the GENERAL RADIO Experimenter

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TO

GENERAL RADIO EXPERIMENTER

VOLUMES XII AND XIII

June, 1937 to May, 1939

GENERAL RADIO COMPANY
CAMBRIDGE MASSACHUSETTS
U. S. A.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

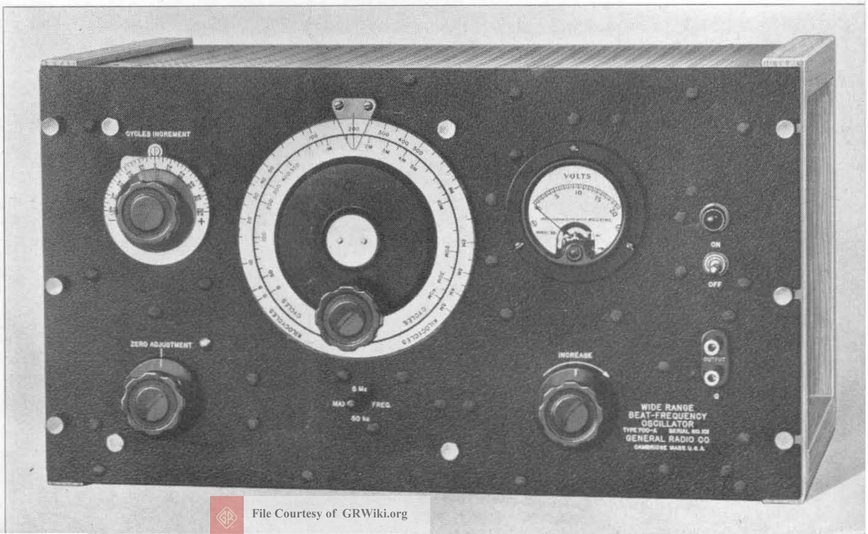
Also IN THIS ISSUE

A BEAT-FREQUENCY OSCILLATOR FOR WIDE-BAND MEASUREMENTS

● **FOR MEASUREMENTS** and testing in the audio-frequency range, many specialized instruments have been developed which are designed primarily to give the desired results quickly and in the most convenient form. A particularly good example is the beat-frequency oscillator as a general source of power. The rapidity and ease with which the frequency can be set at any point in the spectrum, and the relatively large and uniform power output which can be obtained with low harmonic content, render this oscillator of great use as a basic tool.

Intensive development work on broad-band devices, notably television amplifiers, has led to a demand for similar specialized tools for a broader frequency span. Since the so-called video spectrum is simply an extension of the older audio spectrum, it follows that, in many cases,

FIGURE 1. Panel view of the TYPE 700-A Wide-Range Beat-Frequency Oscillator.



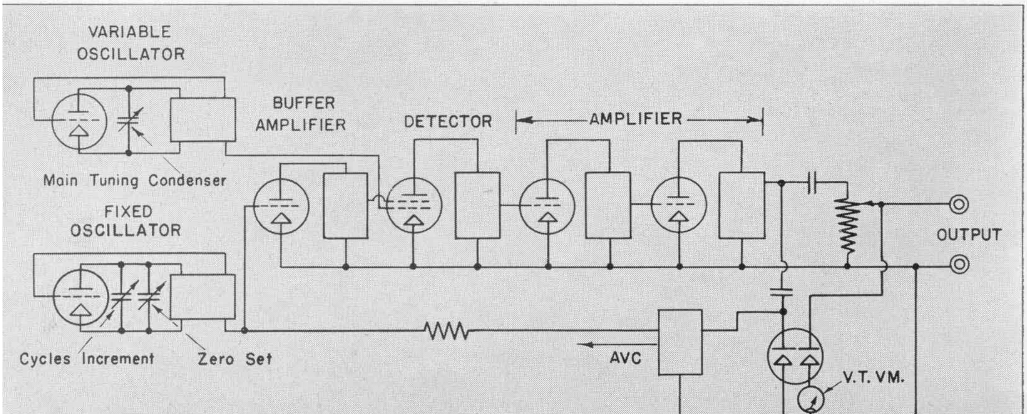
the new testing and measuring instruments are of the same type as the old and differ from them only in degree. This is true, in particular, of the beat-frequency oscillator, which, by an extension of its frequency range, can be made satisfactory for use at video frequencies. The characteristics which make this type of oscillator so serviceable for audio-frequency testing are equally desirable for video-frequency work.

The TYPE 700-A Wide-Range Beat-Frequency Oscillator is intended to satisfy the requirements for a flexible power source at frequencies from 50 cycles to 5 Mc. Because the frequency range is greatly extended in comparison with that covered by the conventional audio-frequency instrument, some of the design problems are markedly different and are of interest as determining factors in general construction and performance.

With an established upper frequency limit of 5 Mc, the frequency of the fixed oscillator is more or less determined at a value of approximately 20 Mc. Lower values will result in excessive spurious beats or "birdies" and higher values in lessened frequency stability. At such a high beating frequency the tendency of the fixed and variable oscillators to lock together near zero beat is accentuated because of residual capacitive and mutual inductive coupling between them. The behavior of the oscillator near zero beat is consequently not quite as good on a percentage frequency basis as a similar low-frequency oscillator. In terms of absolute frequency, the comparison is still less favorable since a given frequency percentage corresponds to approximately a hundred times the number of cycles. The problem of obtaining satisfactory performance through the ordinary audio range and, at the same time, obtaining good performance in the video range has been solved in the TYPE 700-A Wide-Range Beat-Frequency Oscillator by supplying two separate ranges, which can be selected by a switch, one covering the span from 50 cycles to 40 kilocycles and the other 10 kilocycles to 5 megacycles.

The amplifier for an instrument of this type must follow closely the pattern evolved for television purposes. It is particularly interesting in this case to trace through the interlocking requirements and their effects on design. The limiting feature in high frequency performance is the shunting effect of capacitance of the tubes and circuit wiring. In order to raise the frequency at which the shunting effect becomes serious to a value of approximately 5 Mc, it is

FIGURE 2. Functional schematic diagram of the TYPE 700-A Wide-Range Beat-Frequency Oscillator. The automatic-volume-control circuit tends to maintain a constant output voltage as a function of line voltage as well as of frequency and load.



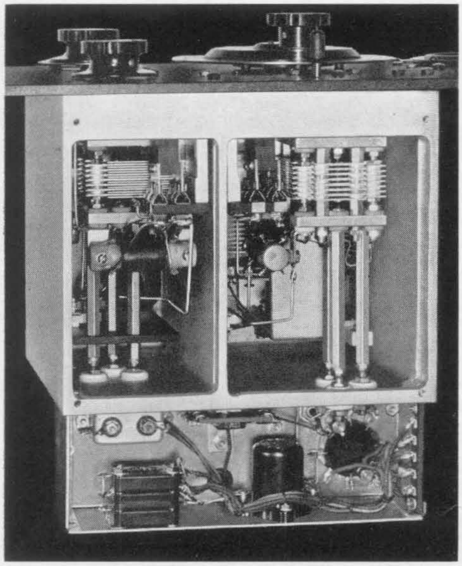


FIGURE 3. View of the heavy aluminum casting which houses the two high-frequency oscillators. Note that the oscillators are of similar construction in order that they may have equal temperature coefficients.

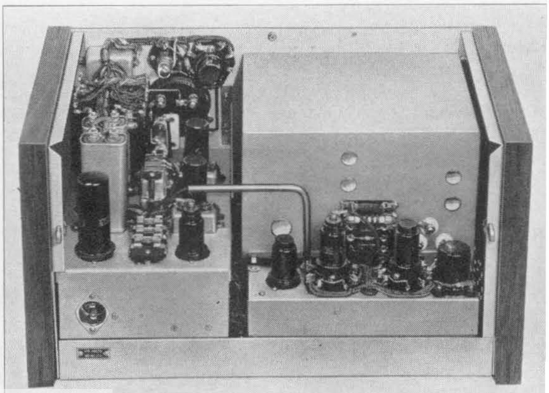
necessary to use low-resistance plate loads and, as a consequence, tubes having a high value of grid-plate transconductance. Because of low load resistances, it is also necessary to use tubes having relatively high plate currents in order to develop appreciable voltages.

Two results immediately follow from these considerations: First, a voltage amplifier requires vacuum tubes of the so-called "power" variety and consequently demands high power input which must be dissipated in the form of heat. Second, at low frequencies the common impedance of the plate supply filter becomes comparable with the plate load impedances, and regenerative and degenerative coupling through the power supply becomes of great importance. The output impedance of the power supply filter must therefore be kept low, either by using very large capacitors or by using an electronic type of voltage regulator.

In the case of the TYPE 700-A Wide-Range Beat-Frequency Oscillator, it was felt that physical smallness was a desirable feature. Because of the large amount of heat generated by the amplifier tubes it was impossible to prevent the temperature of a small instrument from rising appreciably. The effect of this temperature rise on frequency, however, was largely eliminated by designing both oscillator circuits with low temperature coefficients, as nearly equal as possible, and by mounting them in two compartments of a rugged cast aluminum box. The box serves to distribute the heat uniformly between them and to minimize any temperature differential between the compartments, as well as to furnish excellent electromagnetic shielding.

In order to maintain a high degree of electrical isolation between the two oscillators, the detector chosen for use with the TYPE 700-A Wide-Range Beat-Frequency Oscillator was the Type 6L7 Pentagrid Mixer. The capacitive coupling through this tube is small and, since two separate grids are used, both oscillator circuits can be fed in single-ended, with one side grounded. It is interesting to note that, at high frequencies, the greatest coupling between

FIGURE 4. Rear view of the oscillator, showing details of construction. The wooden end pieces can be removed when the instrument is to be mounted in a relay rack.



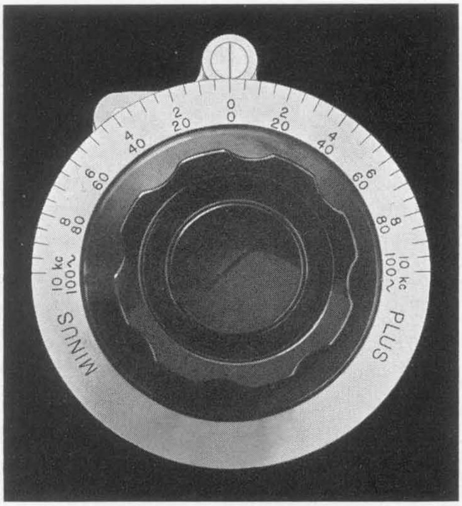


Figure 5. The cycles increment dial, shown here, carries two scales, one for each output frequency range of the oscillator. The range is ±10 kc for the high-frequency range and ±100 cycles for the low range.

the two oscillators appears to come from the small capacitance variations caused by modulation of the space current in the detector tube.

In order to maintain as high a degree of constancy in output level as possible, an automatic volume control has been incorporated in the Type 700-A Wide-Range Beat-Frequency Oscillator. The a-v-c action is obtained by rectifying the output voltage and using the derived dc to control the gain of a buffer amplifier between one of the oscillators and the mixer. The a-v-c circuit reduces any irregularities in the frequency characteristic and also makes the output voltage less dependent upon average line voltage. The control with respect to line voltage is not an inherent property of a-v-c circuits but is obtained in this instrument by deriving the delay voltage from the voltage drop across a neon tube, which is essentially constant as a function of line voltage. Other design features in the amplifier which contribute to over-all uniformity of output are degenerative feedback and both series and shunt inductance compensation.

An interesting side light on the unusual design problems encountered is the fact that extremely good filtering is required on the low range. For this range, which extends from 50 cycles to 40 kilocycles, the beating frequencies are in the neighborhood of 150 to 200 kilocycles. Ordinarily the amplifier in a beat-frequency oscillator of this range does not respond to these frequencies, and the filtering necessary is relatively slight. In the Type 700-A Wide-Range Beat-Frequency Oscillator, however, the amplifier is perfectly flat, not only for the difference frequency and beating frequencies but also for the sum frequency, and consequently a good low-pass filter is switched into circuit when operating on the low-frequency range.

— D. B. Sinclair

SPECIFICATIONS

Frequency Range: Two ranges are provided: 50 cycles to 40 kilocycles, and 10 kilocycles to 5 megacycles.

Frequency Control: The main dial is direct reading in frequency and carries two approximately logarithmic frequency scales covering the ranges specified above. A frequency range switch is provided for rapidly changing from one range to the other. There is also an incremental frequency control which is calibrated between −100 and +100 cycles on the low range and −10 and +10 kilocycles on the high range. Any frequency change made with this control adds algebraically to the frequency of the main control.

Frequency Calibration: The calibration may be standardized at any time by setting the instrument to zero beat with the zero adjustment control. This adjustment can be made within 5 cycles on the low range or 500 cycles on the high range.

After the oscillator has been correctly set to zero beat, the calibration of the main frequency-control dial can be relied upon within ±2% ±5 cycles on the low range and ±2% ±500 cycles on the high range. The calibration of the incremental frequency dial is within ±5 cycles or ±500 cycles on the low and high ranges, respectively.

Frequency Stability: Through careful design adequate thermal distribution and ventilation are provided for minimizing frequency drifts. The oscillator can be accurately reset to zero beat at any time, thereby eliminating errors caused by any small remaining frequency drifting.

Output Impedance: The output is taken from a 1500-ohm Ayrton-Perry-wound potentiometer. One output terminal is grounded.

Output Voltage: The maximum open-circuit output voltage of the oscillator is between 10 and 15 volts. Because of the automatic volume control circuit, this voltage remains constant within ±1.5 decibels over each entire frequency range.

Waveform: The total harmonic content of the open-circuit voltage is less than 3% for frequencies above 200 cycles on the low range and above 20 kilocycles on the high range.

A-C Hum: When the oscillator is operated from a 60-cycle line the power-supply ripple is less than 2% of the output voltage on either range.

Voltmeter: A vacuum-tube voltmeter circuit is used in the oscillator for measuring the output voltage. The indicating meter on the panel is calibrated directly in volts at the output terminals.

Controls: In addition to the main frequency-control dial and the incremental frequency dial, there is a frequency range switch, and a zero beat adjustment. The output voltage is varied by a potentiometer control provided near the output terminals.

Terminals: The output terminals are jack-top binding posts with standard ¾-inch spacing. The lower terminal is grounded to the panel and shields.

Mounting: The instrument is normally supplied for table mounting, but can be easily adapted for relay-rack mounting by removing two walnut brackets at the ends of the panel.

Power Supply: A-C power supply, 110 to 120 volts, 40 to 60 cycles, is used. A simple change in the connections to the power transformer allows the instrument to be used on 220 to 240 volts.

The total power consumption is approximately 85 watts.

Tubes: The following tubes are used:

2 — Type 6C5	2 — Type 25L6
1 — Type 6J7	1 — Type 6H6
1 — Type 6L7	1 — Type 5T4

All tubes are supplied.

Accessories: A 7-foot power cord, spare fuses, and a Type 274-ND Plug are supplied.

Dimensions: Panel, (width) 19 x (height) 10½ inches, over-all; depth behind panel, 11 inches.

Screw holes in the panel are the standard spacing for mounting the instrument in a standard 19-inch relay rack.

Net Weight: 55 pounds.

Type		*Code Word*	*Price*
700-A	....	ORGAN	$555.00

This instrument is manufactured under the following U. S. Patents and license agreements:

Patents of the American Telephone and Telegraph Company solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.

Patent No. 1,525,778.

GANGED VARIACS FOR THREE-PHASE OPERATION

● **VARIACS** mounted in tandem for operation by a single control were described in the March, 1937, issue of the *Experimenter**. In three-phase circuits, two- and three-gang Variac assemblies can be used in the same manner that single Variacs are used in single-phase circuits. The most common methods of connection are the wye and open delta. A complete table of ratings and characteristics will be found in the article referred to above. Economies in manufacturing have made it possible to reduce appreciably the prices previously listed. New prices are as follows:

Type	*Description*	*Code Word*	*Price*
100-KG2	2-gang 100-K	BEAMYGANDU	$85.00
100-KG3	3-gang 100-K	BEAMYGANTY	130.00
100-LG2	2-gang 100-L	BEARDGANDU	85.00
100-LG3	3-gang 100-L	BEARDGANTY	130.00
200-CUG2	2-gang 200-CU	BAKERGANDU	36.50
200-CUG3	3-gang 200-CU	BAKERGANTY	56.00
200-CUHG2	2-gang 200-CUH	BAGUEGANDU	44.50
200-CUHG3	3-gang 200-CUH	BAGUEGANTY	68.00

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*L. E. Packard, "Three-Phase Voltage Control with the VARIAC."

THE TYPE 663 RESISTOR—A STANDARD FOR USE AT HIGH FREQUENCIES

● **IMPEDANCE MEASUREMENTS** at high frequencies, as at low frequencies, are usually carried out by comparing unknown impedances with standard impedances, the properties of which are accurately known at the particular frequency used. In order to specify an unknown impedance completely, it is necessary to measure its vector components, either as magnitude and angle in polar co-ordinates, or as resistance and reactance in Cartesian co-ordinates.

Measurements are most commonly made in terms of resistance and reactance components. For such measurements a comparison method ideally demands both a pure resistance and a pure reactance standard, the one for comparison with the unknown resistance component and the other for comparison with the unknown reactance component. Standards, in practice, are never really pure because a physical realization of any one of the three circuit parameters — inductance, resistance, and capacitance — has, in addition to the main desired parameter, residual amounts of the other two undesired parameters. The existence of these residual parameters causes the impedance of a standard to depart from one of the ideal laws of variation with frequency $j\omega L$, R, and $\frac{1}{j\omega C}$ in both magnitude and phase. The departure means that not only does the effective inductance, resistance, or capacitance vary with frequency, but that there occurs also a resistive component in reactance standards and a reactive component in resistance standards. Since methods of measurement are most commonly evolved on the assumption of ideally pure standards, it is highly desirable in practice to use actual standards which have as small residual parameters as possible in order to minimize correction terms.

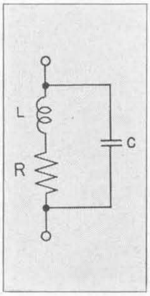

FIGURE 1. Equivalent circuit of fixed resistor. R is the desired resistance, L and C are the undesired residual inductance and capacitance.

In any given impedance element the effects of residual parameters ordinarily increase as the frequency goes up. They also tend to be greater for continuously adjustable units than for fixed units. As reactance standards, variable air condensers achieve a high degree of purity. They may consequently be used over an extensive frequency range[1]. As resistance standards, continuously adjustable resistors have not yet been sufficiently highly developed to meet the exacting requirements of high-frequency operation. Fixed resistance standards, however, can be built with such a degree of freedom from residual parameters that they can be used over a frequency range comparable with that covered by the precision type of variable air condenser.

RESIDUAL PARAMETERS IN RESISTANCE STANDARDS

The effect of residual parameters on the frequency characteristics of a fixed

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[1] See, for instance, "A High-Frequency Model of the Precision Condenser," General Radio *Experimenter*, Vol. XIII, Nos. 5 and 6, October-November, 1938, page 1.

resistor can be deduced from the approximate equivalent circuit of Figure 1.

In this figure, R represents the desired main resistance parameter and L and C the undesired residual inductance and capacitance parameters.

The input impedance of the equivalent circuit can be expressed most conveniently in terms of the quantities.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

and $$D_0 = R/\sqrt{\frac{L}{C}} = \frac{R}{\omega_0 L} = \frac{1}{Q_0}$$

by means of the equation

$$Z_e = R_e + jX_e = \frac{R}{\left[1 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2 + D_0^2\left(\frac{\omega}{\omega_0}\right)^2} + j\left(\frac{\omega}{\omega_0}\right)\frac{R}{D_0}\,\frac{1 - \left(\frac{\omega}{\omega_0}\right)^2 - D_0^2}{\left[1 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2 + D_0^2\left(\frac{\omega}{\omega_0}\right)^2}$$

This equation is readily normalized by dividing through by R. The normalized resistive and reactive components are plotted in terms of the variable (ω/ω_0) and the parameter D_0 in Figures 2 and 3.

While it is logical to suppose that reducing the residual parameters L and C with respect to the main parameter R will render the effective resistance R_e more nearly constant and the effective reactance more nearly zero over a wider frequency range, a survey of the curves of Figures 2 and 3 raises the further question as to whether there is a specific proportioning of the limiting residuals which will lead to an optimum design.

If the product of the residual inductance L and shunt capacitance C can be kept constant, while the quotient is varied, D_0 can be changed without altering ω_0. Under these conditions an optimum design will be reached for constancy of resistance if $D_0^2 \simeq 1.8$ and for lowness of reactance if $D_0^2 = 1$. However, if L and C are not absolutely inversely related to each other, the proper proportioning is not so easily deduced.

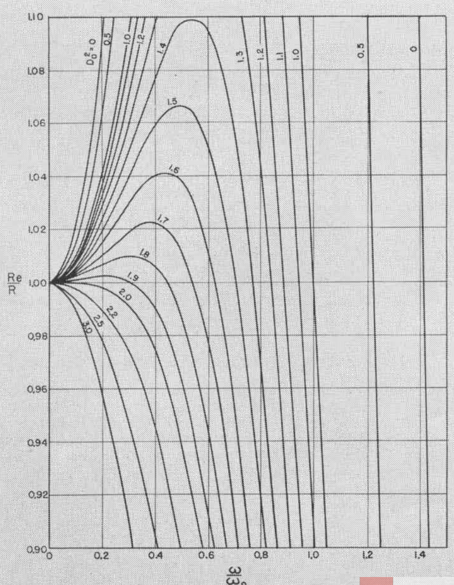


FIGURE 2. General normalized curves of resistance as a function of frequency for fixed resistor.

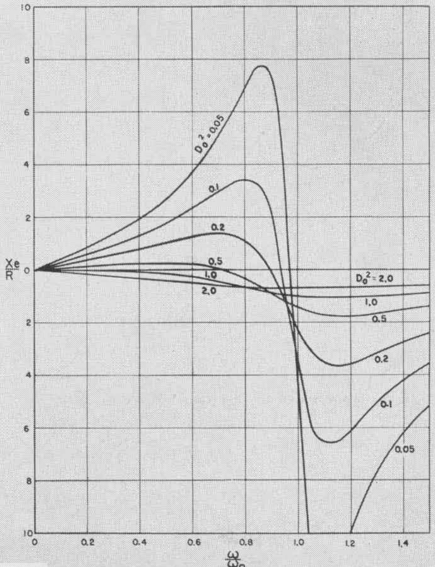
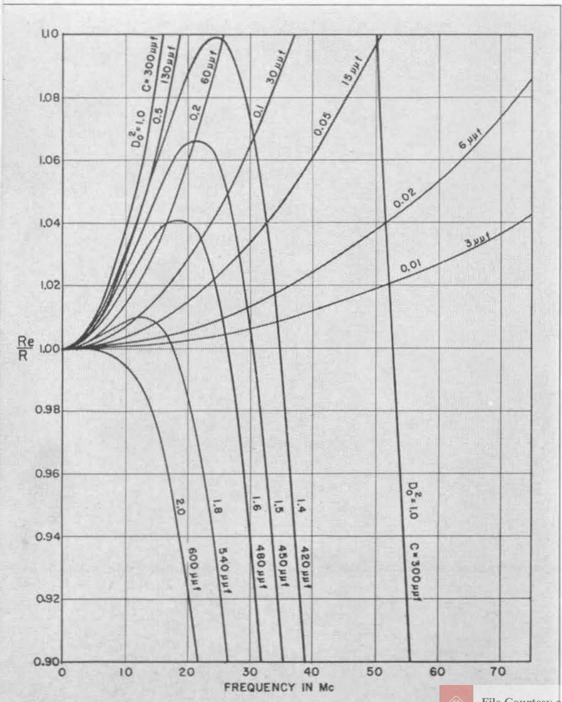


FIGURE 3. General normalized curves of reactance as a function of frequency for fixed resistor.

In particular it is interesting to know whether adding shunt capacitance to a resistor which has a definite fixed inductance will, under any conditions, improve the performance. The question cannot be immediately answered by an inspection of the curves of Figures 2 and 3 because both $\frac{\omega}{\omega_0}$ and D_0 change as the capacitance is added. It can be shown, however, that if the parameter D_0^2 is less than 1 or greater than 2, there is a loss in performance when shunt capacitance is placed across the resistor terminals. If D_0^2 lies between 1 and 2 there may or may not be a gain in performance, depending upon the frequency range and upon the criterion of merit used.

Curves of effective resistance and effective reactance for a typical 10-ohm resistor are illustrated in Figures 4 and 5 as a function of frequency with total shunt capacitance as parameter. For these curves the residual inductance L is taken as 0.030 μh and the minimum shunt capacitance as 3 $\mu\mu$f.

FIGURE 4. Specific curves of normalized resistance as a function of frequency for typical 10 Ω resistor. Residual inductance assumed equal to 0.03 μh. Residual capacitance taken as parameter.



