequency error in attenuation for any setting of these three T-type attenuator units, used individually, does not exceed 1% of its nominal attenuation value. When two or three of these units are cascaded (in the TYPE 1450 Decade Attenuators), a 1% frequency discrimination is limited to 200 kilocycles for absolute db values, but approaches one megacycle for incremental changes.

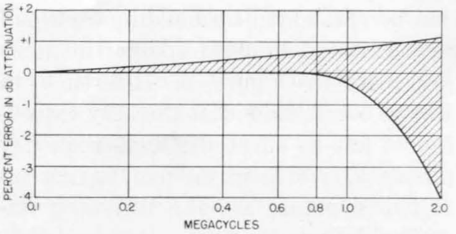


Figure 9. Maximum limits of frequency discrimination in compensated Type 829-TA, -TB, -TC Units.

The Balanced-H Units

Figure 8 indicates how a balanced-H pad is assembled in a bisected shield compartment in such a manner as to eliminate direct capacitance between input and output switches. Each pad contains a pair of series resistors on each side of the transmission line. The shunt resistor consists of two equal units joined in series and having their common junction attached to the C line of the system. For convenience, both shunt elements are in the same compartment, which is not detrimental. No point in the system is connected to the shield. Cross-talk between the several pads can be totally eliminated if these H units can be used with the C line grounded to the shield.

This pad will also possess residual capacitances, analogous to those depicted in Figure 6, which affect its high-frequency characteristic in the manner discussed previously. Compensation is not practical here since these balanced-H units, under different conditions, may

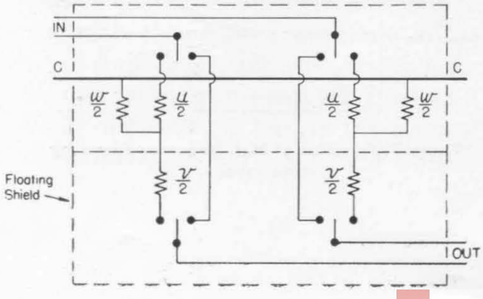


Figure 8. Balanced H-pad in a bisected shield compartment.

be used with the shield either floating or tied to the common line. The required compensation would be quite different in these two cases. However, these units will retain their nominal db values within 1% up to frequencies from 200 to 500 kilocycles, subject to a balanced resistive load 300 + j0 on each side of the common line.

—Horatio W. Lamson

SPECIFICATIONS

FOR TYPE 829 DECADE ATTENUATOR UNITS

Attenuation Range: Three decade ranges are listed in the price table below. The two tapered units, Types 829-HT and 829-TT, introduce an exact insertion loss, as follows:

Matching Ratio	600Ω to 600Ω	150Ω to 600Ω	75Ω to 600Ω	50Ω to 600Ω	30Ω to 600Ω
Attenuation	0 db	12db	15 db	17db	20 db

Characteristic Impedance: 600 ohms both directions except for the tapered units, which are 600 ohms in one direction and either 30, 50, 75, 150, or 600 ohms in the other direction to accommodate microphones, coaxial lines, high-fidelity telephone lines, etc. Either end can be used as input.

Accuracy: Each individual resistor is adjusted within ±0.25% of its correct value. The low frequency error in attenuation is less than ±1% of the indicated value, provided the unit is terminated by the nominal value of pure resistance. Impedance matching within ±0.5% will exist.

Input Power: Based on 1-watt dissipation in any single resistor, the maximum RMS values of input voltage are as follows:

Load Resistance	600 Ω	∞	0
Type 829-TA	117 volts	114 volts	3.8 volts
Type 829-TB	46	39	11.7
Type 829-TC	25	25	25
Type 829-HA	83*	80*	2.6*
Type 829-HB	32*	28*	8.3*
Type 829-HC	18*	18*	18*

Input Impedance	Type 829-TT	Type 829-HT
30 Ω	5.9	4.1*
50	7.4	5.2*
75	9.0	6.4*
150	13.4	9.5*
600	25	17.5*

* Voltages across each side of balanced input.

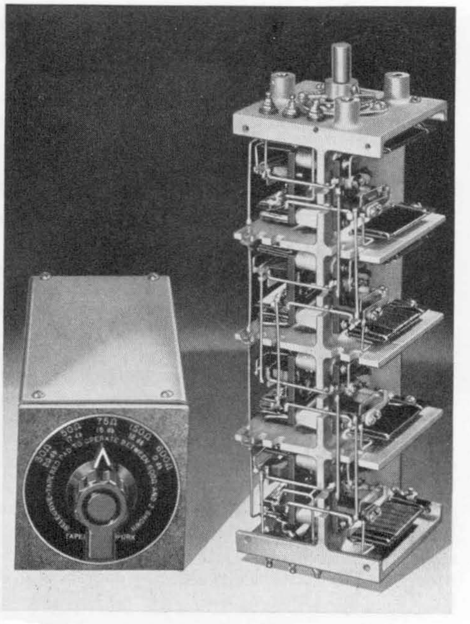


Figure 10. (*Left*) Type 829-HT Decade Attenuator Unit (tapered model) and (*right*) typical internal construction of the Type 829 Decade Attenuator Units.

Frequency Discrimination: Less than ±1% of the indicated value:

At 1 Mc for the TA, TB, and TC units.

At 200-500 kc for the HA, HB, HC, TT, and HT units.

Type of Section: Both balanced-H and T-type sections are available.

Type of Winding: All resistance elements use Ayrton-Perry windings except the shunt elements of 829-HA and 829-TA, which are unifilar cylindrical windings. Where necessary, resistors are capacitance-compensated.

Switches: Cam-type switches are used with twelve positions covering 360°. The dials are numbered from "0" to "10" inclusive (except on tapered models) and the twelfth point is also connected to "0." No stops are provided in the switch mechanism to prevent complete rotation, but spacers, which are provided, can be used under the mounting screws to act as stops for the knob.

Type	*Range*	*Type of Section*	*Code Word*	*Price*
829-HA	**1db in steps of 0.1 db**	**Balanced-H**	TENUTORHAG	**$125.00**
829-HB	**10 db in steps of 1 db**	**Balanced-H**	TENUTORHUB	**118.00**
829-HC	**100 db in steps of 10 db**	**Balanced-H**	TENUTORHIC	**110.00**
829-HT	**(See Specifications above)**	**Balanced-H**	TENUTORHUT	**120.00**
829-TA	**1 db in steps of 0.1 db**	**T**	TENUTORTAD	**85.00**
829-TB	**10 db in steps of 1 db**	**T**	TENUTORTUB	**80.00**
829-TC	**100 db in steps of 10 db**	**T**	TENUTORTIC	**80.00**
829-TT	**(See Specifications above)**	**T**	TENUTORTOT	**70.00**

Terminals: External input and output soldering terminals on opposite ends; common terminal of T units grounded to chassis; common terminal of H units not grounded.

Mounting: The resistors and switches are housed in compartments of an aluminum casting, which is enclosed by aluminum covers. A dial and knob are furnished, and decades may be panel mounted from one end by three mounting screws which are provided.

Dimensions: 3⅛ x 3⅛ inches, extending 9½ inches back of panel. **Net Weight:** 3¼ pounds

SPECIFICATIONS

TYPE 1450 DECADE ATTENUATORS

Attenuation Range: 110 or 111 decibels in steps of 1 or 0.1 decibel, respectively.

Terminal Impedance: 600 ohms in either direction. An etched plate on the cabinet indicates the mismatch loss for other than 600-ohm circuits.

Accuracy: Each individual resistor is adjusted within ±0.25% of its correct value. The low frequency error in attenuation is less than ±1% of the indicated value, provided the attenuator is terminated by a pure resistance of 600 ohms. Input impedance will lie within the limits 600 ±3 ohms.

Frequency Discrimination: Less than ±1% of the indicated value at frequencies below 200 kc.

Maximum Input Power: Determined by the highest valued decade in circuit. See specifications for Type 829 Units.

Switches: See Type 829. Stops are provided on the highest decade only (10 db per step).

Mounting: The decade units are mounted on an aluminum panel in a metal cabinet. Each decade is individually shielded, and all shields are connected to the panel and the "G" terminal. Relay-rack mounting is available at an additional charge on special order.

Terminals: Jack-top binding posts with ¾-inch spacing; common terminal of T units grounded to chassis; common terminal of H units not grounded.