The minimum shunt capacitance is seen to correspond to the best resistance characteristic. For a criterion of goodness, take the maximum frequency for which the resistance remains within ±1% of its d-c value. The addition of shunt capacitance lowers the maximum frequency from 36.5 Mc for $D_0^2 = 0.01$ to 5.3 Mc for $D_0^2 = 1$. Further addition to capacitance, however, improves the resistance characteristic again, until the maximum frequency increases to 19.5 Mc for $D_0^2 = 1.8$. At higher values of D_0^2 the resistance characteristic deteriorates from this figure.

For the reactance characteristic, take as a criterion of goodness the maximum frequency at which the reactance remains within ±25% of the d-c resistance. The addition of shunt capacitance raises the maximum frequency from 13.5 Mc for $D_0^2 = 0.01$ to 58.0 Mc for $D_0^2 = 0.5$. Further addition of capacitance reduces the maximum frequency again.

The optimum conditions for resistance and reactance are seen to be incompatible. If a different criterion for optimum reactance be used, the disparity is even more marked. At $D_0^2 = 1$, for instance, the reactance is a minimum for low frequencies.[2] The frequency characteristic of resistance, on the other hand, is the worst for any value of D_0^2 less than 2.

At high frequencies, resistance units are most often used under conditions in which their effective series reactances can be tuned out. The more important

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[2] This case corresponds to the condition $L = CR^2$ which is often approximated at low frequencies for standard resistors of very low-time constant. An excellent treatment of low-frequency resistance design is given on pages 66–82 of B. Hague's "Alternating Current Bridge Methods," 3rd edition.

characteristic is, therefore, the resistance. On this basis, with the 10-ohm unit, no gain will be made by adding shunt capacitance.

However, a 100-ohm unit with the same residual inductance behaves quite differently. A shunt capacitance of 3 $\mu\mu$f, for this unit, corresponds to $D_0^2 = 1$. In this case, the addition of 2.4 $\mu\mu$f in shunt raises the maximum frequency at which the resistance remains within $\pm 1\%$ of its d-c value from 53 Mc for $D_0^2 = 1$ to 195 Mc for $D_0^2 = 1.8$, a factor of nearly 4:1. The improvement in behavior of the 100-ohm unit, with D_0^2 in the neighborhood of 1, over that of the 10-ohm unit, with D_0^2 in the neighborhood of 0.01, is marked. It occurs because the higher value of D_0^2 is secured without lowering the natural angular velocity ω_0.

PRACTICAL DESIGN CONSIDERATIONS

The design of a line of high-frequency resistors must contemplate, in addition to the problem of residual parameters, the problems of skin effect, power-handling capacity, temperature coefficient, and mechanical ruggedness.

The bearing of these various factors on the design of the TYPE 663 Resistor line can best be illustrated by discussing them in the following order:

(1) Minimization of residual parameters.

In order to minimize residual inductance and capacitance the "straight-wire" type of construction was selected. This type of resistor has been popular with experimenters for many years but has not previously been available commercially.[3]

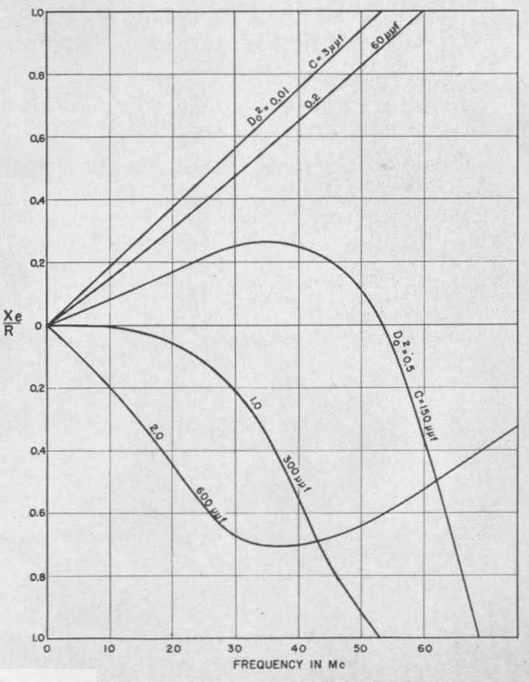
(2) Skin effect and temperature coefficient.

In order to minimize skin effect and temperature coefficient, manganin wires of very small diameter were chosen. Through the use of wire diameters as small as 0.0006 inch (No. 54, B. & S. Gauge) resistances up to 100 ohms can be obtained in wire lengths of less than 2 inches.

(3) Proportioning of residual parameters and power-handling capacity.

The analysis of residual parameters shows that, for a given product of residual inductance and capacitance, optimum results will be obtained for a value of the parameter D_0^2 in the neighborhood of unity. In the case of a line of straight-wire resistors in a standardized type of mechanical mounting the best condition can be obtained at only one value of resistance, since the residual inductance and capacitance are more or less fixed. The resistance characteristics deterio-

FIGURE 5. Specific curves of normalized reactance as a function of frequency for typical 10 Ω resistor. Residual inductance assumed equal to 0.03 μh. Residual capacitance taken as parameter.



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[3] See, for instance, "Radio Instruments and Measurements," Circular No. 74 of the Bureau of Standards, pages 175, 176.

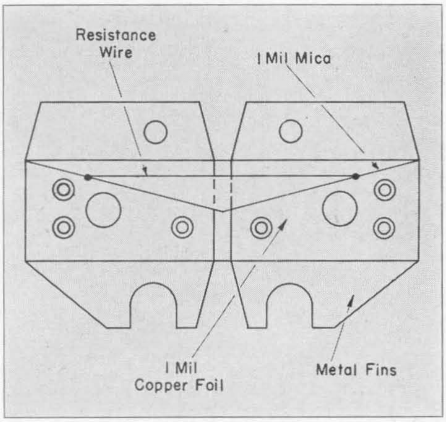

FIGURE 6. Outline sketch of mechanical construction of TYPE 663 Resistors.

rate more rapidly as D_0^2 increases from unity than as it decreases from unity. The design should, therefore, place the $D_0^2 = 1$ point near the high end of the resistance range.

The usual type of straight-wire resistor has relatively high residual inductance in comparison with the residual capacitance. This results in a value of D_0^2 which is small compared to unity for resistance values of 100 ohms and less. In the TYPE 663 Resistor the inductance was reduced at the expense of an increase in capacitance by clamping the resistance wire down on a thin piece of mica, backed by a metal plate which serves as an eddy-current shield.[4]

This construction also serves to increase the power-handling capacity over that obtained with a straight-wire resistor which has the wire suspended in air, because of heat conduction from the wire to the metal plate and subsequent dissipation by convection and radiation.

The final design of the TYPE 663 Resistor is illustrated in the drawing of Figure 6 and photograph of Figure 7.

With this construction, D_0^2 is in the neighborhood of unity for the 100-ohm unit and is less for the lower resistances. Approximate frequency characteristics[5] for TYPE 663 Resistors are illustrated in Figures 8 and 9. The values for residual capacitance and inductance upon which these curves are based are given under Specifications.

The importance of the type of mounting used with these resistors cannot be over-emphasized. Great care has been exercised in reducing the residual parameters to a minimum. The residual parameters associated with the mounting can very easily be comparable to those of the resistor. In the case for which the curves of Figures 8 and 9 are drawn, for instance, more than half of the 6.5 $\mu\mu$f effective shunt capacitance is in the binding posts. For high-frequency measurements, in particular, caution should, therefore, be used to minimize residual parameters inherent in the mounting. Careful attention should also

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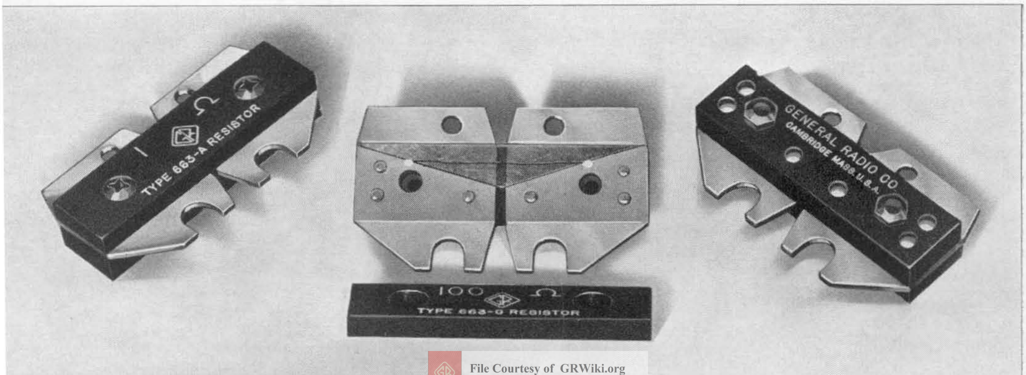
[4] See, for instance, L. B. Arguimbau, "A High-Frequency Voltage Standard," General Radio *Experimenter*, June, 1937.

[5] When mounted on a pair of TYPE 138-VD Binding Posts with one end grounded to a ¼ inch metal panel upon which the binding posts are assembled with TYPE 274-Y Mounting Plates. See cut under Specifications.

FIGURE 7. Photograph of TYPE 663 Resistors. The disassembled unit shows the method of construction.



be given to the question of just what change in circuit conditions occurs when one of these resistors is placed in circuit and taken out. The shorting bar used to replace the resistor, when it is out of circuit, should preferably have an inductance less than 0.005 μh and a capacitance to ground of the same order as that of the resistor.

— D. B. Sinclair

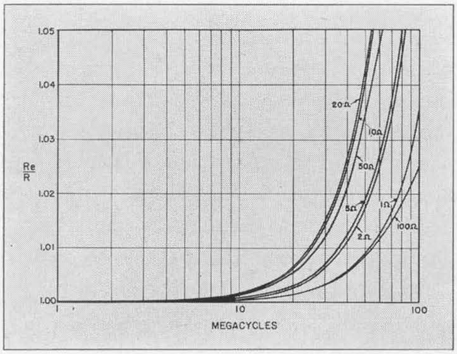


Figure 8. Ratio of effective resistance to d-c resistance as a function of frequency for Type 663 Resistors mounted on binding posts.

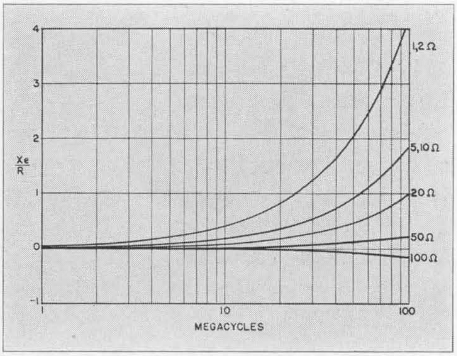


Figure 9. Ratio of effective reactance to d-c resistance as a function of frequency for Type 663 Resistors mounted on binding posts.

SPECIFICATIONS

Resistance Values: Standard units are available in the following resistances: 1, 2, 5, 10, 20, 50 and 100 ohms.

Accuracy: All units are adjusted within 1%.

Residual Parameters: The following table gives approximate values for *L* for the different units:

Resistance	*L*	*Current for 40° C. Rise*
1 ohm	0.0065 μh	1.4 a
2 ohms	0.013 μh	1.0 a
5 ohms	0.015 μh	0.5 a
10 ohms	0.029 μh	0.35 a
20 ohms	0.032 μh	0.2 a
50 ohms	0.034 μh	0.1 a
100 ohms	0.039 μh	0.06 a

Skin Effect: For all units the skin effect is less than 1% for frequencies below 50 megacycles.

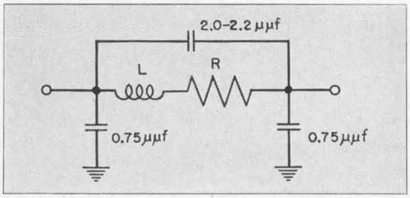
Temperature Coefficient: At normal room temperature the temperature coefficient is less than ±0.002% per degree Centigrade.

Maximum Power and Current: The allowable power dissipation for a 40° Centigrade temperature rise varies slightly with resistance, being 2 watts for the 1-ohm unit and 0.4 watt for the 100-ohm unit. The rated current for this temperature rise for the different units is given in the table.

Terminals: The flat metal plates to which the resistance wire is attached are used as terminals, and are both slotted and drilled for convenience in mounting.

Dimensions: (Length) 2¼ x (width) 1¼ inches. Over-all height, ⅝ inch.

Net Weight: 2 ounces.



Equivalent circuit of a Type 663 Resistor. The 0.75 μμf ground capacitances correspond to a spacing between resistor and ground of ⅞ inch.

Type	*Resistance*	*Code Word*	*Price*
663-A	**1 ohm**	PANIC	**$5.00**
663-B	**2 ohms**	PARTY	**5.00**
663-C	**5 ohms**	PATTY	**5.00**
663-D	**10 ohms**	PEDAL	**5.00**
663-E	**20 ohms**	PENAL	**5.00**
663-F	**50 ohms**	PENNY	**5.00**
663-G	**100 ohms**	PETTY	**5.00**

MISCELLANY

• **DR. DONALD B. SINCLAIR,** author of both articles in this issue, will be one of the speakers at the Second Annual Broadcast Engineering Conference at Ohio State University, February 6 to 17, 1939. His subject: "Measurements on Broadcast Antennas."

The value of this Conference to broadcast engineers is attested by the reports of those who attended last year. Of particular interest this year is the Panel Discussion on "Standards of Good Engineering Practice" led by A. D. Ring of the FCC.

• **APPROXIMATELY** 18 tons of paper were used in the new General Radio Catalog K. About 1200 pounds, or 0.6 ton, are used in each issue of the *Experimenter*.

• **A RECENT INVESTIGATION** by the editor shows 79 Variacs in use in the General Radio plant. Of these, 42 are permanently installed and 37 are used as laboratory accessories. The permanent installations are used for motor speed control on winding machines, lathes, and ventilators; for lighting control in the photographic and drafting departments, in the demonstration room, and in test sets in the testing laboratory. Those in the laboratories are about evenly divided between the standardizing laboratory and the engineering department. The engineering department uses them as a source of variable voltage for development work, the standardizing laboratory to obtain a standard line voltage for testing.

• **THE AIR CONDITIONING BUREAU,** an organization composed of Boston men connected with the air conditioning industry, was addressed on December 14 by H. H. Scott of the General Radio engineering staff. His talk, entitled "Equipment for the Measurement and Analysis of Sound," was accompanied by a demonstration. John A. Chambers of the Boston office of Johns-Manville Corporation was also a speaker on the same program.

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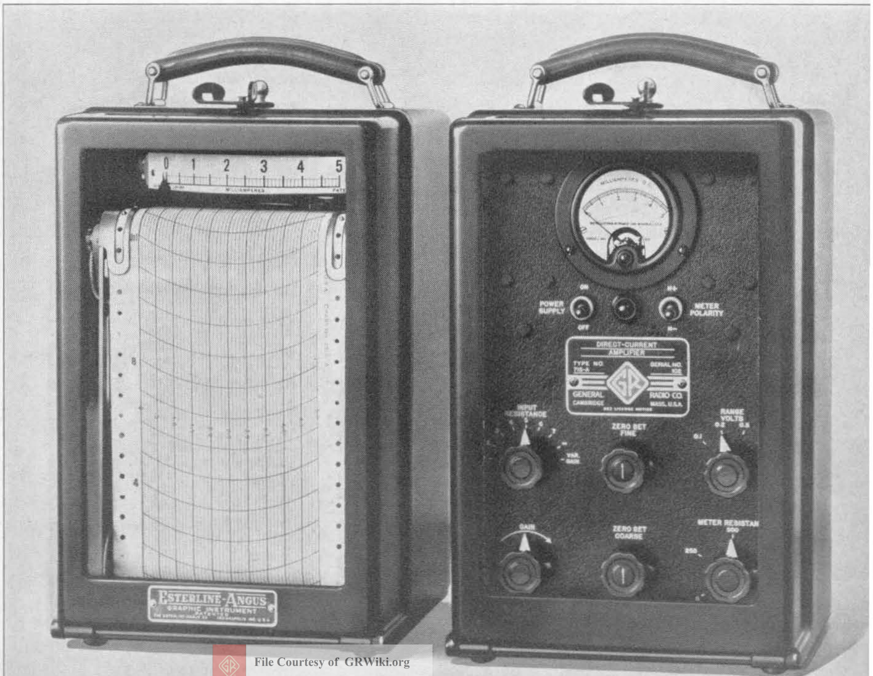
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

A-C OPERATED DIRECT-CURRENT AMPLIFIER FOR INDUSTRIAL USE

● **THE MAIN FUNCTION** of a direct-current amplifier is effectively to increase the sensitivity of direct-current indicating or recording instruments. Used with indicating instruments, it makes possible the use of rugged instruments for indicating small voltages and currents instead of the delicate, high sensitivity instruments which would otherwise be required. Recorders,

FIGURE 1. TYPE 715-A Direct-Current Amplifier and Esterline-Angus 5-milliampere recorder. The amplifier can be obtained in a case to match the recorder as shown here, or in a walnut cabinet as shown on page 3. A relay-rack mounting to hold both the amplifier and the recorder is also available.



because of the higher power required to operate them, cannot be used on weak currents and voltages without an amplifier. The amplifier, therefore, extends the use of these instruments to fields formerly beyond their scope, permitting continuous records of sound level, light intensity, frequency, and other phenomena easily converted to weak direct currents.

An additional use of the d-c amplifier is in automatic control circuits where, instead of being used to operate an indicating or recording instrument, the amplifier output actuates relays to control the original phenomenon or to perform some other function.

While "direct-coupled," "zero-frequency," or "direct-current" amplifiers are by no means new, various difficulties have previously prevented entirely satisfactory performance. Battery operation was once considered essential, and usually one set of heavy and expensive batteries was used for each tube. Such complications naturally limited the use of the equipment to applications where the desired results could be secured in no other way.

In the amplifier here described, operation from the alternating-current power line has been achieved with *no loss in stability* and with complete freedom from fluctuations due to line voltage variations within reasonable limits. Several features are incorporated involving principles and apparatus which have only become available in comparatively recent times. In particular, the use of degeneration, to stabilize the amplifier gain and to improve the linearity of response, and the use of voltage regulating transformers and tubes are important. Figure 2 is a schematic circuit diagram with power supply omitted.

The operation of the instrument is exceptionally simple, and for continuous recording it can be run for weeks without attention, except for a daily check of the zero adjustment which takes perhaps a half minute. The tubes will have a life expectancy of better than 3000 hours (120 days) when continuously used, and the deterioration of other parts is negligible.

One of the most important uses of the amplifier is in recording work. Full-scale output of the amplifier has, therefore, been made 5 milliamperes to operate an Esterline-Angus High-Sensitivity Graphic Instrument which requires 5 milliamperes for full-scale deflection. This output can be obtained for input voltages of 0.1, 0.2, 0.5, and 1.0 volt. A panel meter which is in series with the recorder indicates the output current in milliamperes.

The input resistance can be varied by powers of 10 between 100 ohms and 10 megohms, the operating value being selected by means of a panel switch. An open circuit position is also provided which connects the grid of the first tube directly to the input terminals; and, in addition, an input potentiometer with R-C smoothing filter can be switched in so that the input voltage can be adjusted to any desired value. The input resistance for this position is 150,000 ohms, approximately.

Although the instrument should be considered as a voltage operated device, its extreme sensitivity as a current amplifier should be noted. One-tenth of a volt input will give a full-scale deflection in the five-milliampere output circuit. A current of only 0.01 microampere passed through the 10-megohm input resistance will provide this one-tenth volt input.

(*Continued on page 4*)

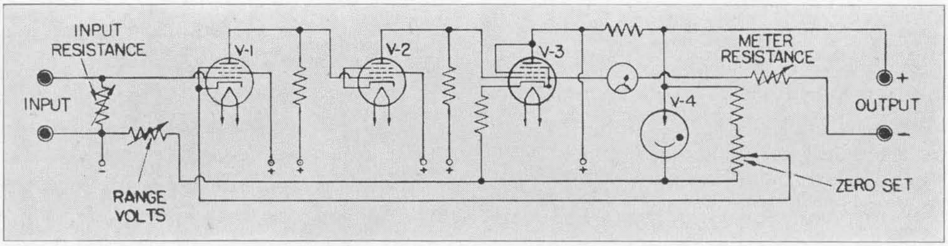


FIGURE 2. Schematic diagram of the TYPE 715-A Direct-Current Amplifier.

The amplifier consists of three stages in cascade, the first two being pentodes, the last a triode. For degeneration to be applied, it is necessary to have an odd number of phase reversals. The simplest arrangement is to use an odd number of amplifier stages. The total output current of the final stage is passed through a resistance placed in series with the cathode-grid circuit of the first tube. By adjustment of this resistance, the effective gain of the amplifier may be set at a desired value, which, when a specified voltage is applied to the input terminals, will result in the desired output current. This degeneration resistance is in the form of preadjusted resistors selected by the RANGE switch.

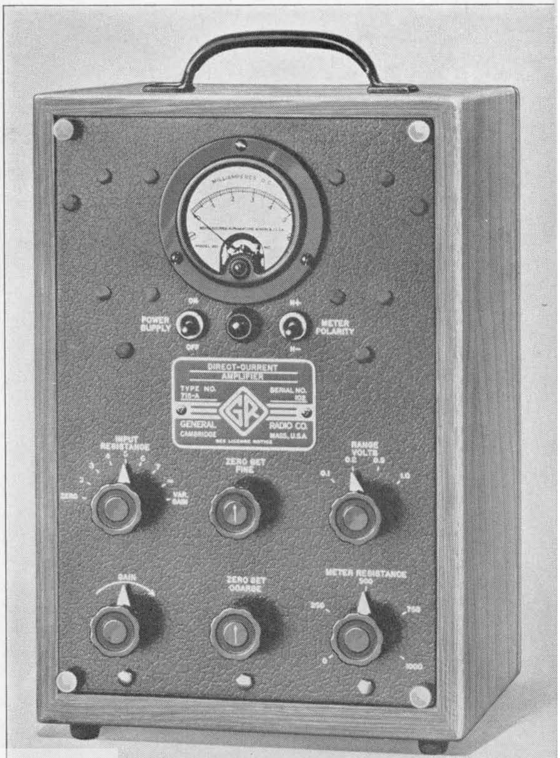
A bias control (ZERO SET) is provided whose normal setting would bring the output current to zero for zero input voltage. In some cases, however, use may be made of the adjustment as an offset zero, to cancel a portion, or all, of a steady input voltage so that the instrument responds to *changes* from this steady value.

In the schematic diagram, certain connections are indicated for supply voltages, but for simplicity the voltage dividers are not shown. Actually, the first two stages operate on individual voltage dividers giving a high degree of isolation from the common plate supply and, in particular, from the last stage.

The steady plate current of the output stage is removed from the output by the use of a bridge-type output circuit having a glow-tube regulator as one arm. A portion of the steady voltage across the glow tube is utilized for bias adjustment. No direct stabilization of the plate voltage supply is required. However, since an increase in plate voltage would result in some unbalance in the output bridge which is not entirely compensated by the increased bias applied through the degenerative resistance, a voltage proportional to plate voltage is fed into the first grid circuit in reverse phase. By factory adjustment of the magnitude of this voltage, compensation of plate voltage supply changes over a wide range is attained. (The network for this is not indicated in the schematic diagram.)

After the amplifier has been made stable in the ordinary sense, a new source of difficulty appears which would cause no trouble in amplifiers which are not direct-coupled. It can be shown that a temperature change of the cathode of the *first* tube is equivalent to a small change in bias. In an amplifier of the usual type no effect on performance would be observed, but in the direct-coupled amplifier an immediate change in output is noted, as a shift in the "zero" position of the output meter or recorder. To overcome this, it is necessary to stabilize carefully the operating voltage applied to the heater of the first tube. A ballast lamp has sufficient range of control to apparently give satisfactory results, but its large thermal lag renders it ineffective for rapid changes in heater supply voltage. Consequently a regulating transformer is used to overcome the effects of sudden changes, while the ballast lamp overcomes any residual slow variations. When properly adjusted, this combination gives a stable zero over a line voltage range of from 100 to 130 volts.

FIGURE 3. The TYPE 715-A Direct-Current Amplifier in walnut cabinet.



APPLICATIONS

A particular application, which was kept in mind during development of the amplifier, is that of recording the frequency indications of a Type 834-A Electronic Frequency Meter. By adjustment of the amplifier gain, full-scale readings on the recorder can be made to agree with full-scale readings of the frequency meter, for each range. By use of an offset zero in the amplifier an expanded record of *changes* in frequency over a portion of the normal range can be obtained. Since many quantities can be observed through frequency changes, this combination can be applied to many problems such as frequency drift in radio transmitters and crystal oscillators, and radio-meteorograph observations.

In conjunction with the Type 759-A Sound-Level Meter a continuous record can be made of average noise or sound levels over long periods of time. This is especially important in noise survey studies of offices, factories, broadcasting studios, and city streets.