Dimensions: 1450-HA and 1450-TA, 10 x 5¾ x 12¼ inches overall; 1450-HB and 1450-TB, 12 x 5¾ x 12¼ inches overall.

Net Weight: 1450-HA and 1450-TA, 10¾ pounds; 1450-HB and 1450-TB, 15½ pounds.

Type	*Range*	*Impedance*	*Type of Section*	*Code Word*	*Price*
1450-HA	110 db in steps of 1 db	600 ohms	Balanced-H	NETWORKHAT	$245.00
1450-TA	110 db in steps of 1 db	600 ohms	T	NETWORKTAM	180.00
1450-HB	111 db in steps of 0.1 db	600 ohms	Balanced-H	NETWORKHUB	370.00
1450-TB	111 db in steps of 0.1 db	600 ohms	T	NETWORKTUB	265.00

AN ACOUSTIC CALIBRATOR FOR THE SOUND-LEVEL METER

The increasing use of the Type 759-B Sound-Level Meter for quantitative measurements in acceptance tests on industrial machinery and consumer appliances has made it desirable to have a simple acoustic device for making an over-all check of the calibration. Although a check on the calibration of the electrical circuits is provided in the sound-level meter, the long-time stability of the microphone calibration becomes important when the meter is continually used to check compliance with test specifications for noise.

The General Radio Type 1552-A Sound-Level Calibrator was developed in response to a number of requests for a simple and convenient means for making this acoustic check. The calibrator,

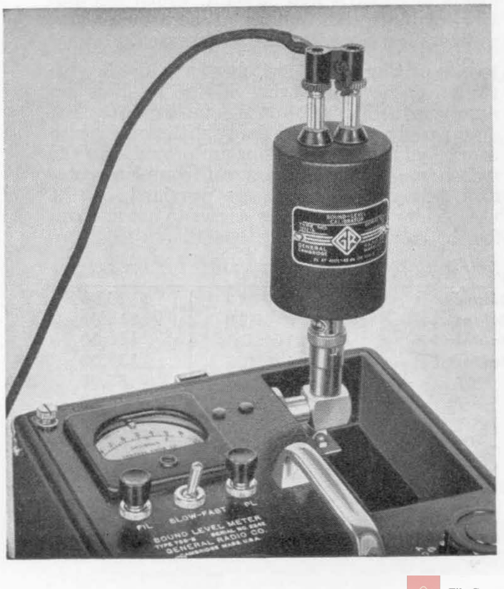


Figure 1. View of Type 1552-A Sound-Leve Calibrator in operating position on microphone of Type 759-B Sound-Level Meter.

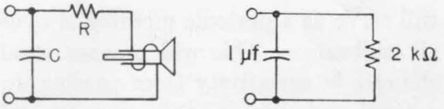


Figure 2. Electrical circuit *(left)* and equivalent circuit *(right)* of the Sound-Level Calibrator.

illustrated in Figure 1, comprises a small, stabilized and rugged loudspeaker mounted in an enclosure which fits over the microphone of the sound-level meter. The chamber is so designed that the acoustic coupling between loudspeaker and microphone is fixed and can readily be repeated. The level is high enough so that readings are unaffected by normal background noises.

The calibrator can be operated from any audio oscillator having reasonably good wave-form (harmonic content should be 5% or less) and capable of supplying 2 volts at 400 cycles across an impedance of 1 μf in parallel with 2000 ohms. Most users will find that they have available a suitable audio oscillator and a voltmeter for use with the calibrator. While 2.0 volts at 400 cycles is the condition under which the nameplate calibration holds, the calibrator is usable over moderate ranges of voltage and frequency as illustrated in Figure 4.

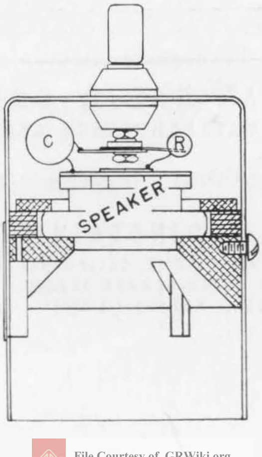
The Type 723-B Oscillator and the Type 727-A Vacuum-Tube Voltmeter are satisfactory battery-operated accessories. With this combination, a potentiometer, such as the Type 301-A, 500 ohms, is necessary, since no output control is provided on the oscillator.