Owing to the high input resistance of the amplifier, it can be used in the recording and measurement of hydrogen ion concentration with low-resistance electrodes.

Comparatively weak radio telegraph signals can be recorded on tape recorders by use of a small oxide rectifier (if a direct-current signal voltage is not otherwise available), the direct-current amplifier, and the recorder. In such applications the amplifier output can be utilized to operate relays, counters, or other devices as well as a signal recorder.

The direct-current amplifier and recorder can be operated directly from the output of a photronic cell. A number of applications are then possible, since the illumination of the photronic cell can be made to vary in accordance with such a large number of factors.

These include:

(a) Variations in daylight, as, for instance, in a manufacturing plant.

(b) Variations in artificial light brought about by dust or smoke in the air.

(c) Amount and duration of sunshine.

Since the amplifier and recorder actually constitute a calibrated recording voltmeter and, through the use of known input resistances, a recording milliammeter or microammeter, records of direct-current voltage or current variations can be obtained directly, opening up many applications where these observable quantities may be made responsive to many factors.

For some applications, the amplifier may serve in place of sensitive direct-current galvanometers. Using a one-megohm input resistance, the amplifier has a sensitivity of the order of 0.0004 microampere for one-fifth of a division on the meter scale, comparing with a good grade of galvanometer having a sensitivity of 0.0005 microampere per mm. at 1 meter. The indicating meter on the panel of the amplifier gives a high-speed response where the galvanometer has roughly a 10-second period.

A survey of the conditions of use should be made before the suitability of the amplifier to any given application can be established. Particular attention must be paid to the conditions of grounding and to voltages developed between the amplifier input terminals and ground. In applications involving rectified voltages or currents, attention must be given to the waveform of the input voltage, because of possible overloading on peaks on waveforms giving small average values.

— J. K. Clapp

SPECIFICATIONS

Range: The instrument is provided with four calibrated ranges, selected by means of a switch, giving 5 milliamperes linear output in the recorder circuit of 1000 ohms, for input voltages of 0.1, 0.2, 0.5, and 1.0 volt applied at the input terminals with either polarity. The gain is best expressed as a transconductance; the maximum value is 50,000 micromhos.

Accuracy: As a calibrated voltmeter, the accuracy of calibration is approximately 1%, this accuracy being maintained over considerable periods of time.

Input Circuit: Means are provided for selecting any one of a number of input resistances, so that the instrument not only has an adjustable input resistance, but can serve as a calibrated millivoltmeter or microammeter. The input resistances range in powers of 10 from 100 ohms to 10 megohms. Short-circuit and open-circuit positions are also supplied on the selector switch.

For those applications where relative values only are of interest and where the voltage available exceeds 1 volt, one of the switch positions connects the input to a variable gain control, so that the voltage applied to the first grid can be adjusted to any desired value. The input resistance for this position is 150,000 ohms approximately.

Output: The output circuit is designed to operate a 5-milliampere meter mounted on the panel and an external meter or device such as the Esterline-Angus 5-milliampere recorder, and is provided with a manually adjusted compensating resistance. The compensating resistance is adjusted to allow for the resistance of the external device, so that the instrument always works into a normal resistance of 1000 ohms. Although the instrument functions perfectly when operating into resistances from 0 to 2000 ohms, its calibration is affected slightly if the total impedance deviates materially from the 1000-ohm value.

Power Supply: The instrument is intended for operation directly from 105-125 or 210-250 volts, 60-cycle mains. Other voltages or other frequencies can be supplied on special order only.

Power Input: The power drawn from the 60-cycle mains is approximately 35 watts. No batteries of any kind are employed.

Vacuum Tubes: The tubes furnished with the instrument are: two type 6J7-G, one 6F6-G, one 6X5-G, one VR-105-30, one 4A1.

Mounting: The amplifier is mounted in a cast metal case identical with that used on the Esterline-Angus recorder, or in walnut cabinet, as desired.

Dimensions: Type 715-AM, (height) 15¼ x (width) 9 x (length) 8½ inches, over-all; Type 715-AE, (height) 15 x (width) 8½ x (length) 8¾ inches, over-all.

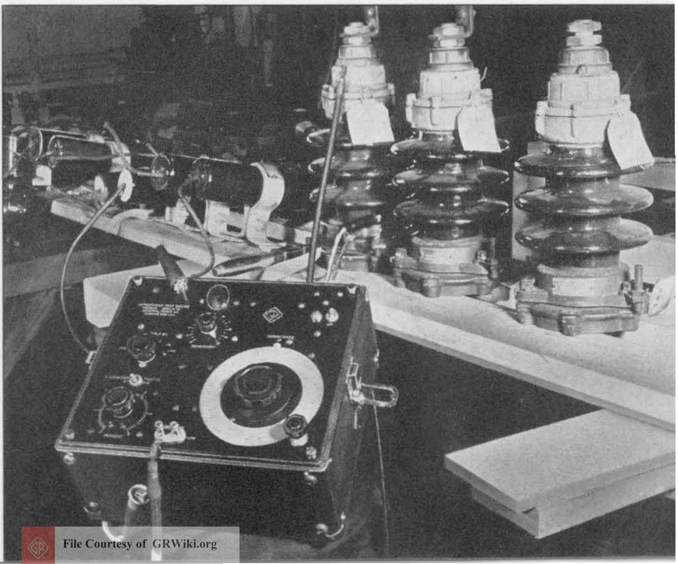
Net Weight: With Esterline-Angus case, 26¼ pounds; with walnut cabinet, 23 pounds.

Type		*Code Word*	*Price*
715-AE	In Esterline-Angus case	ASIDE	$250.00
715-AM	In walnut cabinet	ALOFT	225.00

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

A MODIFICATION OF THE CAPACITANCE TEST BRIDGE FOR MEASURING GROUNDED SAMPLES

● **A MODIFICATION** of the Type 740-B Capacitance Test Bridge is now available which has one of the test terminals grounded. This new model is extremely useful in the electrical manufacturing and electric power fields for capacitance and power-factor tests on insulators, cables, transformers, etc. A folder describing the new bridge (Type 740-BG) will be sent on request. Ask for Form 516-A.



AN ANALYZER FOR NOISE MEASUREMENT

USES OF NOISE ANALYSIS

A sound-frequency analysis is often a necessary step in the location and elimination of noise. While, for production tests and acceptance tests on most mechanical and electrical devices, a measurement of the loudness of the noise with the TYPE 759-A Sound-Level Meter provides all the necessary information, there are many problems in machine design and installation which cannot be solved without a knowledge of the frequencies of the various noise components.

With this information, sources of noise components can be traced and their sources located. Machine parts, for instance, may tend to vibrate at their natural frequencies. These resonant frequencies can be calculated, and when one appears as a prominent component of the total noise, it usually is generated by the corresponding machine part.

TYPES OF NOISES

The noises generated by ordinary types of machinery may be divided into two general classes. The first includes sounds whose pitch corresponds to the fundamental frequency at which the machinery is operating or at some harmonically related frequency. Sounds in this class are characteristically harmonic in nature, and their frequency will vary with the speed of the machine. Many types of high-speed rotating machinery, such as centrifuges, dynamos, etc., produce sound almost entirely in Class One.

The second class of noise includes all of the so-called "unpitched" noises, which are usually generated by mechanical parts of a machine vibrating at or near their natural frequencies as a result of shock excitation. Such noise is in the form of a series of damped waves, which, although they may recur at regularly timed intervals depending upon the

FIGURE 1. View of the TYPE 760-A Sound Analyzer with cover removed.

machinery speed, consist essentially of components corresponding to the natural frequencies of the vibrating parts and bearing no definite harmonic relationship to the fundamental speed of the machine. The actual frequencies involved in such sounds are seldom clearly defined, since the effects of shock excitation and damping, as well as the movements of the various parts or the variation of forces impressed upon them, cause appreciable shifts of frequency. Sounds in Class Two are what are generally described as rattles or clashing sounds and are more often encountered in reciprocating machinery than in rotating machinery.

TYPES OF ANALYZERS

Analyzers hitherto available for separating noises into their component frequencies have been adaptations of instruments originally designed for other purposes. This limited their use to restricted fields. Heterodyne analyzers, for example, are completely satisfactory only when measuring Class-One noises having essentially constant pitch. Owing to their extremely sharp response and constant band width in cycles, they can seldom be used for measuring Class-Two noises. A band width variable in steps is somewhat more satisfactory, but is still subject to large errors. Tuned circuit analyzers have a characteristic nearer the ideal, but are cumbersome and expensive, and are usually not continuously adjustable. Unfortunately, this lack of satisfactory instruments has led many engineers to the conclusion that sound analysis is inherently difficult and unsatisfactory.

TYPE 760-A SOUND ANALYZER

A new analyzer, designed solely for sound and noise measurement, has been developed by the General Radio Company. This new instrument, TYPE 760-A Sound Analyzer, operates on different principles, and is far more satisfactory for analyzing the average noise than any device which has heretofore been generally available.

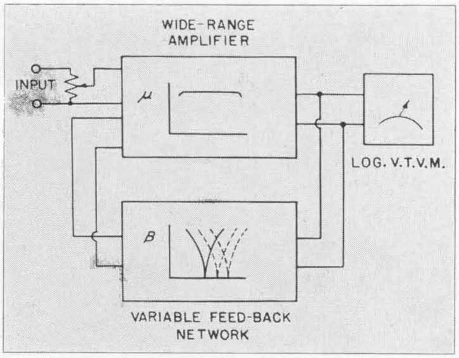


FIGURE 2. Functional block diagram showing the operation of the analyzer. In this circuit the output of an amplifier is fed back to the input in such a manner as to produce degenerative action and cancel the amplifier gain excepting at the frequencies within the pass band. To vary the tuning or the selectivity of this device only the feedback circuit itself need be adjusted, and no changes in the amplifier itself are required. The feedback network balances to a sharp null at a point corresponding to the peak in the pass band of the analyzer. Any variation in the balance frequency of the feedback network produces a corresponding change in the frequency to which the analyzer is tuned.

Briefly, the new instrument operates on the selective inverse-feedback principle,* as shown in Figure 2.

The use of this type of circuit has made possible a selectivity characteristic which is a constant-percentage function of the frequency to which the device is tuned. Most acoustical and sound engineers agree that this type of selectivity curve is ideal for the purpose of noise analysis. For measuring sounds of Class One, an analyzer of this type is relatively unaffected by even large changes in the fundamental speed of the machinery being tested, since any atten-

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*H. H. Scott, "A New Type of Selective Circuit and Some Applications," *Proc. I.R.E.*, Vol. 26, No. 2, pp. 226-235; Feb. (1938).

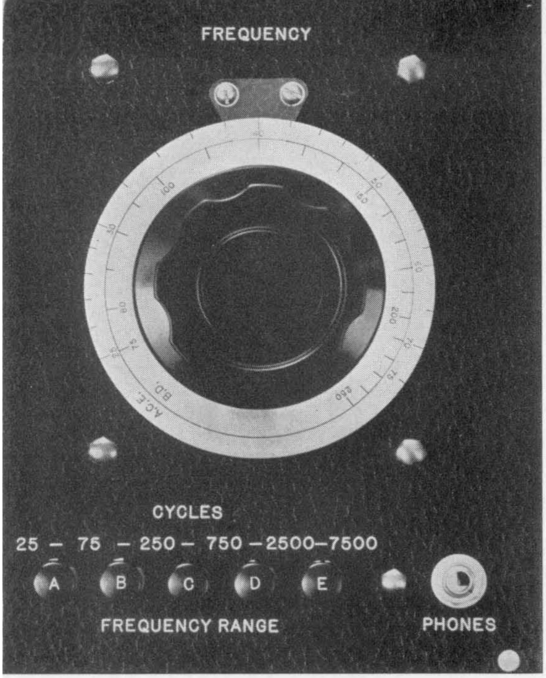


FIGURE 3. The tuning controls consist of a single dial and a row of push-button switches. The dial frequency span in cycles per second for each range is engraved above the corresponding push button, i.e., 25-75, 75-250, etc.

uation caused by such speed fluctuations is constant for the fundamental and all harmonics, so that their relative amplitudes are still measured correctly. For the unpitched sounds of Class Two, which usually cover bands of frequencies, the selectivity curve is sufficiently wide to give accurate readings.

The new analyzer is shown in Figure 1. Many of its mechanical and electrical features are identical with those of the TYPE 759-A Sound-Level Meter. Both instruments are similar in appearance, light in weight, and easily portable. Other features common to both instruments are complete operation from self-contained batteries, the elimination of all battery adjustments, and low battery drain resulting in extremely long battery life. Like the sound-level meter, the analyzer contains no coils or inductances whatsoever and hence is totally unaffected by all ordinary magnetic fields.

TUNING

An outstanding feature of this analyzer is the tuning system, which consists entirely of resistors and condensers. The resistors are ganged together on a common shaft and provide a continuous adjustment of frequency. The condensers are switched by a push-button arrangement to change the frequency range covered by the ganged resistors.

The dial has a spread-out logarithmic frequency scale covering a range of slightly over three to one, and the range is shifted quickly and easily by means of the push-button switch. The dial can be rotated continuously, so that the entire range of the device may be covered in a minimum of time. The push-button switch also allows quick adjustment of the tuning from one extreme of the frequency range to the other.

SELECTIVITY

Figure 4 compares the selectivity curves of TYPE 760-A Sound Analyzer and a typical heterodyne analyzer at several points in the sound-frequency range. Expressed as a percentage of the frequency to which the analyzer is tuned, the pass band of the heterodyne analyzer is undesirably wide at low frequencies and unusably narrow at high frequencies. The new analyzer, however, has a constant percentage band width at all frequencies. For measuring Class-Two sounds or Class-One sounds of varying pitch, this type of characteristic is essential.

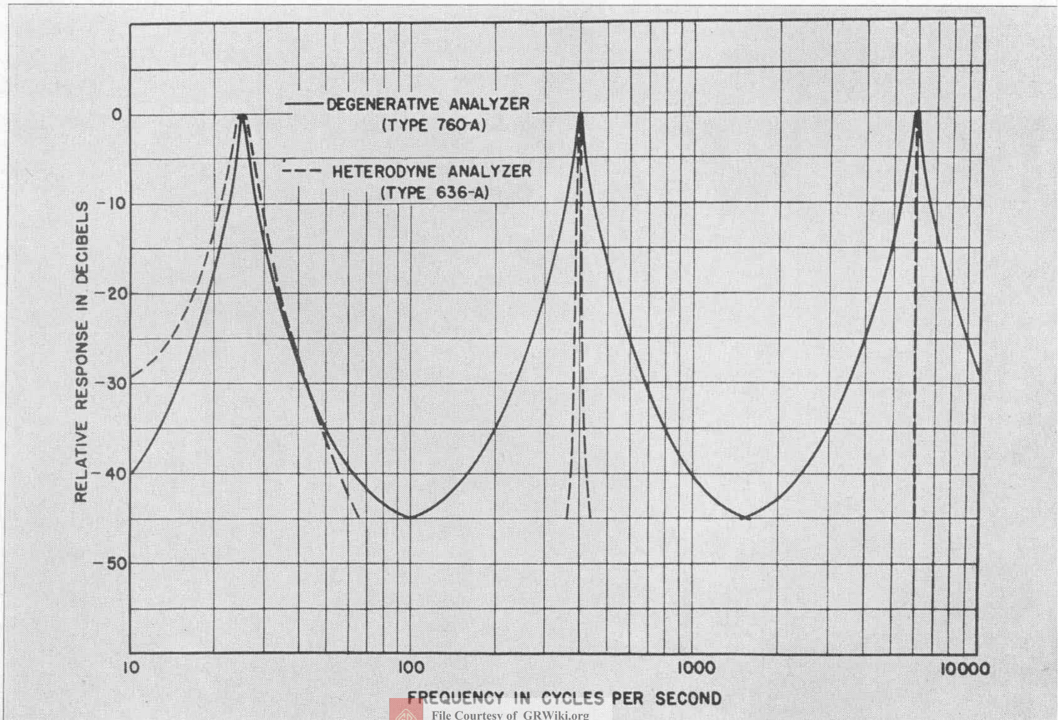
Examples of the errors occurring with different types of analyzers are shown in Figure 5. For purposes of simplification, it is assumed that, after the analyzer is tuned to a component, the frequency shifts by 1%, thus causing an amount of attenuation depending upon the selectivity curve of the analyzer. It will be noted that Curve A, for the TYPE 760-A

Sound Analyzer, shows a constant attenuation at all frequencies within its range. For a Class-One sound measured on this analyzer, therefore, small frequency shifts have no appreciable effect, while large frequency shifts provide an equal reduction of all components, so that they still remain in their proper relationship with one another. Curve B, however, illustrates what happens when a conventional type of heterodyne analyzer is used for this purpose. Under these conditions the error reaches 10 decibels at a frequency only a little above 300 cycles, and in that range from 1000 to 2000 cycles where the ear is most sensitive the response of the analyzer is down by 30 decibels, more or less. Obviously, under these conditions, these heterodyne analyzers will give results which are highly erroneous.

As previously mentioned, attempts have been made to eliminate this difficulty by the use of several band widths, usually related by factors of ten. Curve C shows the result obtained with a typical analyzer having a 5-cycle band-pass characteristic with a sharp cut-off beyond that point. Curve D is a continuation of Curve C into the higher frequency range and shows the extreme attenuation obtained. Curve E represents the response of the same analyzer with a 50-cycle band width. Under normal operating conditions the error obtained with this analyzer would be indicated by Curves C and E. The large discrepancy falling at the cross-over frequency, in this case 500 cycles, should be noted. Under these conditions an error of 25 decibels occurs at this point, which is most serious for all sound-analysis work. If the 50-cycle band were used at lower frequencies in order to minimize this error, the selectivity would probably be insufficient to give satisfactory results, because even at 500 cycles the band width is 10% of the frequency to which this device is tuned.

Of course, the actual results obtained

FIGURE 4. Comparison of the selectivity curves of the TYPE 760-A Sound Analyzer and a typical heterodyne analyzer (TYPE 636-A) having a band width of one cycle.



with any given sound with the heterodyne types of analyzers may be better or worse than that shown in the diagram, depending upon the amount of frequency shift present in the sound being measured and the frequency-versus-time characteristics. The results in most cases would, however, be unpredictable, except through a series of elaborate measurements. The possibility of such serious errors is probably the main reason why the heterodyne type of analyzer has been abandoned for most purposes of sound analysis, excepting in those few cases where the machinery speed can be held within very close limits.

VOLTMETER

Another innovation is the logarithmic vacuum-tube voltmeter, which covers a range of 42 decibels with a spread-out decibel scale. The meter is calibrated in

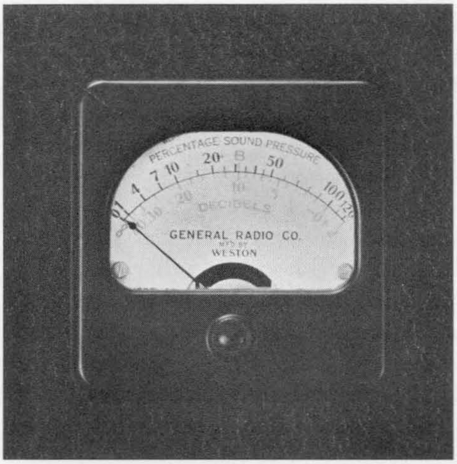
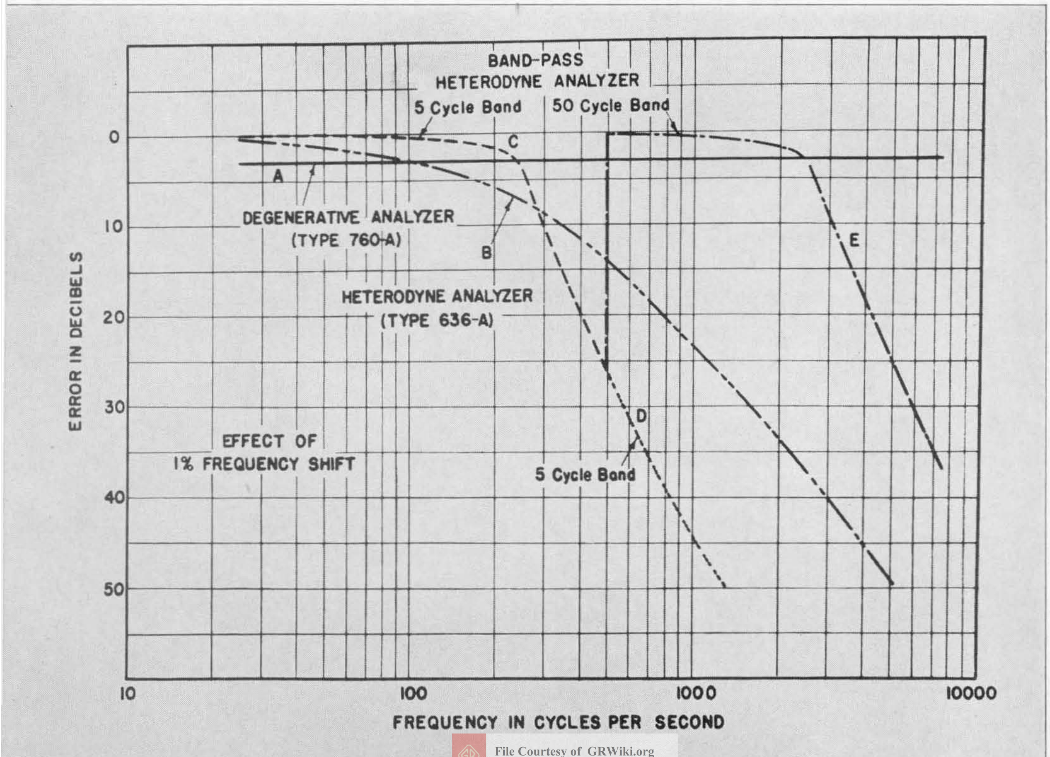


Figure 6. Meter scale of the **Type** 760-A Sound Analyzer.

both decibels and percentage, so that readings may be conveniently taken in any desired units.

The shape of the meter deflection characteristic has been purposely adjusted to provide a higher degree of ac-

Figure 5. Error in indication of various types of analyzers for an arbitrary shift of 1% in the frequency of source under measurement.



curacy of reading at the higher levels, since it is the high-level components which are of most importance when analyzing a noise. Because of this meter characteristic no multiplier switch is required on the sound analyzer, a feature which makes rapid analyses possible and which eliminates many chances of error in recording data.

OTHER USES

As frequently happens with new instruments, many uses have been discovered for the sound analyzer in fields quite outside that for which it was designed. One of the most important of these is the use of the instrument as a tuned amplifier and null indicator in bridge balancing. The selectivity characteristics of the device are ideal for bridge-balancing purposes and provide, particularly at low frequencies, a degree of discrimination which has not hitherto been available in most bridge-balancing devices. Of particular importance is the fact that the analyzer is unaffected by 60-cycle pickup and hence may be used in the many applications involving measurements at this frequency.

The sensitivity of the circuit is such that an input voltage of a millivolt will provide a satisfactory deflection on the indicating meter. This is about equivalent to the sensitivity of a pair of head telephones at 1000 cycles, which corresponds with the resonant frequency of the phones and is nearly at the peak of efficiency of the human ear. Obviously, therefore, since the analyzer will operate at any frequency between 25 and 7500 cycles, it is far superior in sensitivity to a pair of telephones over the greater portion of the range.

The logarithmic voltmeter is a great convenience for bridge-balancing applications. If desired, a pair of head telephones may be plugged into the output of the analyzer to provide aural as well as visual balance. The same automatic gain control which is in the voltmeter circuit will then operate on the telephones, providing an acoustic shock absorber which effectively prevents disagreeable acoustic shock if the bridge is suddenly unbalanced.

The use of the Type 760-A Sound Analyzer for wave analysis is, of course, not restricted to acoustical applications. It is quite suitable for the analysis of audio-frequency electrical waves over a voltage range of 100:1.

— H. H. Scott

SPECIFICATIONS

Frequency Range: Calibrated directly in cycles from 25 to 7500. This total range is covered in five complete turns of the tuning knob, the ranges on the various dial rotations being 25 to 75, 75 to 250, 250 to 750, 750 to 2500, and 2500 to 7500 cycles. A push-button switch allows immediate change of the main control to any of these ranges.

Input Voltage: The analyzer will give usable indications on input voltages ranging from 1 millivolt to 10 volts. The meter scale is calibrated for reading directly component tones down to 1% of the sound pressure (or voltage) of the fundamental or loudest component. Accordingly, to make full use of this feature, the input voltage at the loudest component or fundamental should be 0.1 volt or higher.

Selectivity: The average selectivity is such that the relative attenuation is 3 db at 1% off the peak to which the analyzer is tuned. The attenuation is at least 35 db at twice the frequency to which the analyzer is tuned.

Circuit: The circuit consists of a three-stage amplifier made selective by the use of degeneration, and an approximately logarithmic vacuum-tube voltmeter circuit, which allows a range slightly in excess of 40 decibels, or 100 to 1, to be read on the meter scale.

Meter: The indicating meter is calibrated down to 1% of the fundamental or loudest component of the sound. A decibel scale is also included, extending to 40 decibels below the fundamental or loudest component.

Telephones: A jack is provided on the panel for plugging in a pair of head telephones, in order to listen to the actual component of the sound to which the instrument is tuned. This is also useful when using the analyzer as a bridge-balance indicator.

Tubes: Three 1H4G and one 1F7GV tubes are required. A neon regulator tube is also used. A complete set of tubes is supplied with the instrument.

Batteries: The batteries required are four Burgess No. F2BP 3-volt batteries, or the equivalent, and three Burgess No. Z30N 45-volt batteries, or the equivalent. A compartment is provided in the case of the analyzer for holding all batteries, and connections are automatically made to the batteries when the cover of this compartment is closed. A set of batteries is included in the price of the instrument.

Case: The analyzer is built into a shielded carrying case of airplane-luggage construction, covered with a durable black waterproof material and equipped with chromium-plated corners, clasps, etc. This case has been designed to combine durability with light weight and good appearance. When operating the analyzer, the cover is ordinarily removed. An additional handle is provided on the panel of the instrument for convenience in moving it about while it is in operation.

Dimensions: (Length) 15 x (width) 10 x (height) 11½ inches, over-all.

Net Weight: 37 pounds, with batteries; 30 pounds, without batteries.

Type	*Code Word*	*Price*
760-A	ATTAR	$260.00
Set of replacement batteries for above	ATTARADBAT	8.00

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

Patent applied for.

MISCELLANY

- **A LIMITED NUMBER** of reprints is available of the article by D. B. Sinclair, entitled "Parallel Resonance Methods for Precise Measurements of High Impedances at Radio Frequencies." This article appeared in the December, 1938, issue of the *Proceedings of the I.R.E.*

- **AT A MEETING** of the student section A. I. E. E. at the University of Wisconsin on January 12, 1939, Martin A. Gilman of the General Radio engineering staff was the speaker. His subject: "Problems in Instrument Design."

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

MULTI-FREQUENCY DISTORTION MEASUREMENTS ON THE BROADCAST TRANSMITTER

• **IT HAS BEEN** the general practice to assume that an audio-frequency distortion measurement of a broadcast transmitter taken somewhere near the middle of the audio-frequency spectrum is indicative of the distortion that may be expected at all frequencies in the spectrum.

The advent of the inverse feedback type of transmitter with its lower over-all distortion has altered this situation considerably, because a relatively small amount of misadjustment in the phase of the feedback system may cause a serious increase in distortion, particularly at the

Figure 1. Panel view of Type 732-B Distortion and Noise Meter and Type 732-P1 Range-Extension Filters.

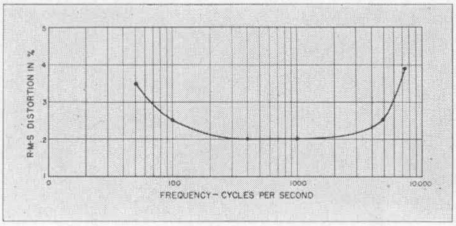

FIGURE 2. Distortion vs. frequency curve for a typical transmitter.

high end of the audio-frequency range.

There are two methods for the measurement of distortion over the audio-frequency range. One is by the use of a continuously variable analyzer which permits measurements at any selected audio frequency, and the other by a discrete step system. Each method has its uses.

In the original design of the transmitter the use of the continuous method is almost essential. Design engineers rely upon these measurements to guide them in making circuit modifications to reduce non-linearity to a minimum. Generally they need to know not only the amount of total distortion at various test frequencies, but also the value of each individual harmonic that is present. For this purpose the General Radio TYPES 636-A or 736-A Wave Analyzers are used in the laboratories of virtually every transmitter manufacturer.

The wave analyzer is also used in many broadcasting stations as an aid in maintaining extremely high quality for test purposes and in making detailed studies of transmitter performance. For routine test purposes, however, these elaborate and somewhat time-consuming measurements are not necessary. The effects of aging and drift in circuit elements, and of incorrect adjustment of controls, can be detected by measurements at a series of fixed frequencies through the audio range. Another important consideration is the time required for the tests. The discrete-frequency method is simple, rapid, and accurate.

In "Standards of Good Engineering Practice," published by the FCC, it is stated that distortion should be measured at six test frequencies: 50, 100, 400, 1000, 5000, and 7500 cycles. These frequencies are chosen to give the desired information about the transmitter. The distortion curve plotted against frequency for a typical transmitter is shown in Figure 2. Distortion nearly always rises rapidly at both the low and high frequencies. It is necessary to keep it low at the low-frequency end, because harmonics of these frequencies will be present in the transmitter's own signal, and thus will adversely affect its quality. Distortion is lowest in the band from 200 to 2000 cycles. Two check points are provided in this range, one at 400 cycles, the other at 1000 cycles.

The two high-frequency testing points of 5000 and 7500 cycles are especially important because harmonics of these frequencies will fall into adjacent channels, causing interchannel crosstalk. In feedback-type transmitters low distortion at these frequencies is critically maintained at a low value by the feedback adjustment, and slight changes in the adjustment may result in a rapid increase in distortion.

In order to provide a simple and accurate means for making distortion tests at the FCC test frequencies over the wide frequency range, a multi-frequency filter panel has been developed for use with the TYPE 732-B Distortion and Noise Meter.

The original TYPE 732-A Distortion and Noise Meter, which was announced*

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* L. B. Arguimbau, "Monitoring of Broadcasting Stations," *Experimenter*, January and February, 1935.

about four years ago, was the first instrument designed around the particular requirements for distortion and noise measurement of broadcast transmitters. Hundreds have been in constant service since that time.

The new TYPE 732-B Distortion and Noise Meter employs all of the good features of the original instrument, but has been redesigned to operate in conjunction with the TYPE 732-P1 Range-Extension Filters. The distortion meter itself contains the 400-cycle band-pass filter for measurements at this frequency, and the auxiliary filter panel contains the other filters for 50, 100, 1000, 5000, and 7500 cycles. The two instruments are both rack-mounting and interconnect with convenient Jones plugs. A schematic diagram of the distortion and noise meter, showing the principle of operation, is given in Figure 3.

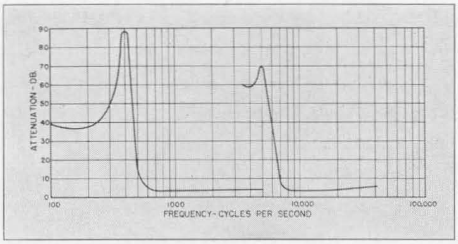
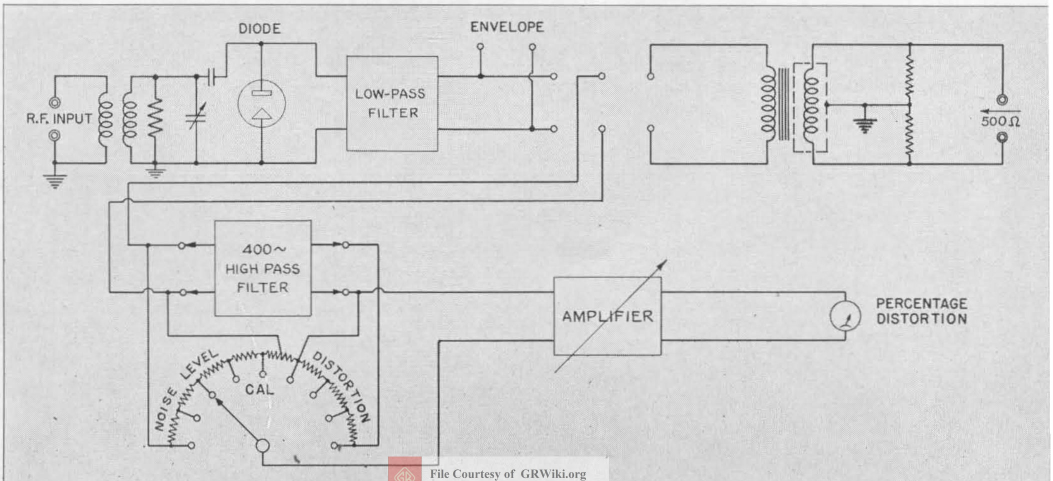


FIGURE 4. Attenuation characteristics of the 400-cycle and 5000-cycle filters. Characteristics of the other filters are similar.

The radio-frequency input system has been redesigned to allow its operation over the wide carrier ranges from 0.5 to 8 megacycles or from 3 to 60 megacycles, depending upon the input coil selected. The input volume control used on the older instrument was a capacitance voltage divider which operates well over the standard broadcast range, but draws excessive power from the transmitter at high and ultra-high carrier frequencies. The new input arrangement is a tuned-circuit system which requires about the same power over the entire range from 0.5 to 60 megacycles. Two sets of coils are used to cover this

FIGURE 3. Schematic circuit diagram of the TYPE 732-B Distortion and Noise Meter. The carrier modulated at the test frequency is applied to the tuned input and is rectified by a linear diode detector. The r-f components are removed by a filter, and the audio-frequency envelope is applied to a filter which removes the fundamental. The harmonic voltage is passed through an attenuator and amplifier to a meter which reads per cent distortion directly. The scales are standardized by applying a known fraction of the audio-frequency voltage to the amplifier and adjusting the gain for full-scale deflection of the meter. This is done at the CAL position of the attenuator. The high-pass filter for 400 cycles is included in the distortion and noise meter. Filters for other frequencies are switched into the circuit externally. For noise measurement, the gain adjustment is made as before with the transmitter modulated. The modulation is then removed from the transmitter and the residual audio (noise) component in the carrier envelope is impressed on the amplifier. The ratio of noise to signal is indicated directly in db on the meter.



range; one set is used for carrier frequencies between 0.5 Mc and 8 Mc; the other set is for frequencies between 3 Mc and 60 Mc. One set is supplied with the instrument.

The test signal for use with the new distortion meter can be supplied by any low-distortion audio oscillator which covers the desired frequency range. A particular advantage of the Type 732-B Distortion and Noise Meter is that the distortion of the oscillator can be measured prior to the measurement of the transmitter and allowance made for it in the result.

The Type 608-A Oscillator* is designed for this use and has the advantage of convenience in operation because of its push-button frequency control. The Type 713-B Beat-Frequency Oscillator is also satisfactory for this use.

To make a complete set of distortion measurements, the input to the instrument is adjusted as in the present unit to a fixed reference level, and readings of distortion are made directly from meter and multiplier as the single control switch of the filter panel is shifted in turn to each of the six test frequencies. The exciting oscillator is, of course, simultaneously adjusted to the same frequencies. The whole test can be made in about a minute and *by personnel who have had very little experience.* The simplicity and speed of the measurement mean that it can be worked into the station's routine as readily as the required daily meter readings.

— Arthur E. Thiessen

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* To be described in the April, 1939, *Experimenter*.

SPECIFICATIONS FOR TYPE 732-B DISTORTION AND NOISE METER

Distortion Range: Distortion is read directly from a large meter. Full-scale values of 30%, 10%, 3%, and 1% are provided, and are selected by a multiplier switch. The range for carrier-noise measurement is from 30 to 70 db below 100% modulation or 65 db below an audio-frequency signal of zero level.

Audio-Frequency Range: 380 to 420 cycles for distortion measurements; 30 to 24,000 cycles for noise or hum measurements. For extending the frequency range, use Type 732-P1 Range-Extension Filters.

Carrier Frequency Range: From 0.5 to 60 megacycles. This range is covered by two coils. A single coil (either for the 0.5- to 8-Mc range or for the 3- to 60-Mc range) is supplied with the instrument unless both coils are specifically ordered. The coils are readily interchanged. (See price list.)

Accuracy: The over-all accuracy of measurement of each distortion range is better than ±5% of full scale ±0.1% distortion.

Vacuum Tubes: One 37, two 6C6, one 1-V, and one 84 are supplied.

Other Accessories Supplied: Spare fuses and pilot lamps. Two dummy plugs to be used if the Type 732-P1 Range-Extension Filters are not connected. One carrier input coil.

Terminals: In addition to the radio-frequency input binding posts at the rear, two normal-through Western Electric output double jacks are provided on the panel, one at high impedance for the modulated envelope from the rectifier, and one at 500 ohms for use in audio-frequency testing.

Power Supply: 115 or 230 volts, 40 to 60 cycles.

Mounting: The instrument is relay-rack mounted. The panel is aluminum with the standard General Radio black-crackle lacquer finish.

Dimensions: Panel, 19 x 8¾ inches; depth behind panel, 12 inches.

Net Weight: 40 pounds.

Type	*Description*	*Code Word*	*Price*
732-B	Equipped for 0.5- to 8-Mc Carrier Range	EXPEL	$245.00
732-B	Equipped for 3- to 60-Mc Carrier Range	EQUAL	245.00
732-P5	Coils for 0.5- to 8-Mc Carrier Range	CULER	10.00
732-P6	Coils for 3- to 60-Mc Carrier Range	CYNIC	10.00

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

SPECIFICATIONS FOR TYPE 732-P1 RANGE-EXTENSION FILTERS

Audio-Frequency Range: 50, 100, 1000, 5000, and 7500 cycles ±5%.

Accuracy: At distortions greater than 0.5%, the error is less than 10% of the true value ±0.15% distortion.

Test Voltage: Type 608-A Oscillator is recommended as a source of test voltage.

Accessories: Two shielded cables are supplied for connecting the Type 732-P1 Range-Extension Filters to a Type 732-B Distortion and Noise Meter.

Mounting: The instrument is relay-rack mounted. The panel is aluminum with standard General Radio black-crackle lacquer finish.

Dimensions: Panel, 19 x 5¼ inches; depth behind panel, 12 inches.

Net Weight: 25 pounds.

Type	*Description*	*Code Word*	*Price*
732-P1	Range-Extension Filters	ESSAY	$150.00

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

MODIFICATION OF TYPE 732-A DISTORTION AND NOISE METERS

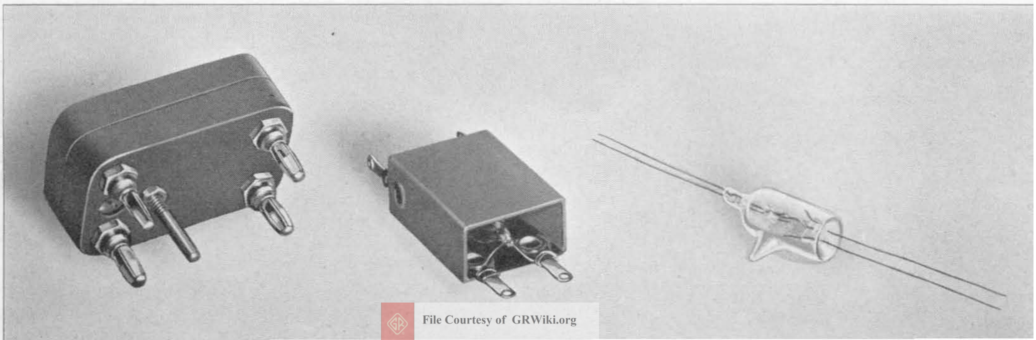
• **TYPE 732-A** Distortion and Noise Meters can be modified for operation with the Type 732-P1 Range-Extension Filters at a price of $60. This does not include the change in the radio-frequency input circuit. The r-f circuit change can be made for $50. The price for both modifications, if made at the same time, is $85. Before returning instruments for modification, write the Service Department for shipping instructions.

NEW TYPE 493 VACUUM THERMOCOUPLES FOR USE AT HIGH FREQUENCIES

• **FOR ACCURATE MEASUREMENTS** of r-m-s values of current at radio frequencies, thermocouples have been universally accepted. Because of the small physical dimensions which can be realized in the construction of thermocouples, residual inductance and capacitance can be limited to very small values. Thermocouples may consequently be used at frequencies considerably higher than those at which more bulky devices become inaccurate.

General Radio Type 493 Vacuum Thermocouples, in the past, have been widely adopted for measurements of currents at frequencies up to the limit of the so-called high frequencies, in the neighborhood of 30 Mc. The contemporary interest in frequencies extending well into the ultra-high-frequency region has created a demand for accurate current measurements which are beyond the capabilities of the older units. In order to meet the exacting requirements

FIGURE 1. (*Left*) Mounted Type 493 Thermocouple; (*center*) unmounted model in shipping case; (*right*) unmounted model.



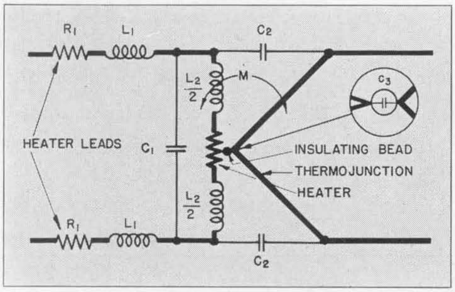


FIGURE 2. Equivalent circuit of the TYPE 493 Thermocouple.

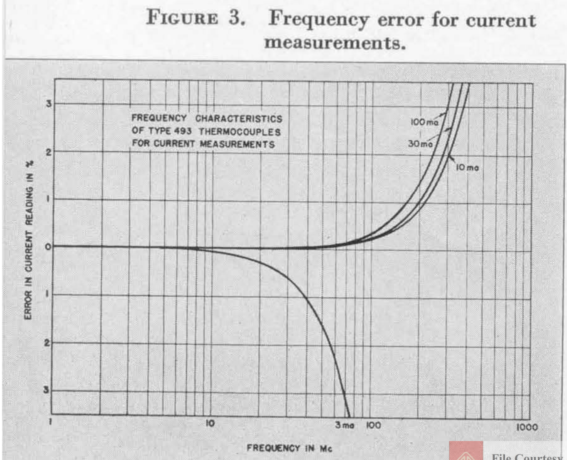
of ultra-high-frequency operation, the TYPE 493 Vacuum Thermocouples have been completely redesigned, and an improved new line is offered to supersede the old.

DESIGN FEATURES

The design of the new TYPE 493 Vacuum Thermocouples is directed especially toward good high-frequency operation. The constructional features which have been adopted to secure this performance are as follows:

(1) The heater and thermo-junction leads are brought out at opposite ends of the glass bulb as shown in Figure 1. The presses are so oriented that the planes in which the leads lie are normal to each other. This method of construction decreases to a minimum both capacitive and mutual inductive coupling between the heater and thermo-junction circuit.

FIGURE 3. Frequency error for current measurements.



(2) The separate-heater type of construction has been adopted for all models since it has proved so superior to the contact type. The advantage to be gained through use of the separate-heater type of construction, in which the thermo-junction is spaced away from the heater wire by a small insulating bead, is that the heater and junction are electrically separated from each other except for a minute capacitance through the bead.

(3) The leads to the heater wire are made as short as possible and are led through only one glass press. The residual inductance and capacitance are thereby reduced to a minimum. The spacing between the lead wires is chosen to effect a compromise between inductance and capacitance. The lead wires may be considered as a transmission line of approximately 280 Ω characteristic impedance.

(4) The heater wires are all made of absolutely non-magnetic materials — platinum, platinum-silver and carbon — in order to avoid the small magnetic effect sometimes exhibited by nickel alloy resistance materials. Skin-effect and inductance are thereby rendered as small as possible.

ERRORS IN THERMOCOUPLE MEASUREMENTS

The high-frequency errors which are found in measurements made with TYPE 493 Vacuum Thermocouples are caused principally by residual parameters. They can arise either because of inductance and capacitance in the heater circuit itself or because of mutual inductance and capacitance between the heater and thermo-junction circuits.

In the TYPE 493 Vacuum Thermocouples the errors caused by residual inductance and capacitance in the heater circuit have been reduced to as small a value as the present design will permit.

If the leads to the heater be clipped to as short a length as possible and the thermocouples used unmounted, best high frequency performance will be obtained. An equivalent circuit which represents the thermocouples to a first approximation under these conditions is shown in Figure 2.

In this diagram R_1 and L_1 are the resistance and inductance of the heater leads; C_1 is the capacitance between the heater leads, mostly concentrated in the glass press; R_2 and L_2 are the resistance and inductance of the heater wire; C_2 is the capacitance between heater and thermo-junction; M is the mutual inductance between heater and thermo-junction circuits; C_3 is the capacitance through the insulating bead.

With a length of 2 cm for the heater leads, typical values of the residual parameters are:

$R_1 = 0.1\ \Omega$ (at 300 Mc)
$L_1 = 0.01$
$C_1 = 0.7\ \mu\mu\text{f}$
$L_2 = 0.007\ \mu\text{h}$
$C_2 = 0.3\ \mu\mu\text{f}$
$M < 0.0003\ \mu\text{h}$
$C_3 < 0.05\ \mu\mu\text{f}$

Frequency characteristics for stock types of thermocouples are shown in Figures 3 and 4. For current measurements the limiting error at high frequencies is largely caused by resonance between L_2 and C_1 in the high-current models and by the shunting effect of C_1 in the lowest current model.[1] For voltage measurements the error at high frequencies is mainly caused by the series impedance of R_1 and L_1 in the high-current models and by series resonance between L_1 and C_1 in the lowest-current model.

Errors caused by mutual inductance and capacitance between the heater and thermo-junction circuits cannot be readily predicted since they depend greatly upon the manner in which the thermocouple is used. Two conditions which can arise when a thermocouple is operated with one side grounded are as follows:

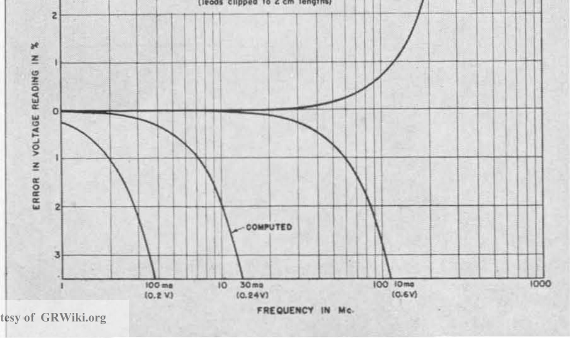
(1) Series resonance through L_1, C_2, and meter leads to ground.

(2) Series resonance around the thermo-junction circuit.

The first of these conditions causes current to be by-passed around the heater so that, as an ammeter, the meter reads low. A compensating effect may occur because of the concomitant heating of the thermo-junction caused by the passage of high-frequency current through it.

The second of these conditions also causes two effects. Mutual inductance between heater and thermo-junction circuits causes circulating current to flow in the thermo-junction circuit. This, in turn, reflects back into the heater circuit a component of resistance which causes the meter, as a voltmeter, to read low. The circulating current in the thermo-junction circuit, on the other hand, heats the junction and causes the meter to read high.

Figure 4. Frequency error for voltage measurements.



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[1] The critical condition for which the frequency characteristic changes from the resonant-rise to the capacitive-shunted type occurs at a resistance value between that of the 10 ma and 30 ma units. The optimum location of this point with respect to a line of resistance values has been discussed in "The Type 663 Resistor," General Radio *Experimenter*, Volume XIII, No. 8, January, 1939.

The order of magnitude of these errors can be deduced from an exaggerated case. At 300 Mc, a mutual inductance of 0.0003 μh has a reactance of 0.6 Ω. With 100 ma flowing in the heater circuit, this induces a voltage of 0.06 volt in the thermo-junction circuit. Suppose the series resistance around the thermo-junction circuit is 20 Ω. For a condition of series resonance, 3 ma flows. This causes a loss of 0.09 mw in the 10 Ω thermo-junction itself compared to a loss of 20 mw in the heater wire. Since the 20 mw loss in the heater is only partly effective in heating the thermo-junction, the loss in the thermo-junction can cause an appreciable error.

Errors caused by coupling between thermo-junction and heater can be detected quite easily by observing the effects of connecting by-pass condensers across the meter leads and from the meter leads to ground. In order to minimize coupling it is recommended that the meter leads be kept as short as is feasible and that the meter and leads be isolated to as great an extent as possible from the r-f fields associated with the heater current, both by judicious spacing and by electro-magnetic shielding.

—D. B. Sinclair

SPECIFICATIONS

Heater Resistance: Heater resistances, at rated current, are adjusted approximately to the nominal values given in the table. The actual value, at rated heater current, is given within 5% for each thermocouple.

Temperature Coefficient: The temperature coefficient of resistance for the heaters is −0.0005 per degree Centigrade for Type 493-L, and +0.004 per degree Centigrade for Types 493-P, -Q, and -R.

Overload Characteristics: All heaters will withstand a continuous overload of 50% of rated heater current, given in table below.

Thermo-junction Resistance: The resistance is adjusted between 10 and 12 ohms for all couples. The actual value, accurate to 0.1 ohm, is given for each thermocouple.

Output Voltage: With rated heater current the open-circuit output voltage is 10 millivolts ±10%.

Thermal Sensitivity: 47 microvolts per °C.

Meter: The Type 588-AM Direct-Current Meter is specifically recommended for use with the Type 493 Thermocouples.