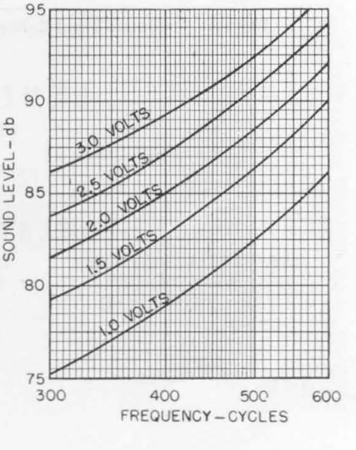
The electrical circuit of the Type 1552-A Calibrator is shown at the left in Figure 2. A representative input impedance at 400 cycles is

Figure 5. Calibrating a sound-level meter with the sound-level calibrator. A Type 723-B Oscillator and Type 727-A Vacuum-Tube Voltmeter provide the standard 400-cycle voltage.

that of a 1.0 μf condenser in parallel with a 2000-ohm resistor as shown at the right in Figure 2. The condenser C of Figure 2 is used to minimize the effects of harmonics in the 400-cycle source, and the resistor R is chosen to adjust the output of the loudspeaker to the correct level.

A cross-section drawing is shown in Figure 3. The cylindrical case forms a chamber at the rear of the speaker unit. The skirt of the case extends down over the microphone under test, so that background noises and lateral positioning of the calibrator are not critical. Three spacers inside the case rest on the microphone, so that the loudspeaker is always located at the correct distance from the diaphragm of the microphone.





(*Left*) Figure 3. Cross section of the calibrator. (*Right*) Figure 4. Variation of calibrator output with voltage and frequency.

The calibrator was designed primarily for use with the Shure Brothers Type 9898 microphone used on the TYPE 759-B Sound-Level Meter. It can be used, however, on other microphones such as the Brush BR2S Sound Cell Microphone and the Western Electric Type 633-A Dynamic Microphone. The calibration of sound-level meters using other than the Shure Brothers Type 9898 microphone can be checked with the TYPE 1552-A Calibrator, but the correct sound-level reading will not necessarily be that on the calibrator nameplate. For example, the nominal levels for the two General Radio Sound-Level Meters are listed in Table I.

TABLE I

Microphone	*Sound-Level Meter*	*db Reading*
Shure 9898	Type 759-B	85
Brush BR2S	Type 759-A	72.5

With the TYPE 1552-A Sound-Level Calibrator as an accessory, the scope and usefulness of the TYPE 759-B Sound-Level Meter will be improved. If the sound-level meter is being used in a prolonged series of tests, the calibrator will serve as a periodic monitor of overall calibration. This will prevent small changes in sensitivity from passing unnoticed and, even more important, will show up a damaged microphone before much useless data have been taken. The use of the calibrator will not, in general, improve the absolute accuracy of the sound-level meter, but it should prove to be a valuable aid in assuring constancy of calibration throughout a period of measurements or between groups of measurements which may be separated not only in time but in distance. Should a question of absolute calibration arise, it would prove much quicker and less expensive to obtain a check on the validity of the calibrator than it would be to return the sound-level meter to the factory for recalibration.

Many organizations are using two or more sound-level meters. Intercomparison of sound-level meters, using the calibrator, is a simple and straightforward operation which can be performed at any time.

— E. E. GROSS

SPECIFICATIONS

Input: 2.0 volts, 400 cycles (harmonic content of the oscillator must not exceed 5%).

Output: When in position on the microphone of the TYPE 759-B Sound-Level Meter, the calibrator produces a sound pressure of 85 ±1 db (above a reference level of 0.0002 microbars, i.e., 0.0002 dynes per square centimeter) at the microphone diaphragm.

Terminals: Input terminals are two General Radio TYPE 938-W Binding Posts.

Accessories Required: 400-cycle oscillator with output control, and vacuum-tube voltmeter.

Dimensions: (Length) 4½ x (diameter) 2½ inches, overall.

Net Weight: 10½ ounces.

Type		*Code Word*	*Price*
1552-A	**Sound-Level Calibrator**	NATTY	**$45.00**

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