Mounting: The thermocouples are supplied either mounted or unmounted. (See price list.) The letter "M" distinguishes the mounted from the unmounted models. That is, Type 493-L is unmounted, and Type 493-ML is mounted.

The unmounted units are shipped in small rectangular tubes as shown in Figure 1. Lugs are provided so that the tube may be used as a protective mounting.

The mounted models are supplied in yellow bakelite cases with Type 274 Plugs. The Type 274-RJ Mounting Base is recommended for use with the mounted units.

Dimensions: Mounted models, (length) $2\frac{1}{8}$ x (breadth) $1\frac{3}{8}$ x (depth) $\frac{3}{4}$ inches, exclusive of plugs.

Unmounted models: Dimensions of thermocouple, length $1\frac{1}{8}$ inches; diameter $\frac{1}{2}$ inch. Over-all dimensions of packing tube, (length) $2\frac{1}{2}$ x (breadth) 1 x (depth) $\frac{9}{16}$ inches.

Net Weight: 2 ounces, all models.

Type	*Rated Current*	*Heater Resistance at Rated Current*	*Code Word*	*Price*
493-L	3 ma	600 Ω	ESTOP	$10.00
493-P	10 ma	40 Ω	EXCEL	10.00
493-Q	30 ma	8 Ω	EXERT	10.00
493-R	100 ma	2 Ω	EXULT	10.00
493-ML	3 ma	600 Ω	FABLE	12.50
493-MP	10 ma	40 Ω	FACET	12.50
493-MQ	30 ma	8 Ω	FAIRY	12.50
493-MR	100 ma	2 Ω	FATTY	12.50

GENERAL RADIO COMPANY
30 STATE STREET - CAMBRIDGE A, MASSACHUSETTS
BRANCH ENGINEERING OFFICES
90 WEST STREET, NEW YORK CITY
1000 NORTH SEWARD STREET, LOS ANGELES, CALIFORNIA

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also
IN THIS ISSUE

A LOW-DISTORTION OSCILLATOR

• VARIOUS FEEDBACK ARRANGEMENTS have been used to obtain new operating conditions for vacuum-tube circuits. Regeneration, or positive feedback, in which a voltage from the output circuit is fed back to the input in phase with the input voltage, was used to obtain a high degree of sensitivity in most of the early vacuum-tube radio receivers and is used in most ordinary vacuum-tube oscillator circuits. Within the past few years the principle of degeneration, also known as inverse or negative feedback, in which the voltage fed back is opposite in phase to the input voltage, has been applied to vacuum-tube circuits in order to provide wide frequency response and a low order of distortion. Following the original work of Black[1] and others, the application of this principle to communication equipment has resulted in higher-fidelity transmission.

More recently inverse feedback has been applied to the problem of providing sharply selective circuits.[2] A basic selective amplifier cir-

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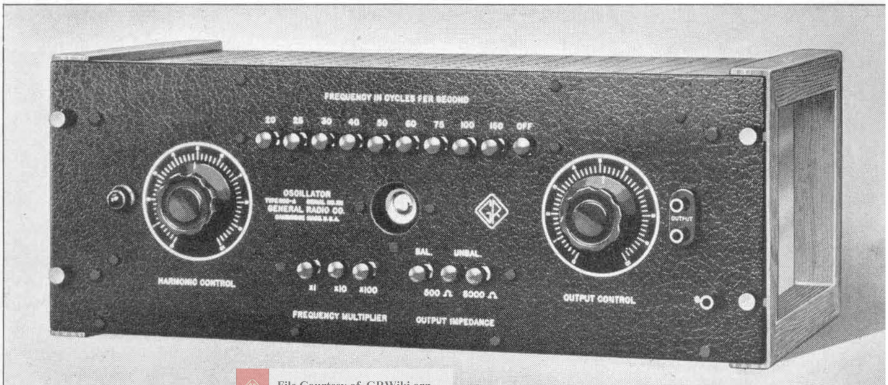
[1] See H. S. Black, "Stabilized Feedback Amplifiers," *Electrical Engineering*, Volume 53, pages 114–120, January, 1934; or *Bell System Technical Journal*, Volume 13, pages 1–18, January, 1934.

[2] See H. H. Scott, "A New Type of Selective Circuit and Some Applications," *The Proceedings of the Institute of Radio Engineers*, Volume 26, No. 2, pages 226–235, February, 1938.

FIGURE 1. Panel view of the TYPE 608-A Oscillator. Both frequency and output impedance are selected by means of push-button switches.



cuit has been developed which can be used either as a wave analyzer or as an oscillator. The use of the selective degeneration principle in the design of a commercial wave analyzer for noise and other purposes has already been described.[3] A basically similar circuit has been used in the development of a new oscillator, which has unusually desirable characteristics, particularly in the low-frequency range.

THE FEEDBACK CIRCUIT

The circuit used in the oscillator includes three separate sections, as shown in Figure 2. The amplifier section represented by *A* has both a substantially flat frequency response and a negligible phase shift over a range extending from below 20 cycles to above 15 kilocycles. Section *B* is the degeneration network, which balances to a sharp null at the oscillation frequency, thus providing full amplifier gain at this frequency and cancellation of the gain at other frequencies. Section *C* represents the regenerative feedback network, which is fed through a phase-reversing vacuum tube *D* in order to provide the proper regenerative action. This circuit is flat in its transmission characteristics and is adjusted to provide just sufficient regeneration to produce self-oscillation in the circuit.

The actual results obtained with the circuit are considerably better, from several viewpoints, than those obtained with more conventional oscillators.

(1) The frequency can be controlled by a relatively inexpensive resistance-capacitance network, smaller and lighter than the usual inductance-capacitance arrangements.

(2) The extremely high selectivity of the combination of the amplifier *A* and the feedback network *B* produces a high degree of stability and suppression of harmonics, as well as of any hum and tube noise which may be developed in the circuits themselves.

(3) The possibility of appreciable distortion occurring in the power output stage is eliminated by taking the inverse feedback voltage directly from the output of that stage so that the net amplification is practically zero for all frequencies other than the oscillation fundamental. Thus, as contrasted with conventional oscillator circuits, the use of a power amplifier stage does not noticeably increase the distortion in the output voltage.

(4) Since the regenerative network has a flat transmission characteristic, it has no appreciable effect upon the oscillation frequency and provides a far better degree of control over the amplitude of oscillation than is possible with most conventional circuits.

THE OSCILLATOR

This new oscillator (TYPE 608-A) covers the range from 20 cycles to 15 kilocycles in 27 steps, the exact frequency being selected by means of two push-button switches. Other frequencies

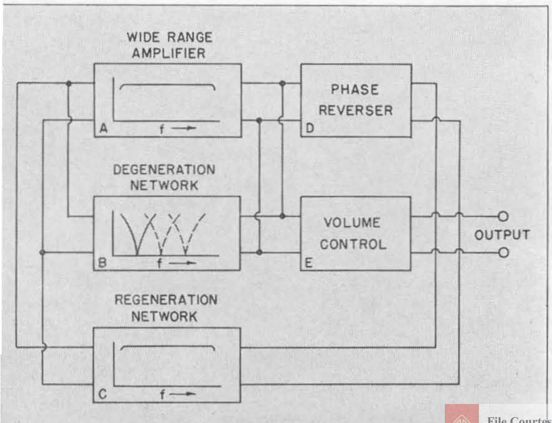


FIGURE 2. Block diagram showing functionally how the TYPE 608-A Oscillator operates.

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[3] See H. H. Scott, "An Analyzer for Noise Measurement," General Radio *Experimenter*, Volume XIII, No. 9, February, 1939.

within this range can be obtained by plugging in three resistances, which may be decade boxes, rheostats, or fixed units. Under normal operating conditions approximately ¼ watt of power can be obtained from the unit with less than 0.1% of distortion, even at 20 cycles. For bridge measurements and other applications, where such a low degree of distortion is not required, the output can be increased to ½ watt.

The unit is provided with a 500-600 ohm output circuit, which may be operated either balanced or unbalanced. This output circuit includes a constant-impedance pad which maintains the correct impedance at all settings of the volume control and reduces the output to approximately 80 milliwatts maximum, which is more suitable for use with the average 500- or 600-ohm line.

USES

The availability of this new oscillator has made possible many measurements which were hitherto impracticable. Because of the low hum level and low distortion, bridge measurements can be made at low frequencies with a higher degree of accuracy than has been possible in the past, and the low-distortion feature allows accurate measurements of harmonic distortion to be made at the lowest audible frequencies. Compared to conventional oscillators of the beat-frequency type, the new unit drifts considerably less with temperature, particularly at low frequencies. This feature is a great convenience in applications where a large number of low-frequency measurements must be made.

One important use of this oscillator is found in radio-broadcasting stations as a test-signal source for distortion measurements with the Type 732-B Distortion and Noise Meter and the Type 732-P1 Range-Extension Filters. The push-button frequency-selector system is rapid in operation and, for this use, is even more convenient than the single-dial control of the usual beat-frequency oscillator. Since the Type 608-A Oscillator supplies frequencies over the entire audio range, it can also be used with the Type 731-A Modulation Monitor to measure the over-all frequency characteristic of the transmitter. For making harmonic analyses, the oscillator can be used in conjunction with the Type 736-A Wave Analyzer, which provides a high degree of selectivity and discrim-

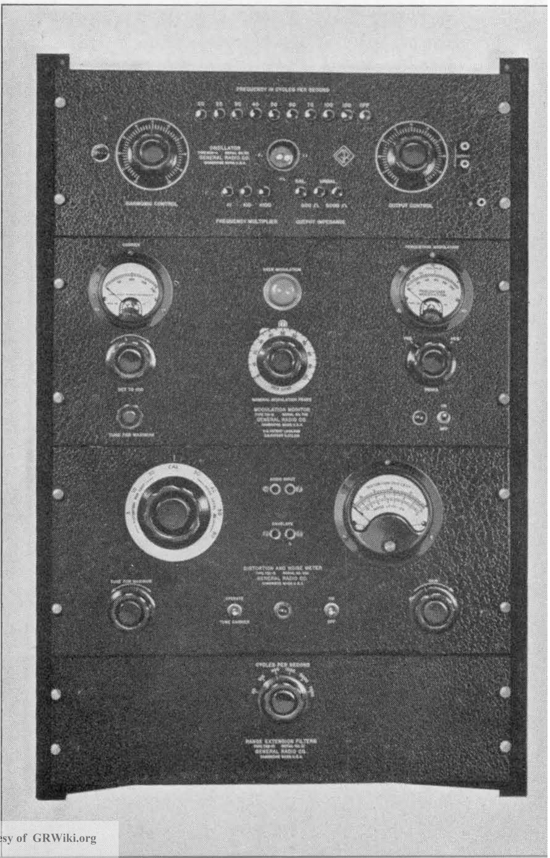


Figure 3. In broadcasting stations, the Type 608-A Oscillator is used as a source of test voltage for distortion measurements and for measurements of over-all frequency response. This photograph shows the oscillator mounted on a relay rack as part of the Class 730 Transmission Monitoring Assembly.

ination, as well as a high order of accuracy.

For bridge measurements it is recommended that the TYPE 608-A Oscillator be used in conjunction with the new TYPE 707-A Cathode-Ray Null Detector (described in this issue of the *Experimenter*), or, as an alternative, with the TYPE 760-A Noise Analyzer used as a detector. Both of these instruments provide a high degree of selectivity and operate also on the inverse-feedback principle. Either of these combinations provides an unusual degree of accuracy in low-frequency bridge measurements.

— H. H. SCOTT

SPECIFICATIONS

Frequency Range: 20 to 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.

Other frequencies within the operating range of the instrument may be obtained by plugging in external resistances.

Frequency Calibration: Each instrument is adjusted within ±2% or 1 cycle, whichever is the greater, of the frequency engraved on the panel.

Frequency Stability: When this oscillator is operated at normal room temperatures, the frequency will not drift by more than 1% over a period of several hours. The harmonic control provides a means whereby the operating conditions of the oscillator may be brought back to the correct values regardless of ordinary changes in load or line voltage.

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. 500-ohm balanced to ground.
2. 500-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 output circuit will vary between 1000 and 8500 ohms, depending upon the setting of the volume control. Suitable resistance pads keep the impedance of the 500-ohm output circuit between 400 and 600 ohms regardless of the volume control setting.

Output Power: The 5000-ohm output circuit provides an output power of approximately 0.5 watt into a matched load when the instrument is operated on a 115-volt line. The maximum power obtainable from the 500-ohm output circuit is approximately 80 milliwatts.

Waveform: With the harmonic control set at maximum and the oscillator delivering its maximum power output, the harmonics will be approximately 5% of the output voltage.

The harmonic control provides a means of obtaining unusually pure waveform at some sacrifice in output voltage. When this control is adjusted to reduce the output voltage by approximately 10%, the total harmonic content will be reduced to approximately 0.2% of the fundamental voltage. A further reduction in the output voltage reduces the total harmonic content to less than 0.1% for all output frequencies on the 5000-ohm output circuit. Because of the impedance-matching transformer, the harmonic distortion on the 500-ohm output terminals is slightly greater at frequencies below 50 cycles.

Hum Level: When the oscillator is properly grounded and operated from a 60-cycle line, the hum level is less than 0.05% or 0.1 millivolt, whichever is the greater.

Mounting: The instrument is designed for either table or relay-rack mounting. The wooden ends supplied with the oscillator are removed when it is used on a relay rack. A perforated metal shield is provided.

Power Supply: 110 to 120 volts, 25 to 60 cycles, ac. A simple change in the connections to the power transformer allows the instrument to be used on 220 to 240 volts. The total power consumption is approximately 60 watts.

Tubes: The following tubes are used: 1 6F5G, 1 6Y6G, 1 6X5G, 1 6E5. A complete set of tubes is supplied with each instrument.

Accessories: A 7-foot connecting cord and spare fuses and pilot bulb are supplied.

Dimensions: (Length) 19½ x (depth) 11½ x (height) 7⅜ inches, over-all. Panel, 19 x 7 inches.

Net Weight: 35 pounds.

Type		*Code Word*	*Price*
608-A	....	ORBIT	$260.00

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

Patent applied for.

A NEW NULL DETECTOR FOR A-C IMPEDANCE BRIDGES

• **THE DETERMINATION** of the resistive and reactive components of an unknown impedance by the use of an impedance bridge requires some form of null detector for indicating when the potential difference between two junctions of the bridge network is zero. The types of null detectors ordinarily used for this purpose are: (1) headphones, (2) tuned vibration galvanometers, (3) a–c galvanometers, and (4) electronic visual indicators such as the electron-ray tube and the cathode-ray oscillograph.

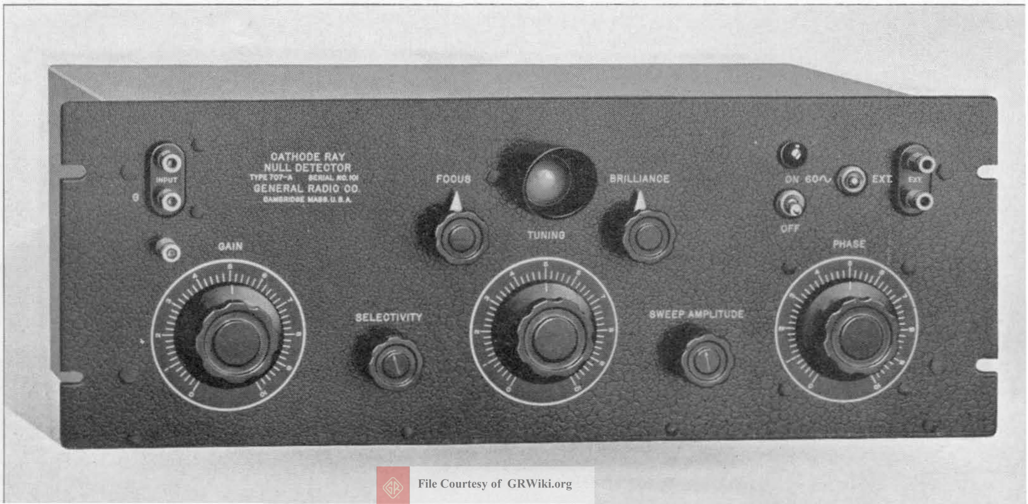
Headphones require a relatively quiet environment, and their use is limited to the audible frequency range. The remaining types, being visual indicators, can be used in a noisy location and can operate at lower and higher frequencies than those for which headphones are satisfactory.

The complete balance of any impedance bridge requires the separate adjustment of two bridge elements; the one to balance the resistive and the other the reactive component of the unknown impedance. The controls must be adjusted to give successively decreasing minima, until a sufficiently precise balance is obtained. The approach to balance usually necessitates also a progressive increase, as a separate adjustment, of the sensitivity of the null detector. While perfectly feasible, this technique is rather troublesome and time-consuming. In order to minimize these difficulties, the General Radio Company has developed the Type 707-A Cathode-Ray Null Detector, which can be used at any frequency up to the upper limit of the audible range (20 kc).

This null detector utilizes the one-inch 913-type cathode-ray tube. The output from the detector terminals of the bridge is amplified and applied to the vertical deflecting plates. A sinusoidal sweeping voltage from the bridge generator is applied to the horizontal plates. When the bridge is completely balanced there is no vertical deflecting voltage, and a horizontal line is seen on the screen (Figure 2a). If the bridge is unbalanced slightly, the pattern becomes an ellipse whose major axis is tilted from the horizontal (Figure 2b). The adjustment of either bridge control will, in general, simultaneously tilt the ellipse and open or close its minor axis.

By varying the phase relation between

FIGURE 1. Panel view of the TYPE 707-A Cathode-Ray Null Indicator.



the sweeping voltage and the terminal voltage of the generator, the phase of the sweeping voltage with respect to the output voltage of the bridge can be controlled. When the proper phase relation is obtained, the adjustment of the reactive balance control will merely tilt the ellipse without opening or closing it, and the resistive balance control will open or close the ellipse without tilting it. If the phase of the sweeping voltage is shifted by 90°, the resistive balance control will tilt the ellipse while the reactive balance control will open and close it.

The effect of adjusting either bridge control can be observed separately, and one can avoid the settings to successive minima that are necessary with any null detector which does not separate the two components of the detector voltage. Separation of the indications of resistive and reactive balance is especially helpful in balancing those types of bridge which have a "sliding zero," and in measuring non-linear impedances such as iron-core inductors. It is possible to make a precise balance of either the reactive or the resistive bridge balance control with only a moderately precise setting of the other control. If either the resistive or the reactive component of the unknown impedance is varying erratically, a precise measurement of the steady component can still be made. Furthermore, without disturbing the bridge controls, it is possible to observe which component of the unknown impedance may be drifting progressively with time.

It is evident that merely noting whether the tilt is up-to-the-right or down-to-the-right gives a definite indication of the direction off balance. The other control, which opens or closes the ellipse, gives no indication of direction. If desired, the angle of tilt and the length of the minor axis may each be calibrated to indicate the degree of unbalance in order to establish tolerance limits for both the resistive and the reactive components of the unknown impedance.

After the correct phase relationship between the sweeping voltage and the terminal voltage of the generator has been established, the technique for using the null detector consists of setting one bridge control to make the ellipse horizontal (see Figure 2c), and then adjusting the other bridge control to close the ellipse into a straight line (Figure 2a).

With the bridge far off balance, and the detector at maximum sensitivity, a distorted ellipse will appear on the screen. Then, as the reactive bridge control is changed, a sudden, pronounced, and easily detected shift in the shape of the distorted ellipse will occur when the control passes through its approximately correct position. Thereafter, the balancing of the bridge, even with maximum sensitivity, is easily accomplished. Comparable operation of other types of null detectors is usually impossible because, with full sensitivity, the initial balance of one component cannot be detected.

The Type 707-A Null Detector has the advantage, common to all electronic devices, of being instantaneous in its response. This feature permits one to disregard transients which are introduced into the bridge or detector circuit

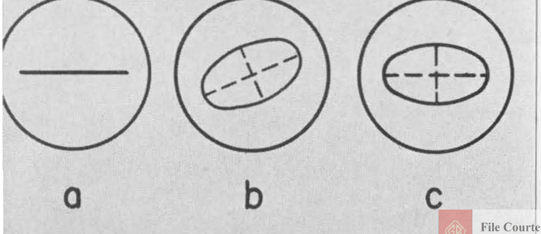


Figure 2. Diagram showing the screen patterns for balance and out-of-balance conditions. Pattern *a* is seen when the bridge is perfectly balanced.

and which cause considerable annoyance and confusion when a more sluggish indicator such as a meter is used. Another advantage of this null detector is its ability to withstand, without injury, any degree of overloading such as might be caused by a pronounced lack of balance of the bridge circuit.

For shifting the phase of the sweeping voltage, the Type 707-A Null Detector includes a bridge network[1, 2] consisting of two capacitive and two resistive arms, the latter being simultaneously adjustable by a single control knob to permit a total phase shift of nearly 180° with essentially constant amplitude of sweeping voltage.

Most impedance bridges, when balanced for the fundamental frequency of the applied voltage, are not balanced for the harmonics. Consequently, a considerable degree of frequency discrimination is desirable for all types of null detectors. One way of obtaining the desired selectivity is by using tuned filters in the amplifier circuit. Inductance elements, however, are exceedingly susceptible to electromagnetic pickup from stray fields, particularly at commercial power frequencies.

In the Type 707-A Null Detector this difficulty is avoided by the use of a non-inductive degenerative form of amplifier, which was proposed by H. H. Scott and is referred to elsewhere in this issue of the *Experimenter*. A functional diagram of the system is shown in Figure 3. The amplifier system has an input impedance of 1 megohm, a gain of 80 decibels, and a selectivity of 40 decibels against the second harmonic. The minimum observable deflection then occurs at 60 cycles, at about 100 microvolts r-m-s. At higher frequencies the sensitivity falls somewhat, being about 200-300 microvolts at 1000 cycles.

The tuning control permits a variation of ±5% about a mean frequency which is determined by a plug-in unit designed for a specified nominal frequency. For low frequencies another plug-in unit is required for the phase shifting network. These plug-in units should be ordered to meet the contemplated uses of the instrument; see specifications on page 8.

Many other uses of this device will doubtless occur to the reader. For example, it can be used as a cathode-ray oscillograph for comparing frequencies by means of Lissajous figures. The verti-

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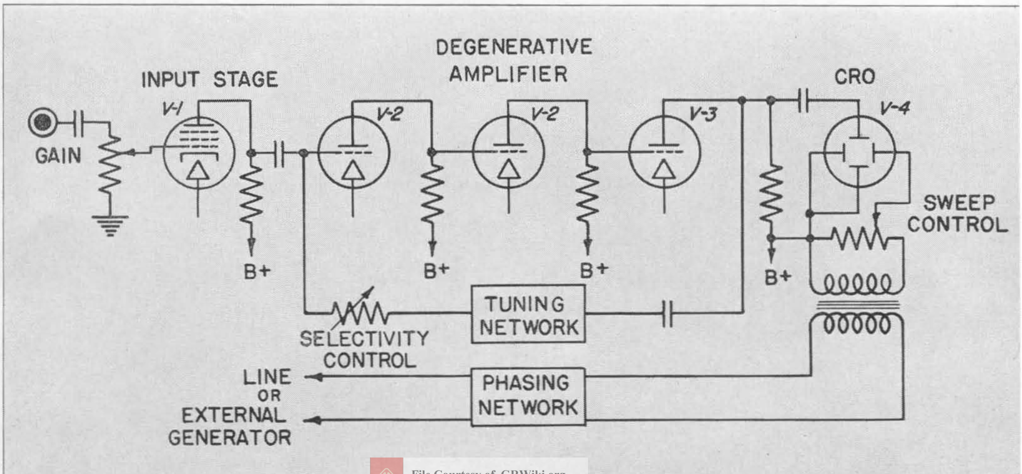
[1] Horatio W. Lamson, "An Electronic Null Detector for Impedance Bridges," *The Review of Scientific Instruments*, Vol. 9, No. 9, September, 1938.

[2] H. M. Turner and F. T. McNamara, "An Electron Tube Wattmeter and Voltmeter and a Phase Shifting Bridge," *Proc. I. R. E.*, 18, 1743 (1930).

Figure 3. Schematic circuit diagram of Type 707-A Cathode-Ray Null Indicator.



cal deflection can be calibrated for a rough measurement of small a-c potentials, hum levels, harmonic components of voltages or currents, etc.

— Horatio W. Lamson

SPECIFICATIONS

Input Impedance: One megohm.

Sensitivity: 100 μv at 60 cycles; 200 to 300 μv at 1000 cycles.

Selectivity: 40 decibels against second harmonic.

Frequency Range: Plug-in units tune the amplifier for any desired operating frequency between 20 and 2000 cycles. Continuous tuning range ±5% for each unit.

Controls: Panel controls are provided for adjusting the focus and brilliance of the cathode-ray pattern, the phase and amplitude of the horizontal sweeping voltage, and the gain, selectivity, and tuning of the amplifier.

Accessories Supplied: One power cord and one shielded input cord.

Accessories Required: One plug-in phasing circuit is used at any frequency below 400 cycles; one plug-in tuning unit. These are not included in the price of the instrument.

Power Supply: 115 volts, 40 to 60 cycles.

Power Input: 20 watts at 60 cycles.

Vacuum Tubes: One 6K7G pentode, one 6F8G twin triode, one 6J5G triode, one 913 cathode-ray tube, and one 6X5 rectifier; all are supplied with the instrument.

Mounting: Standard 19-inch relay-rack panel.

Dimensions: Panel, 19 x 7 inches; depth behind panel, 9 inches.

Net Weight: 30½ pounds.

Type		*Code Word*	*Price*
707-A	....	NULTY	**$195.00**

This instrument is manufactured and sold under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

Patent applied for.

PLUG-IN UNITS FOR TYPE 707-A CATHODE-RAY NULL DETECTOR

These units are required for use with Type 707-A Cathode-Ray Null Detector and are not included in the price of that instrument.

A phasing unit is necessary for operation at any frequency *below* 400 cycles. At 400 cycles and above, none is required. A tuning unit is required for each operating frequency. The tuning range is ±5 per cent.

All units plug into mounting jacks provided inside the null detector.

PHASING UNITS

Type	*Description*	*Code Word*	*Price*
707-P1	**For Frequencies below 100 Cycles**........	NULLTECANT	**$7.00**
707-P2	**For Frequencies between 100 and 400 Cycles**..................................	NULLTECBOY	**7.00**

AMPLIFIER TUNING UNITS

Type	*Frequency*	*Code Word*	*Price*
707-P42	**42 cycles**	NULLTECCAT	**$25.00**
707-P50	**50 cycles**	NULLTECDOG	**25.00**
707-P60	**60 cycles**	NULLTECEYE	**25.00**
707-P400	**400 cycles**	NULLTECFIG	**25.00**
707-P1000	**1000 cycles**	NULLTECGUM	**25.00**
707-P2000	**2000 cycles**	NULLTECHIM	**25.00**

Units designed for use at any other frequency can be supplied on order.

GENERAL RADIO COMPANY
30 STATE STREET - CAMBRIDGE A, MASSACHUSETTS
BRANCH ENGINEERING OFFICES
90 WEST STREET, NEW YORK CITY
1000 NORTH SEWARD STREET, LOS ANGELES, CALIFORNIA

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THE General Radio EXPERIMENTER

VOLUME XIII NO. 12 MAY, 1939

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

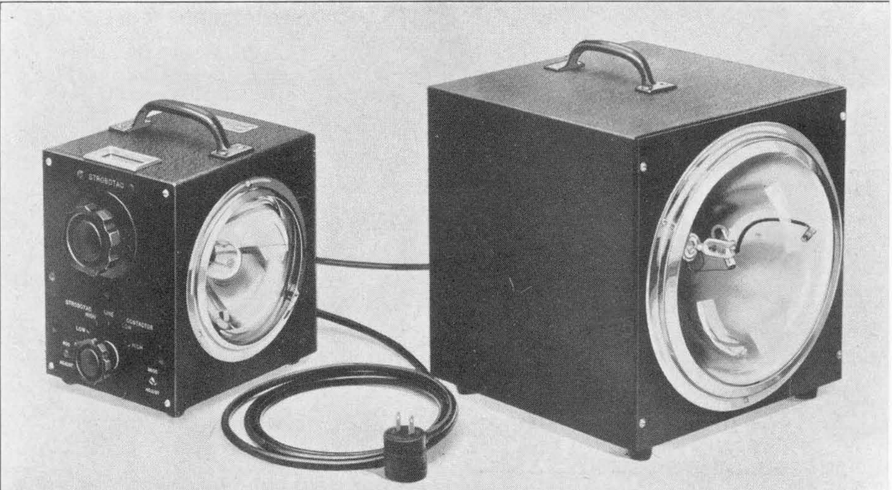
Also IN THIS ISSUE

TWO NEW INDUSTRIAL STROBOSCOPES

● THE EDITOR OF A WELL-KNOWN industrial magazine remarked, not long ago, that the stroboscope held more promise for future usefulness to industry than any other instrument in the mechanical field. This opinion is well borne out by the multiplicity of uses to which General Radio stroboscopes have been applied. Manufacturers of such diverse products as streamlined trains and tin cans use stroboscopes to make better products and to lower production costs.

The two new General Radio stroboscopes will undoubtedly develop still more applications. These new instruments, TYPE 631-B Strobotac and TYPE 648-A Strobolux, embody a number of improvements in both design and construction over previous models.

FIGURE 1. The Strobotac (left) and the Strobolux (right) with connecting cables.



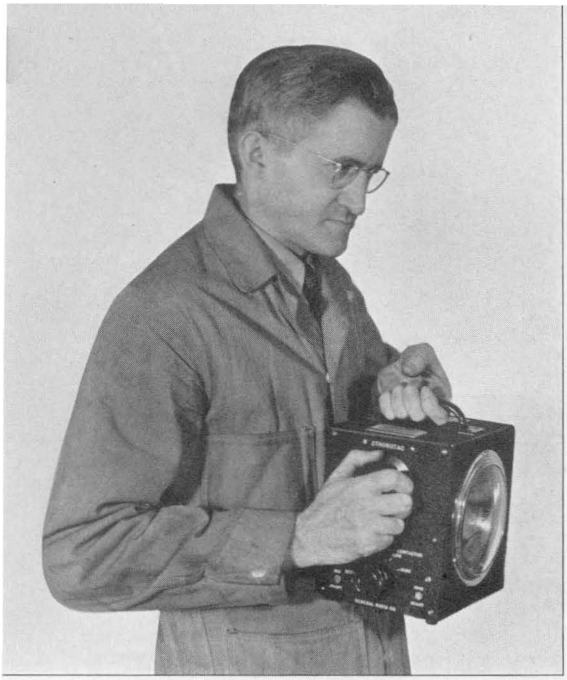


FIGURE 2. The controls and the scale of the Strobotac are arranged for maximum convenience. When the instrument is held in the left hand, as shown, the right hand is used to adjust the speed, which is read directly from the scale on the top of the case.

STROBOTAC

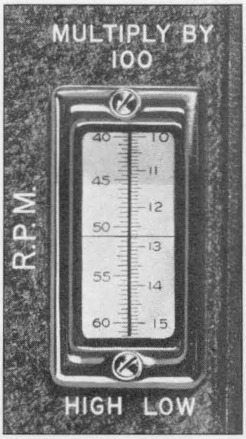
The Strobotac, TYPE 631-B, is basically the same as its predecessor, TYPE 631-A*, but improved performance and greatly increased convenience of operation make it a much better instrument. Greater accuracy of speed measurement, lighter weight, more easily read scale, more convenient location of controls — these are the features of the new instrument.

The unique scale standardization system used with the Strobotac and the increased oscillator stability in the new design make possible an accuracy of ±1% for speed measurements. This accuracy is obtainable when the Strobotac is standardized in terms of a frequency-controlled power line, i.e., one on which synchronous electric clocks can be operated. The standardization adjustment is explained in Figure 4.

Although the accuracy specification of 1% brings the Strobotac into the class of precise tachometers, still better accuracy, often as good as 0.1%, can be obtained over small scale intervals, by standardizing the scale at two points in the range where speed measurements are to be made. The trimmers, or scale adjustment controls, are accessible from the side of the instrument.

The speed scale covers the same range as that of the old model, 600 to 14,400 rpm. Two ranges are provided, one of which is approximately four times the other. The drum-type scale, shown in Figure 3, is conveniently located on the top of the instrument. Scale graduations are in black on a translucent material, behind which a lamp is mounted. The flashing speed controls are located on the side of the case and are so arranged that, when the instrument is held in the left hand, the speed can be controlled by the right hand, and speed can be read from the top.

FIGURE 3. The scale of the Strobotac is graduated in revolutions per minute for speed measurement. The total range of 600 to 14,400 rpm is covered in two bands. The lower band extends from 600 to 3600 rpm, the upper from 2400 to 14,400 rpm. The scale can be read to better than 0.5% over most of its range.



Although the over-all size of the Strobotac has not been changed, the weight has been decreased by 25%. The total weight is now but 10 pounds.

---

* "A New Stroboscope for Speed Measurements," *Experimenter*, August, 1935.

The Strobotac is provided with a jack for connection to the Strobolux, described below.

STROBOLUX

The new Type 648-A Strobolux supersedes the Type 548-B Edgerton Stroboscope. It consists of an a-c power supply and lamp, capable of supplying about 100 times as much illumination as the Strobotac. No means for controlling the flashing rate is provided in the Strobolux. Flashing impulses are obtained from the Strobotac*, and hence the flash control may be (1) the Strobotac oscillator, (2) the a-c power line, or (3) an external oscillator or contactor.

The Strobolux is intended for use in those applications where large areas must be illuminated, or where strong background lighting exists. Its upper speed limit is somewhat less than that of the Strobotac and is about 6000 flashes per minute.

A particularly important application of the Strobolux is in taking high-speed single-flash photographs. With large-aperture lenses and the new high-speed films, excellent pictures of areas of about one square foot are possible. Events in transient or non-repetitive motion can be recorded in this way as easily as can those in cylic motion.

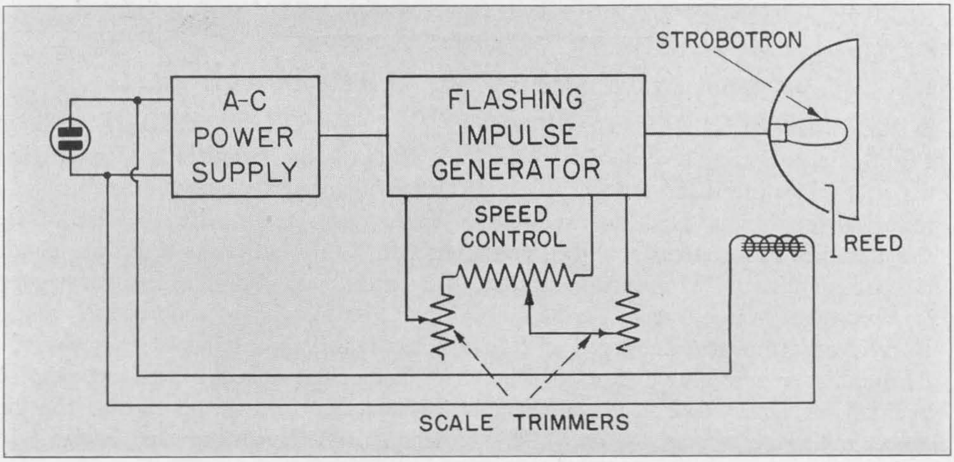
— C. E. W.

---

* The older Type 631-A Strobotac can be used to flash the Strobolux if a jack for making the connection is installed. This installation will be made without charge if a Strobolux is purchased.

Figure 4. Showing the operation of the standardizing system. The reed is driven electromagnetically from the a-c line, and it vibrates at a frequency of 7200 per minute when the line frequency is 60 cycles. When the flashing rate of the Strobotron is equal to, or a submultiple of, the reed frequency, a single stationary image of the reed will be seen. The procedure in standardizing is to set the speed control at a submultiple of 7200 at the low end of the scale and adjust the LOW trimmer until a stationary reed image is seen, then to set the scale to a submultiple at the high end, adjust the HIGH trimmer for a stationary pattern. The speeds used are 900 and 3600 on the low scale, 3600 and 14,400 on the high scale. At 14,400 a double image will be seen because the lamp flashes twice for each vibration of the reed.

A stationary pattern of one or more images can be obtained at any scale setting where the ratio of flash speed and reed speed is an integer or an integral fraction. If only one- and two-image patterns are used, twenty-one such points will be found on the low scale alone. Consequently, for any given small speed range, a standardizing point can usually be found at each end of the range. This results in an extremely high accuracy of measurement over small ranges.



TYPE 631-B STROBOTAC

SPECIFICATIONS

Range: The fundamental range of flashing speed is from 600 to 14,400 per minute. The speed is read directly from a scale graduated in rpm. By using multiples of the flashing speed, the range of measurement can be extended above 50,000 rpm and, by multiple images, speeds somewhat below 600 rpm can be measured. At very low speeds, a darkened room should be used.

Accuracy: ±1% of the dial reading above 900 rpm when the Strobotac is standardized in terms of a frequency-controlled power line. Controls for this standardization adjustment are provided.

Duration of Flash: Between 5 and 10 microseconds.

Power Supply: 115 volts, 60 cycles. Prices for operation from lines of other voltages and frequencies will be quoted on request.

Power Input: 25 watts.

Vacuum Tubes: One Type 631-P1 Strobotron, one 6X5-type and one 6N7-type are required. A complete set of tubes is furnished with the instrument.

Mounting: Aluminum case with carrying handle. Cord and plug for connection to the power line are included.

Dimensions: 7½ x 8¾ x 9⅞ inches, over-all.

Net Weight: 10 pounds.

Type		*Code Word*	*Price*
631-B	....	BRAVO	$95.00

TYPE 648-A STROBOLUX

SPECIFICATIONS

Range: Up to 100 flashes per second (6000 per minute). Single flashes for photography can also be obtained.

Accuracy: The accuracy is that of the source controlling the flashing speed. See specifications for Type 631-B Strobotac.

Duration of Flash: 10 to 15 microseconds.

Power Supply: 115 volts, 60 cycles.

Power Input: 150 watts, maximum.

Vacuum Tube: One 5Z3-type vacuum tube and one 648-P1 lamp are required. Both are supplied with the instrument.

Accessories Required: Must be used with Type 631-B Strobotac.

Mounting: The complete assembly is housed in a sheet metal case. The detachable lamp and its 9-inch reflector are mounted on one side, the power supply on the other. Cables for connection to the power line and to the Strobotac are supplied.

Dimensions: 13 x 11⅛ x 13⅛ inches, over-all.

Net Weight: 25 pounds.

Type		*Code Word*	*Price*
648-A	....	SCALY	$175.00

General Radio stroboscopes are manufactured under designs and patent applications of Harold E. Edgerton, Kenneth J. Germeshausen and Herbert E. Grier.

OPERATION OF THE VARIAC IN OIL

● **USERS IN THE CHEMICAL INDUSTRIES** have found it desirable to immerse Variacs in oil for the purposes of reducing explosion hazards, reducing maintenance requirements, and increasing power ratings. Oil immersion, in fact, is advantageous wherever a Variac must work in an atmosphere charged with inflammable or corrosive gases, or whenever it is necessary to exceed the normal power rating.

EXPLOSION PROOFING

Under some conditions of operation, sparking occurs when the brushes of a Variac pass from wire to wire of the winding. The oil tends to reduce sparking and, by excluding inflammable gases from the vicinity of the brushes, makes harmless any sparks which may occur.

Obviously, for the greatest possible safety, the oil level should be checked frequently. Mounting the Variac with the brush end at the bottom of the oil tank insures that the brushes will remain covered unless the oil level becomes excessively low.

It should be pointed out that oil immersion does not remove all possibility of explosion. Ordinary transformer oils evaporate slowly, and their vapors can be ignited by external causes. Since the flash point of transformer oils is about 130° C. (240° F.), there is no chance of spontaneous ignition except in cases of prolonged, very high overloads.

Fireproof oils are available, but must not be used with Variacs because they destroy the insulation of the windings.

REDUCED MAINTENANCE

When a Variac is used in an atmosphere of corrosive gases or is subject to spattering with corrosive liquids, the oil protects it, prolongs its life, and reduces the amount of servicing required. Even in ordinary uses the oil serves as a lubricant and keeps the winding bright and smooth with less cleaning than would otherwise be needed. The reduced sparking under heavy loads prolongs the life of the brushes.

INCREASED RATING

The maximum safe current which can be drawn from a Variac is, in general, limited by the rate at which heat can be carried away from the brushes. Surrounding the Variac with oil greatly increases the rate of cooling of the brushes and permits a corresponding increase in the maximum current. The oil also increases the cooling of the Variac as a whole and makes possible a moderate increase in the rated current.

The advantages of oil cooling are most striking in the case of the Type 100 Variacs where the brush limitation is greatest.

EXAMPLE

The following table gives an approximate idea of the effect of oil cooling, for the case of a Type 100-Q* Variac. The Variac was mounted in a cylindrical steel tank, 9 inches in diameter and 10 inches deep, and the brush end was about ⅛ inch from the bottom of the tank. Somewhat less than two gallons of oil were required to fill the tank 9 inches deep. Space must be allowed for expansion of the oil as it warms up.

	100-Q Variac in Air	*100-Q† Variac in Oil*
Rated Current	18 amp.	22 amp.
Maximum Current	18 amp.	35 amp.
Rated Power	2000 v. a.	4000 v. a.

Similar, though less striking, increases in safe power output can be expected with other types. The addition of water cooling by means of a cooling coil in the oil as close as possible around the Variac will of course permit further increases in power rating.

If the Type 100-K or Type 100-L Variac is used in oil, the brushes and brush springs must be replaced by those now used in the Type 100-Q and Type 100-R Variacs. The new brushes have flexible leads for connection to the radiator. Without these flexible leads the oil makes the connection between brushes and radiator uncertain and excessive heating may result, nullifying the advantages of the oil coating.

REPLACEMENTS

	Type 100-K	*Type 100-L*
Brushes	2—type 100-321	2—type 100-322
Brush Springs	1—type 100-345A 1—type 100-345B	1—type 100-345A 1—type 100-345B

— Stephen A. Buckingham

---

*Type 100-Q and Type 100-R Variacs are new models replacing Type 100-K and Type 100-L. The new models have approximately the same ratings as the old, but furnish output voltages greater than the input line voltage.

† Comparable results can be obtained with Type 100-K.

CHECKING ANTENNA POWER WITH THE TYPE 726-A VACUUM-TUBE VOLTMETER

● **POWER, AT RADIO FREQUENCIES,** is ordinarily computed from measured currents and resistances because no generally accepted method of direct measurement has yet been discovered. Unfortunately, the indirectness of the method makes it necessary to measure current and resistance with much greater accuracy than that required in the value of power because the errors may accumulate in the computation. Even if the current and resistance are both measured to an accuracy of ±1%, for instance, the computed power may be in error by as much as 3%.

Considerable stress has been laid upon improving the technique of making antenna resistance measurements at broadcast frequencies in recent years, and methods and circuits have been developed that are rapid and reliable. Current measurements have not received as much detailed attention, probably because they are, in general, much more easily made than impedance measurements, and because the specified accuracy of the meters themselves is usually high. Errors in the current measurements, however, enter twice into the computed power since the current enters as the square. In order to take full advantage of the accuracy of resistance measurement that can be obtained, it has consequently been found desirable in the field to be able to obtain an accurate check on the antenna current.

Experience in the measurement of antenna impedance has emphasized the desirability of using two or more dissimilar methods, when possible, to eliminate the chance of neglecting some significant error specifically associated with one of the methods. The measurement of current with two different types of instruments is desirable for the same reason.

With capacitive shunts, the TYPE 726-A Vacuum-Tube Voltmeter can be used as an ammeter that requires relatively little power[1]. The antenna ammeter can be checked against the shunted voltmeter as shown in Figure 1.

This method is particularly useful, first, because the voltmeter-condenser combination is small and can be connected in circuit at the point where the antenna impedance is measured and, second, because the check can be made at the operating frequency.

The principal reasons for lower accuracy in the ammeter than in the voltmeter-condenser combination are that skin effect in the heater of thermocouple meters designed for relatively large currents is often appreciable, and that shunting capacitances in the wiring

---

[1] "The TYPE 726-A Vacuum-Tube Voltmeter as a Radio-Frequency Ammeter," General Radio *Experimenter*, Volume XIII, Nos. 3 and 4, August-September, 1938.

between the meter and the point at which the antenna impedance is measured often by-pass current, which is read by the meter but which does not enter the antenna[2]. The capacitance of the voltmeter-condenser combination, on the other hand, can be measured at the operating frequency with the equipment used to measure the antenna impedance, and the frequency error of the voltmeter is completely negligible at broadcast frequencies.

It should be recognized that the condenser of Figure 1 must carry the total current without overheating. Its capacitance is determined from the maximum reading, I_{max}, of the antenna ammeter, the maximum voltage reading, V_{max}, of the TYPE 726-A Vacuum-Tube Voltmeter, and the frequency by the expression

$$C = \frac{1}{\omega} \frac{I_{max}}{V_{max}}$$

For a 5-kw station, using a shunt-excited antenna with a 65 Ω resistive component, at a frequency of 1000 kc, for instance, a suitable value of C would be 0.01 μf.

—D. B. SINCLAIR

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[2] The shunting capacitance is particularly important if an extension meter is used with a shielded lead from the thermocouple. It should be emphasized that the shield should be connected to the transmitter side of the thermocouple rather than to ground or to the antenna side of the thermocouple in order to minimize the error.

TOWARD A SILENT SUBWAY

● **THE OTHER DAY** in New York City's Eighth Avenue Subway, crowds of harassed commuters, battling for seats, were thwarted by the closed doors of a car marked "No Passengers." Inside was a group of engineers who had installed the most up to date of testing instruments in preparation for a trial express run between 59th and 125th Streets. When the train got under way, Mr. V. A. Schlenker, New York acoustical engineer, concentrated on the fluttering stylus of a recorder operating from a General Radio Sound-Level Meter. The results of this test run were of critical importance both to the subway and to the Firestone Rubber Company, for on one mile of track between 81st and 99th Streets, Central Park West, Firestone had made a trial installation of rubber tie plates, designed to reduce the noise and vibration of the trains and prevent undue transmission through the subway foundations to adjacent buildings.

These tie plates are hard rubber pads, about five inches square and one inch deep, assembled in a steel harnessing jacket and installed under the track at each tie. Should they absorb enough vibration, the pads would prolong the life of the trucks and the rails. Buildings adjacent to the subway, often receivers of transmitted vibration, would also benefit from the installation, and, more important from the commuter's point of view, the clatter, din, and sidesway of the cars would be diminished, to the great relief of the underground New Yorker's nervous system.

At fifty miles an hour, top speed, the northbound express roared up the trial run, and Mr. Schlenker noted on the sound-level record the beginning and the end of the treated mile marked off by flares of lights placed beside the track. Afterward, the sound-level record was checked accurately with the graphs of speed and acceleration. The corrected record showed that the noise in the car was less on the rubber-studded mile. Later measurements with the sound-level meter in a west side hotel, whose foundations abut the subway opposite the installation, showed a noise reduction of twelve decibels. This represents a reduction of the subway sound in the hotel to one-quarter its former level.

The results obtained using a vibration pickup with the sound-level meter were even more revealing. The rubber installation was responsible for a three-decibel decrease in floor vibration in a car racing ahead at fifty miles an hour, and in the steel columns supporting the northbound track there was a seven-decibel reduction. In the hotel, again, the meter registered eleven decibels of vibration improvement.

In New York's current enthusiastic campaign for lessening the city tension by eliminating unnecessary noise, the test mile along Central Park West is a forward stride. The Type 759-A Sound-Level Meter was the technical witness in the trial of the new development.

MISCELLANY

● **COLLABORATING IN THE DESIGN** of the new Strobotac and Strobolux were H. E. Edgerton, K. J. Germeshausen, and H. E. Grier of Massachusetts Institute of Technology and H. S. Wilkins of the General Radio engineering staff.

● **IN A FORTHCOMING ISSUE** of the *Experimenter*, Dr. S. A. Buckingham will describe several new Variacs, including the Types 100-Q and 100-R mentioned in his article in this issue.

● **AMONG RECENT VISITORS** to the General Radio plant were Eugenio Fubini-Ghiron and Paolo Pontecorvo of the Instituto Elettrotecnico Nazionale Galileo Ferraris at Turin, Italy, and Stuart L. Bailey and Ronald H. Culver of Jansky and Bailey, Washington, D. C.

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VOLUME XIV NO. 1 JUNE, 1939

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

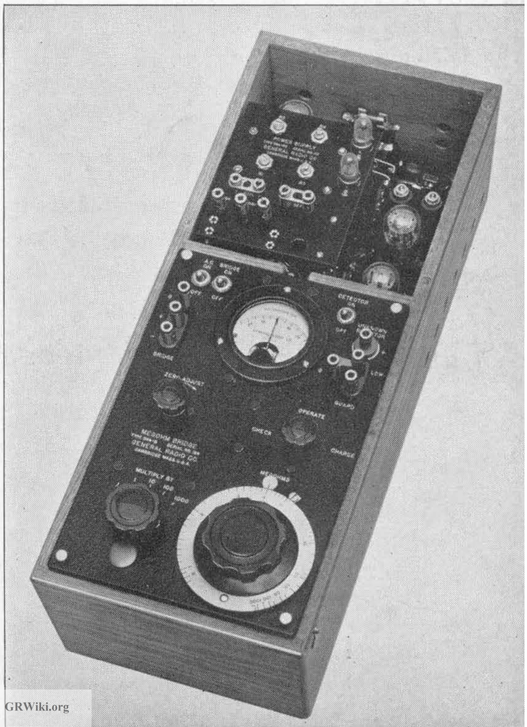
A 500-VOLT MEGOHM BRIDGE

● **THE TYPE 544-B MEGOHM BRIDGE** with a 90-volt power supply operated either from the 60-cycle supply or from batteries was introduced less than two years ago* and has been widely used for the measurement of insulation resistance. This bridge uses a vacuum-tube voltmeter as a detector of balance, which permits the measurement of resistances much higher than the limit of a few megohms imposed by the low resistance of a wall galvanometer. While the bridge is designed so that 500 volts may be applied to it, this higher voltage has seldom been used because of the bulkiness of the necessary batteries. The Type 544-P3 500-volt Power Supply now available allows the full possibilities of the bridge to be realized.

VOLTAGE COEFFICIENT OF RESISTANCE

The need for the higher voltage on the bridge comes not from a lack of sensitivity, but from the fact that insulation resistance has a

Figure 1. The Type 544-B Megohm Bridge with cover removed to show the Type 544-P3 Power Supply.



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*General Radio *Experimenter*, July, 1937.

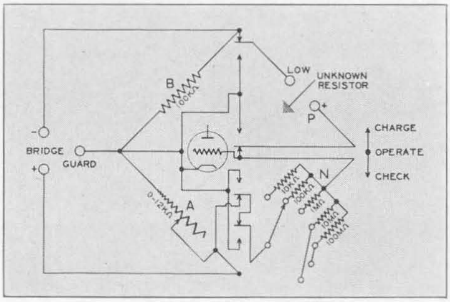

FIGURE 2. Schematic circuit diagram of the TYPE 544-B Megohm Bridge.

huge voltage coefficient. It is not at all unusual for this resistance to decrease by a factor of two or even three when the voltage is increased from 100 to 500 volts. The magnitude of this change in resistance varies with the type of insulation and also with temperature, humidity, and time. No single multiplying factor exists by which resistance at one voltage can be converted to resistance at some other voltage. It is, therefore, desirable that all insulation resistance measurements be made at the same voltage to facilitate the intercomparison of results. A value of 500 volts has been widely adopted as standard.

DIELECTRIC ABSORPTION

It has long been recognized that the apparent insulation resistance of an electric machine or cable rapidly increases after the application of voltage. In spite of this fact it became standard practice to take the value of resistance at the end of one minute and to disregard the further increase. While this method is reasonably satisfactory for the poorer types of insulation, it fails entirely for the better grades, particularly those that are laminated, like the pasted mica used in high-voltage generators. The time needed to attain equilibrium is measured in hours and even days.

This phenomenon has been referred to as dielectric absorption or volume charge. An extra charge of electricity, other than that associated with the normal capacitance of the insulation, appears to be stored throughout the volume of the material. This is now better described as interfacial polarization.* A building up of charge occurs at every interface between the different materials of a heterogeneous insulation. While the effect is most pronounced in a laminar structure, it also occurs in materials whose component parts are finely divided and thoroughly mixed. The smallest particles are still molecular aggregates which present interfaces to each other. The total charge stored throughout the volume of the dielectric may be many times that of the con-

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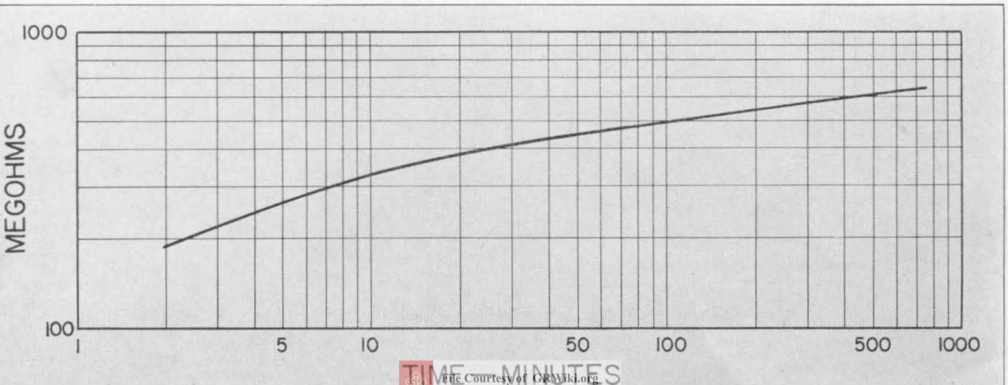
*Murphy & Morgan, "The Dielectric Properties of Insulating Materials," *Bell System Technical Journal*, October, 1937.

FIGURE 3. Plot of insulation resistance vs. time for a 23,750 kva generator.



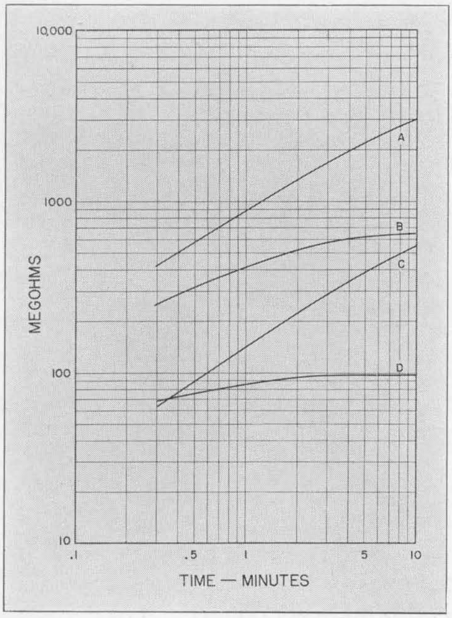


FIGURE 4. Plots of insulation resistance for four generators having the same type of insulation, but differing in voltage, age, and physical condition.

denser formed by the external electrodes, and the larger part of this charge can be recovered on discharge.

Under these conditions the apparent resistance for one minute electrification bears no relation to true insulation resistance, but merely measures the current due to volume charge at that instant. The value of the true insulation resistance can be estimated by observing the resistance at increasing time intervals and plotting the observed data. The slope of the resistance-time plot at some convenient time interval is also of considerable significance.†

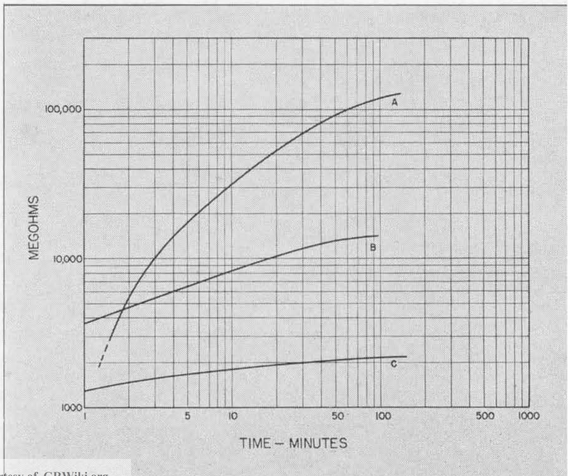
INSULATION RESISTANCE OF ELECTRICAL MACHINES

A plot showing the way the apparent insulation resistance of a 23,750 kva generator varies with time is shown in Figure 3. A reasonable estimate of its true insulation resistance is 900 MΩ, while the one-minute reading is only 140 MΩ. Similar curves for a group of generators varying widely in age and power rating are given in Figure 4. Although the insulation is the same for all of these machines, its physical condition and moisture content at the time of measurement differed widely. The slopes of these curves at the end of one minute are probably equal in importance to the actual values of resistance at that time.

Transformer insulation also has considerable dielectric absorption. The curve for a 5-kw, 6900-volt transformer is shown in Figure 5-B.

Curves *A* and *C* in Figure 5 are for two rubber-insulated cables. These curves illustrate the difference that can occur in cables designed for different applications. Apparently the corona-resistant design of the cable of curve *C* results in a lower insulation resistance and a correspondingly lower dielectric absorption. In spite of the large difference in insulation resistance for these two cables, the one-minute readings are very nearly equal.

FIGURE 5. Plots of insulation resistance for a transformer and two cables. *A* is a 1500-foot, 600-volt, rubber-insulated cable. *B* is a 5 kw, 6900–volt transformer. *C* is a 7-kilovolt, rubber insulated cable, 1040 feet long. This cable is designed to be ozone-resistant.



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†R. W. Wiesman, "Insulation Resistance of Armature Windings," *Electrical Engineering*, June, 1934.

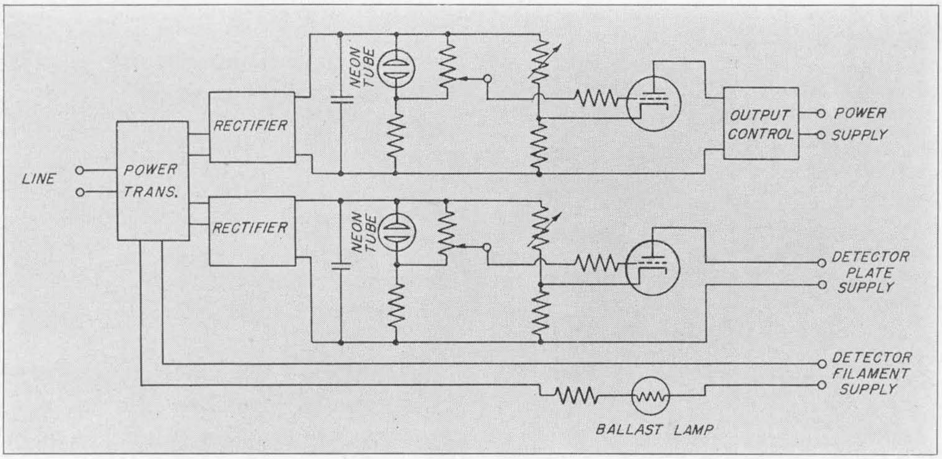

FIGURE 6. Schematic circuit diagram of the TYPE 544-P3 Power Supply.

RESISTANCE RANGE

Resistance measurements with the TYPE 544-B Megohm Bridge can be carried up to 10,000 MΩ with no loss in sensitivity of setting. Over the next decade to 100,000 MΩ the scale reading is crowded, while a resistance of 1,000,000 MΩ can just be distinguished from an infinite resistance.

500-VOLT POWER SUPPLY

The most important requirement of an a-c power supply for a megohm bridge is that it maintain a constant d-c voltage output in the face of the small rapid fluctuations which occur in any line voltage. While the balance of a d-c bridge is independent of applied voltage if the unknown resistance is non-reactive, the existence of a parallel capacitance immediately makes apparent the changes in bridge voltage because of the resulting changes in charging current. The resulting kicks in the galvanometer deflection are larger the greater the parallel capacitance and the insulation resistance.

Both the power supply to the bridge and to the detector tube are stabilized by series triodes whose varying grid bias is referred to a constant voltage obtained from a small neon tube. A diagrammatic representation of the circuits is shown in Figure 6. The filament supply of the detector tube is also stabilized by an iron-wire-type ballast tube. Means are provided on the small panel at the top of the power supply for obtaining either 100 v or 500 v for the bridge. Any intermediate voltage values can be obtained by adjustment of one of the resistors mounted on this panel.

— ROBERT F. FIELD

Specifications for the TYPE 544-B Megohm Bridge and TYPE 544-P3 Power Supply are given on the next page. For the convenience of users of the megohm bridge who may wish to replace existing 90-volt power supplies with the 500-volt unit, the TYPE 544-P3 Power Supply is also listed separately.

SPECIFICATIONS

Range: 0.1 megohm to 10,000 megohms, covered by a dial and a 5-position multiplier switch. A resistance of 1,000,000 megohms can be detected.

Accuracy:

Resistance	*Error*
.1 MΩ– 100 MΩ	± 3%
100 MΩ– 1000 MΩ	± 6%
1000 MΩ–10,000 MΩ	±10%

Above 10,000 megohms, the error is essentially that with which the scale on the MEGOHMS dial can be read.

Terminals: The terminals for connecting the unknown resistor include connections for guard electrodes so that either two- or three-terminal resistors can be measured.

Controls: Megohms dial, with multiplier; zero adjustment; CHECK-OPERATE-CHARGE switch; power ON-OFF switch.

Power Supply: The TYPE 544-P3 a-c power supply unit operates from a 105- to 125-volt, 40- to 60-cycle a-c line, and supplies either 500 volts or 100 volts to the bridge.

Operating Voltage: Terminals are provided so that the bridge voltage can be obtained from an external source if desired. Up to 500 volts can be applied.

Vacuum Tubes: The TYPE 544-P3 Power Supply uses a 6K7G detector, a 6X5G rectifier, a 5U4G rectifier, and, in the voltage regulators, a 6J5G, a 6K6G, and two CD-2005 neon lamps. All tubes are supplied.

Mounting: Shielded oak cabinet.

Dimensions: Cabinet with cover closed, (width) 8½ x (length) 22½ x (height) 8 inches, over-all.

Net Weight: With battery power supply, 30¼ pounds; with a-c power supply, 25¼ pounds.

Type	*Description*	*Code Word*	*Price*
544-B	A-C Operated (500 volts)	AGREE	$235.00
544-P3	500-volt Power Supply Only	AGREEAPACK	75.00

PROPERTIES OF SOLID INSULATING MATERIALS

• **ON THE FOLLOWING TWO PAGES** is presented a table of the mechanical and electrical properties of some of the more common insulating materials. The mechanical properties given are those which enable the user to determine the suitability of a material for a given application. The electrical properties listed are those which are most important at the frequencies used in electrical communication, namely dielectric constant and power factor.

Many of the plastics listed are manufactured under a variety of trade names. Different products of the same general type will often differ widely in some characteristics, such as tensile strength, softening point, etc. For these materials, an attempt has been made to list representative values, or, wherever possible, a range of values.

These data have been compiled at General Radio over a period of several years. They are taken from a number of sources, including scientific publications, handbooks and manufacturers' literature. In spite of this, there are a number of blank spaces in the table, and there are undoubtedly some inaccuracies. We hope that *Experimenter* readers who have more recent data than are shown here will send us additions and corrections which will enable us to complete the table.

	Specific Gravity	Tensile Strength Lbs. per square inch (Multiply by 10^3)	Compressive Strength Lbs. per square inch (Multiply by 10^3)	Softens at °C.	Stable at °C.	Specific Heat	Coefficient of Linear Expansion Parts in 10^6 per °C.	Heat Conductivity c.g.s.
Amber	1.1			250	180		44	
Casein — Moulded	1.33	7		177	165		80	
Cellulose Acetate	1.3	3	4	70	65	.5	150	.0005
Cellulose Nitrate	1.5	3–6		85	85	.36	140	.0003
Fibre	1.3	10	25	130	95		25	.0011
Glass — Crown	2.48	2–5	10–30	1100		.161	8.9	.0025
Glass — Flint	3.7	3–6	6–10			.117	7.9	.002
Glass — Pyrex	2.25		40	600	520	.2	3.2	.0027
Methacrylic Resin	1.19	8–9	12	135	90	.45	70	.00055
Mica — Clear India	2.8			1200	600	2.06	3–7	.0018
Mycalex	3.5	6–8	25–40		350	.22	8–9	.0014
Marble — White	2.7	2	8–15			.21	8–12	.0015
Phenol — Pure	1.3	5–11	15–30		120	.3	28	.0004
Phenol — Yellow	1.9	5.5			130			
Phenol — Black Moulded	1.35	7.5	30		140	.35	40	.0005
Phenol — Paper Base	1.35	10–15	30		125	.3	30	.00065
Phenol — Cloth Base	1.38	11	35		115	.35	20	.0005
Porcelain — Wet-Process	2.4	3–6	30–50	1610	1050	.25	4–5	.0025
Porcelain — Dry-Process	2.3	2–3	30–50		1050	.26	3–4	.0025
Quartz — Fused	2.21	7–10	200	1430	1150	.18	.45	.0024
Rubber — Hard	1.15	4–7	7	70	65	.33	70–80	.0004
Slate	2.8	5	15			.22	10	.005
Steatite	2.5	8–10	50–100	1500	1000		6–8	
Styrene (Polymerized)	1.05	6–9	14	90	75	.324	70	.0004
Sulphur	2.05			113	95	.17	64	.0006
Shellac	1.1	.9	7	85	75			.0006
Titanium Dioxide	4–5	4	60	1600			7–8	
Urea — Formaldehyde Compounds	1.48	6–9	25–30	200	80			.00017
Vinyl Resins — Unfilled	1.35	8–10			50	.244	70	.0005

PROPERTIES OF SOLID INSULATING MATERIALS

	Specific Gravity	Tensile Strength Lbs. per square inch (Multiply by 10^3)	Compressive Strength Lbs. per square inch (Multiply by 10^3)	Softens at °C.	Stable at °C.	Specific Heat	Coefficient of Linear Expansion Parts in 10^6 per °C.	Heat Conductivity c.g.s.	Dielectric Constant	Power Factor in per cent			Machine-ability	Water Absorption % in 24 hours	Cost per pound Dollars	REMARKS
										60 Cycles	1 Kc	1 Mc				
AMBER	1.1			250	180		44		2.9			.2	Very Good	0	12	Natural Petrified Resin
CASEIN — MOULDED	1.33	7		177	165		80		6.4			6	Very Good	4–9		
CELLULOSE ACETATE	1.3	3	4	70	65	.5	150	.0005	6–8	7		3–6	Very Good	4	.50	"Tenite" "Safety Film" — Burns very slowly
CELLULOSE NITRATE	1.5	3–6		85	85	.36	140	.0003	4–7	5–9	5	5	Very Good	2–3	.50	"Celluloid" "Pyralin" "Pyroxylin" — Burns rapidly
FIBRE	1.3	10	25	130	95		25	.0011	4–5	6–9	5	5	Very Good	30	.35	
GLASS — CROWN	2.48	2–5	10–30	1100		.161	8.9	.0025	6.2		1		No	0		Window Glass
GLASS — FLINT	3.7	3–6	6–10			.117	7.9	.002	7		.45	.4	No	0		
GLASS — PYREX	2.25		40	600	520	.2	3.2	.0027	4.5		.5	.2	Very Poor	0		
METHACRYLIC RESIN	1.19	8–9	12	135	90	.45	70	.00055	2.8	3	2	2	Very Good	.3		"Lucite" "Plexiglass" — Slow burning
MICA — CLEAR INDIA	2.8			1200	600	2.06	3–7	.0018	7–7.3	.03	.02	.02			5	
MYCALEX	3.5	6–8	25–40		350	.22	8–9	.0014	6–8		.6	.3	Poor	.035	.80	Mica and Lead Borate
MARBLE — WHITE	2.7	2	8–15			.21	8–12	.0015	7–9			4	Fair	Very high		
PHENOL — PURE	1.3	5–11	15–30		120	.3	28	.0004	5	2		1	Very Good	.15	1	"Catalin" "Bakelite" — Burns very slowly
PHENOL — YELLOW	1.9	5.5			130				5.3	2.5	1.4	.7	Poor	.2	.65	"Low-Loss Bakelite" — Nearly non-burning
PHENOL — BLACK MOULDED	1.35	7.5	30		140	.35	40	.0005	5.5	8	6	3.5	Fair	.3	.40	Nearly non-burning
PHENOL — PAPER BASE	1.35	10–15	30		125	.3	30	.00065	5.5	6	5	3.5	Good	.2–1	.55	Nearly non-burning
PHENOL — CLOTH BASE	1.38	11	35		115	.35	20	.0005	5.6	5	5	5	Good	.7	.65	Nearly non-burning
PORCELAIN — WET-PROCESS	2.4	3–6	30–50	1610	1050	.25	4–5	.0025	6.5–7	2	1	.6	No	Low		
PORCELAIN — DRY-PROCESS	2.3	2–3	30–50		1050	.26	3–4	.0025	6.2–7.5	2	1	.7	No	.1–1		
QUARTZ — FUSED	2.21	7–10	200	1430	1150	.18	.45	.0024	4.2	.03	.03	.03	Very Poor	0		SiO_2 conducts at 800° C.
RUBBER — HARD	1.15	4–7	7	70	65	.33	70–80	.0004	2–3	1	1	.5–.9	Fair	.02	.60	Burns slowly
SLATE	2.8	5	15			.22	10	.005	6–8		.9		Fair	High		
STEATITE	2.5	8–10	50–100	1500	1000		6–8		6.1	1	.4	.3	No	.02		Magnesium Silicate — "Isolantite" "Lava"
STYRENE (Polymerized)	1.05	6–9	14	90	75	.324	70	.0004	2.4–2.9	.02	.02	.03	Good	.01	1.20	"Victron" "Trolitul" — Very slow burning
SULPHUR	2.05			113	95	.17	64	.0006	3–3.8						.03	Burns rapidly
SHELLAC	1.1	.9	7	85	75			.0006	2.5–4	2.5		.9		.1	.25	Burns readily
TITANIUM DIOXIDE	4–5	4	60	1600			7–8		90–170		.1	.06	No	0	.20	Rutile
UREA — FORMALDEHYDE COMPOUNDS	1.48	6–9	25–30	200	80			.00017	6–7	5	3.8	3	Fair	.4		"Beetle" "Plaskon"
VINYL RESINS — UNFILLED	1.35	8–10			50	.244	70	.0005	4		1.4	1.7	Very Good	.15		"Vinylite" — Non-burning

Dielectric Constant	Power Factor in per cent			Machine-ability	Water Absorption % in 24 hours	Cost per pound Dollars	REMARKS
	60 Cycles	1 Kc	1 Mc				
2.9			.2	Very Good	0	12	Natural Petrified Resin
6.4			6	Very Good	4–9		
6–8	7		3–6	Very Good	4	.50	"Tenite" "Safety Film" — Burns very slowly
4–7	5–9	5	5	Very Good	2–3	.50	"Celluloid" "Pyralin" "Pyroxylin" — Burns rapidly
4–5	6–9	5	5	Very Good	30	.35	
6.2		1		No	0		Window Glass
7		.45	.4	No	0		
4.5		.5	.2	Very Poor	0		
2.8	3	2	2	Very Good	.3		"Lucite" "Plexiglass" — Slow burning
7–7.3	.03	.02	.02			5	
6–8		.6	.3	Poor	.035	.80	Mica and Lead Borate
7–9			4	Fair	Very high		
5	2		1	Very Good	.15	1	"Catalin" "Bakelite" — Burns very slowly
5.3	2.5	1.4	.7	Poor	.2	.65	"Low-Loss Bakelite" — Nearly non-burning
5.5	8	6	3.5	Fair	.3	.40	Nearly non-burning
5.5	6	5	3.5	Good	.2–1	.55	Nearly non-burning
5.6	5	5	5	Good	.7	.65	Nearly non-burning
6.5–7	2	1	.6	No	Low		
6.2–7.5	2	1	.7	No	.1–1		
4.2	.03	.03	.03	Very Poor	0		SiO_2 conducts at 800° C.
2–3	1	1	.5–.9	Fair	.02	.60	Burns slowly
6–8		.9		Fair	High		
6.1	1	.4	.3	No	.02		Magnesium Silicate — "Isolantite" "Lava"
2.4–2.9	.02	.02	.03	Good	.01	1.20	"Victron" "Trolitul" — Very slow burning
3–3.8						.03	Burns rapidly
2.5–4	2.5		.9		.1	.25	Burns readily
90–170		.1	.06	No	0	.20	Rutile
6–7	5	3.8	3	Fair	.4		"Beetle" "Plaskon"
4		1.4	1.7	Very Good	.15		"Vinylite" — Non-burning

MISCELLANY

● **THROUGH AN OVERSIGHT,** Figure 1 was omitted from the article entitled "Checking Antenna Power with the Type 726-A Vacuum-Tube Voltmeter," which appeared in the May issue. This drawing is reproduced herewith, and the editor apologizes to both the author and the readers.

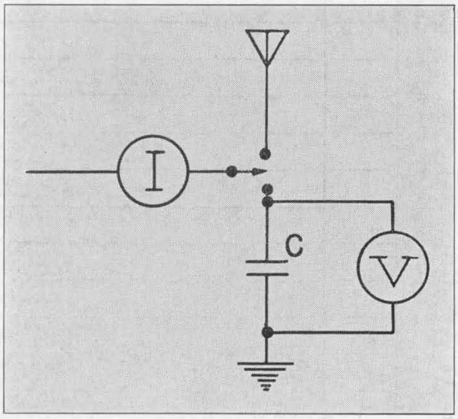

Figure 1. Circuit for checking the accuracy of an antenna ammeter with the Type 726-A Vacuum-Tube Voltmeter. The transmitter output should be reduced when making this check in order to avoid burning out the ammeter. Several calibration points can be checked by adjusting the transmitter output to give different ammeter readings.

● **TWO TECHNICAL SOCIETIES** are holding conventions in San Francisco this month. The National Convention of the Institute of Radio Engineers will be held June 27 to 30 at the Mark Hopkins Hotel, and the combined Pacific Coast and Summer Convention of the American Institute of Electrical Engineers will be held at the Hotel Fairmont, June 26 to 30.

General Radio Company will have a display of apparatus at the Mark Hopkins Hotel, in a room adjacent to the I.R.E. convention hall. Many of the new instruments will be on display, and engineers will be on hand to answer questions.

● **RECENT VISITORS** to the General Radio laboratories include: J. K. Laakso of the faculty of Tampere Polytechnic Institute, Finland; Cecil E. Brigham, Technical Director of Kolster-Brandes, Ltd., London; and Major Edwin H. Armstrong.

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 name, company address, type of business company is engaged in, and title or position of individual.

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THE General Radio EXPERIMENTER

VOLUME XIV NO. 2 JULY, 1939

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also

IN THIS ISSUE

NEW MODELS OF THE VARIAC

● **WITH THE TWO NEW MODELS** of the Variac now available, the amount of power controllable by a single unit is more than doubled. Type 50-A, for 115-volt service, will handle 5 kva, and Type 50-B, operating at 230 volts, will handle 7 kva. Because of their high power-handling capacity, the Type 50 Variacs find many industrial applications where failure would be serious and where they are subjected to considerable abuse. Consequently, much effort in the design has been directed toward making as rugged, reliable and serviceable a unit as possible.

Figure 1. View of the Type 50-B Variac with cover.

BRUSH ASSEMBLY

Among the features contributing to reliability is the brush assembly. Six independent carbon brushes are used, each in a brass holder. The two springs that hold each brush in place are sufficiently long to assure uniform tension as the brushes wear.

The brushes are mounted on a cast-aluminum radiator, so shaped as to conduct heat rapidly from the region of the brushes to cooler regions where it can be radiated easily. To assure low resistance connections, each brush holder is connected electrically to the radiator through a flexible copper lead. Connection from the radiator to the Variac terminal is made through a pigtail lead.

WINDING AND CORE

The winding form is molded with radial slots to hold each turn firmly in place and insure the maintenance of a good commutator surface. As in other Variacs, the core is toroidal, built up of ring-shaped laminations.

MOUNTING

Type 50 Variac is suitable for either table or panel mounting. The base is of cast iron with four feet drilled for mounting with ½-inch bolts on a 7¼-inch radius. The ¾-inch shaft is held by two setscrews. To convert the Variac for panel mounting, the setscrews are loosened and the shaft pushed through to the desired position.

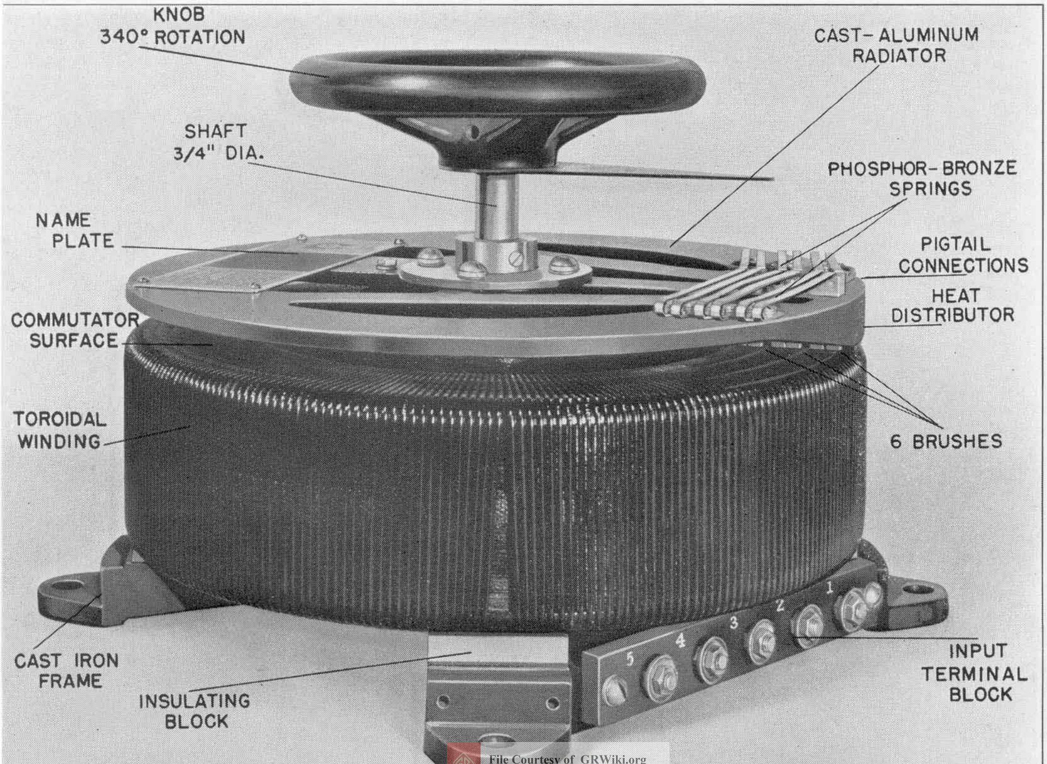
TERMINALS

Two terminal plates are provided, one for input connections, the other for output. Both are protected by the cover.

COVER

A perforated brass housing covers the winding, brushes, terminals, etc. Two

Figure 2. Type 50-B Variac with cover removed.



handles for lifting the Variac are provided. Both a name plate and a dial are mounted on this brass cover.

DIAL

The dial is two-sided and reads output voltage directly in terms of a 115-volt input for Type 50-A, or 230-volt input for Type 50-B. One side of the dial is used when the Variac is connected to give a maximum output voltage equal to line voltage; the other side is used when the connections are for 135-volt output on the Type 50-A or 270 volts on the Type 50-B.

NAME PLATE

The name plate carries a circuit diagram and brief operating instructions. As is shown in the photographs, two name plates are provided. One is mounted on the cover, the other on the radiator.

— S. A. Buckingham

SPECIFICATIONS

Type	*50-A*	*50-B (230 v in)*	*50-B (115 v in)*
Load Rating*	5000 va	7000 va	2300 va
Rated Current	40 a	20 a	10 a
Maximum Current	45 a	31 a	31 a
Input Voltage	115 v	230 v	tapped for 115 v
Output Voltage	0-115 v 0-135 v	0-230 v 0-270 v	0-230 v
No-Load Loss†	60 watts	75 watts	75 watts
Line Frequency‡	60 cycles	60 cycles	60 cycles

Dimensions: 13⅝ x 13⅝ x 9⅜ inches, over-all.

Net Weight: 75 pounds.

---

*Ratings are for 50° C. temperature rise, with cover.

†At 60 cycles.

‡These Variacs can be operated at 50 cycles with slightly more heating or slightly reduced rating.

Type		*Code Word*	*Price*
50-A	Variac.	TOKEN	
50-B	Variac.	TOPAZ	

IMPROVED TYPE 100 VARIAC

● **THE 2-KVA VARIACS,** Types 100-K and 100-L, have recently been replaced by new models, Type 100-Q and Type 100-R, respectively. Most important change is the provision for overvoltage output; the Type 100-Q will give a maximum output of 135 volts and the Type 100-R, 270 volts. The height of the core and, consequently, the overall height of the Variac have been increased, but all other dimensions remain unchanged.

Pigtails have been added to the brush holders to give better electrical contact between brush and radiator. This has resulted in a lower brush temperature with consequent increase in brush life. Longer brush springs help to keep the force between brush and winding constant as the brush wears.

A two-sided dial, reading directly in output voltage, is provided for each model. One side is used for maximum output voltage equal to input line voltage; the other side is for the overvoltage connection.

A slight increase in the rated current has been made possible by the new design. See specifications for details.

The terminal plate (see Figure 1 below) carries a wiring diagram of the internal connections so that the work of installing and wiring the Variac is simplified. The number of turns between taps on the winding is also given. This makes it possible to determine whether or not the rating (voltage per turn) is exceeded in unusual applications.

— S. A. Buckingham

SPECIFICATIONS

Type	*100-Q*	*100-R (230 v in)*	*100-R (115 v in)*
Load Rating	2 kva	2 kva	1 kva
Rated Current	18 a	9 a	4.5 a
Maximum Current	18 a	9 a	9 a
Input Voltage	115	230	tapped for 115
Output Voltage	0-115 0-135	0-230 0-270	0-230
No-Load Loss*	20 watts	25 watts	25 watts

Dimensions: 7¾ x 9 x 7⅝ inches.

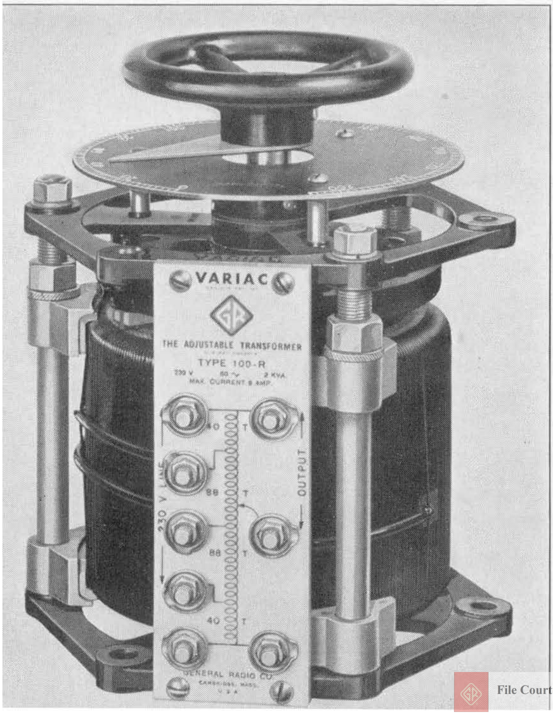
Net Weight: 29 pounds.

---

*At 60 cycles.

Type		*Code Word*	*Price*
100-Q	Variac.	BEAMY	
100-R	Variac.	BEARD	

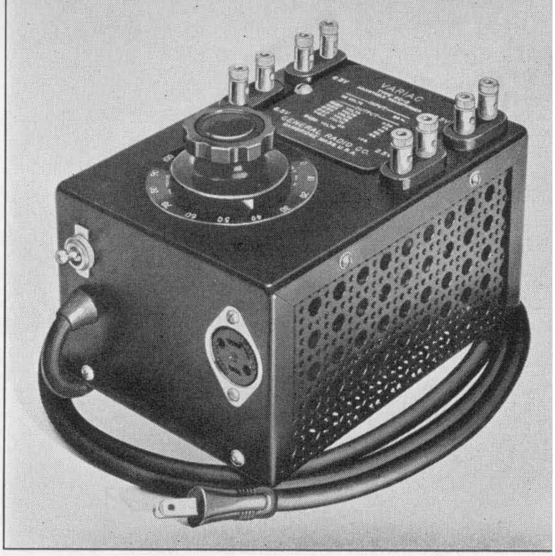
Figure 1. View of the new Type 100 Variac, showing the terminal plate.



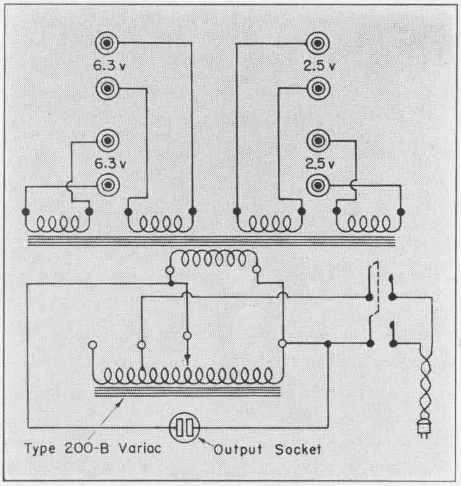
A VARIAC WITH LOW-VOLTAGE OUTPUT

● **ANOTHER RECENT ADDITION** to the Variac line is the Type 90-B. This unit, which consists of a Type 200-B Variac and a step-down transformer, is extremely useful in the communication laboratory as a source of cathode power for vacuum tubes. Figure 1, page 5, is a photograph of the Type 90-B Variac; Figure 2 shows the internal connections.

From the built-in Type 200-B Variac itself, 0 to 135 volts can be obtained. From the auxiliary transformer, which is controlled by the Variac, the two commonly used cathode heater voltages are available. Two secondaries are provided for each voltage. The actual voltages are 7.4 and 2.9 volts for use on 6.3- and 2.5-volt circuits, respectively.



(*Right*) FIGURE 1. The TYPE 90-B Variac. The binding posts are the low-voltage terminals. The output of the TYPE 200-B Variac is available at the plug receptacle.



(*Below*) FIGURE 2. Wiring diagram of TYPE 90-B Variac. Note that independent windings are used for the low-voltage circuits.

SPECIFICATIONS

Load Rating: *170 va, total.

Input Voltage: 115.

Output Voltage: 0-135, 0-7.4, 0-2.9

Rated Current: 1 a, 4 a, 4 a

Maximum Current: 1.5 a, 4 a, 4 a

No-Load Loss: 8 watts

Dimensions: 7¼ x 5 x 6 inches, over-all.

Net Weight: 8¾ pounds.

---

*With all secondaries operating at once, 82 watts can be drawn from the low-voltage circuits and 70 va from the Variac output.

Type		*Code Word*	*Price*
90-B	Variac.	PIVOT	

THE SERVICE DEPARTMENT SAYS:

● **THE SUMMER MONTHS**, when instruments used in educational and industrial laboratories are idle for considerable periods because of staff vacations, offer an excellent opportunity to have instruments reconditioned and repaired with minimum interruption to the laboratory program. Before returning instruments for repair, please communicate with the Service Department.

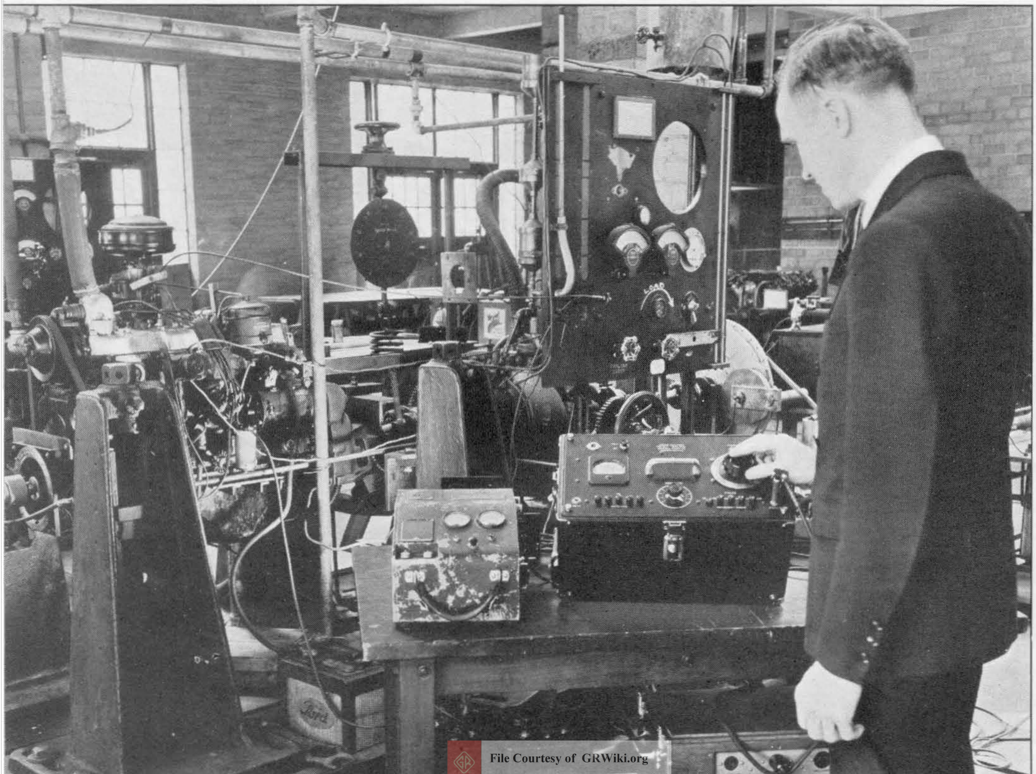
CRANKSHAFT VIBRATION MEASUREMENTS WITH THE SOUND ANALYZER

● **BEHIND THE MARKED IMPROVEMENT** in the smoothness and quietness of the automobile which has taken place in the last few years is a continuous program of research carried out in the laboratories of automotive manufacturers. An important factor in the success of this program is the increasing availability of instruments for measuring mechanical and electrical qualities. Not only are rule-of-thumb and guesswork rapidly giving way to accurate measurement, but the speed and ease of measurement are being improved. The measurement of torsional vibration in crankshafts is a good example.

In the accepted method of measuring the amplitudes of the components of torsional vibration, an oscillogram of the vibration wave is analyzed on a mechanical harmonic analyzer. The oscillogram is obtained from the amplified output of a vibration pickup mounted on the shaft to be measured. Because the mechanical method is excessively time-consuming, there has been considerable interest in the Type 760-A Sound Analyzer as a faster and more convenient means of making the measurement. This analyzer operates directly from the amplifier output of the vibration pickup and does not require an oscillogram. The amplitude of each component is measured directly, simply by turning the frequency dial and reading the deflection on the meter.

A series of measurements made on an

FIGURE 1. The Type 760-A Sound Analyzer set up for measuring torsional vibration. The pickup on the end of the crankshaft is at the extreme left.



automobile crankshaft through the courtesy of the automotive engineering laboratory at the Massachusetts Institute of Technology has enabled us to compare directly the technique of measurement and the results obtained on the TYPE 760-A Sound Analyzer with those of the older mechanical method. The same vibration pickup and amplifier were used in both methods.

The speed and ease with which the measurement could be made were in marked contrast to the slowness of the older method, while the agreement in results was well within the moment-to-moment fluctuations in the quantity under measurement.

The plot of Figure 2 shows the results of two mechanical analyses and a single analysis with the sound analyzer. The engine was operating at 1800 revolutions per minute (30 revolutions per second).

The three measurements were not taken simultaneously and, consequently, the agreement among the results is influenced by the fact that the amplitudes of the components under measurement are not constant. The results obtained with the TYPE 760-A Sound Analyzer agree with those of the mechanical method as well as the latter do among themselves.

The outstanding advantage of the sound analyzer is the speed with which the measurement can be made. The complete analysis can be made in about five minutes. With the mechanical analyzer, on the other hand, several minutes are required to evaluate each component in addition to the time consumed in making and developing the oscillogram.

A further advantage lies in the fact that, if the component under measurement varies appreciably, a maximum, a minimum, or an average reading can be taken at will.

There are, of course, a number of applications of this type of measurement outside the automotive industry. Vibration in airplane engines and propellers can be analyzed in the same way. For many machine tools, particularly where vibration would have a direct bearing on product quality, this type of analysis is extremely valuable.

— L. E. PACKARD

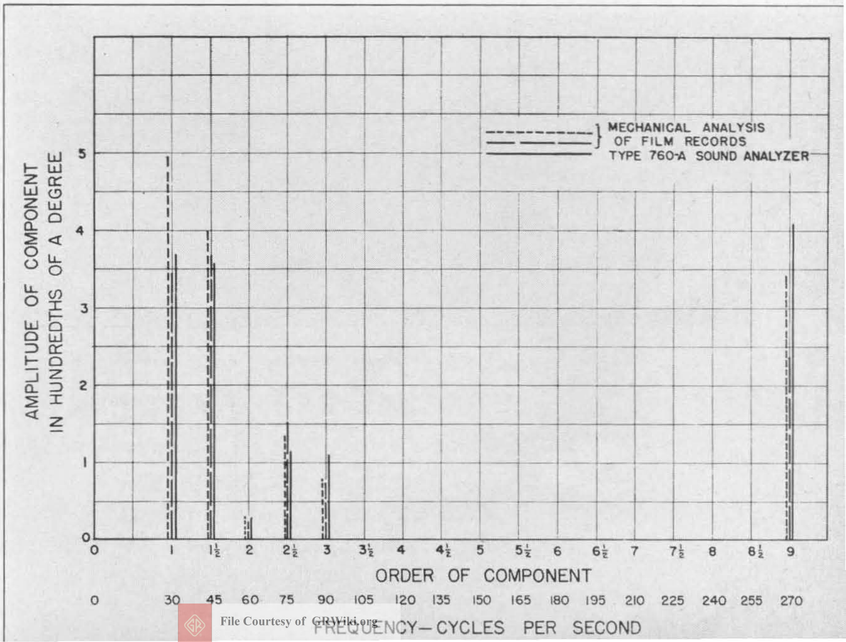


FIGURE 2.

Results of the measurements of crankshaft vibration. For purposes of comparison, two mechanical analyses are also plotted.

● **TO SHOW THEIR FAMILIES AND FRIENDS** how General Radio products are made, General Radio employees recently held an open house. Guests came in such numbers that the single afternoon originally scheduled was increased to two. Guides conducted the guests around the plant in small groups to allow ample opportunity for questions. Highlight of the program was a hobby show in which employees exhibited the products of their leisure hours. As the accompanying photographs show, exhibits were many and varied. Among the products of home craftsmen were furniture, telescopes, surf boards and jewelry. The artists showed paintings, drawings, sculpture and photographs. Collectors displayed stamps, coins, historic vacuum tubes and other interesting items.

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THE General Radio EXPERIMENTER

VOLUME XIV NO. 3 AUGUST, 1939

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also
IN THIS ISSUE

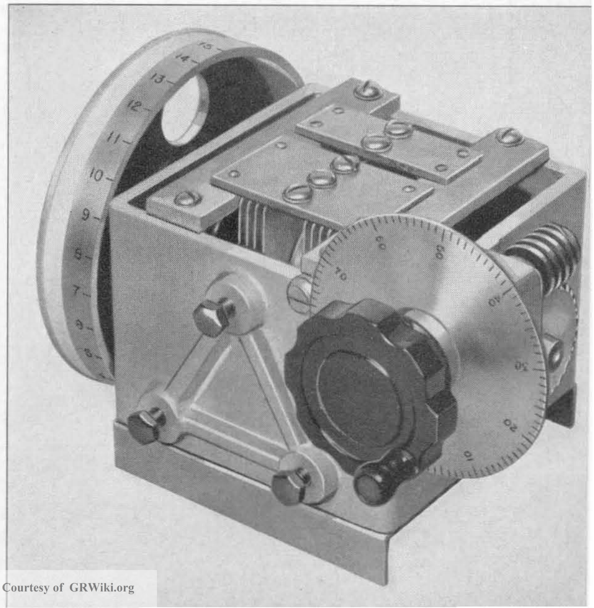
A NEW CONDENSER FOR HIGH-FREQUENCY CIRCUITS

● **THE TYPE 755-A CONDENSER** is designed for use in high- and ultra-high frequency radio equipment, such as standard-signal generators, oscillators, and measuring circuits. It is a ruggedly constructed condenser, of small dimensions and capable of being set with high precision. The equivalent series inductance is extremely low, so that it can be used as the frequency controlling element in ultra-high frequency oscillators.

The condenser is shown fully assembled in Figure 1 and with the base removed in Figure 2. As can be seen from Figure 2, the frame is a four-sided aluminum casting. The metal base, shown in Figure 1, forms a fifth-side shield. Copper-plated brass terminal strips are mounted on mycalex insulators on the unshielded side.

The drive is a worm and gear combination with a helical spring between the worm and the gear to reduce backlash to a minimum. The gear ratio is 15:1. Ball bearings are used on the main shaft. The total number of scale divisions is 1500, 15 on the main scale and 100 on the worm scale. On the drum which carries

Figure 1. Low inductance, low losses, small size, and precision drive are some of the features of this condenser.



the main scale, a blank paper scale is provided, so that direct-reading calibrations can be made. This paper scale is easily removable for replacement.

The plates are of brass, soldered together and heavily copper plated. Both rotor and stator are insulated from the frame. Contact to the rotor is made by a 5-finger brush bearing on a slip ring. Plates are shaped to spread out the frequency scale at the high-frequency end.

The direct capacitance from rotor to stator is variable between 8.5 $\mu\mu$f and 145 $\mu\mu$f. The capacitances of rotor and stator to ground are approximately equal and are each about 10 $\mu\mu$f.

The equivalent series inductance is about 5.5 centimeters (0.0055 μh) at minimum capacitance setting. This low inductance, combined with low effective resistance, makes the condenser an excellent tuning element at ultra-high frequencies. It can be used, in conjunction with a coil-switching system, as the frequency control in an oscillator at frequencies as high as 350 megacycles. With an "Acorn" tube, and a single-turn coil of copper ribbon, $\frac{3}{4}$ inch in diameter and $\frac{1}{2}$ inch wide, the frequency is 390 megacycles at minimum capacitance.

SPECIFICATIONS

Direct Capacitance: Maximum, 145 $\mu\mu$f; minimum, 8.5 $\mu\mu$f.

Equivalent Series Inductance: 0.0055 μh at minimum capacitance setting.

Grounding: Both rotor and stator are insulated from frame. Rotor-to-frame capacitance is 10 $\mu\mu$f; stator-to-frame, 8 $\mu\mu$f.

Shielding: Completely shielded on five sides; terminals brought out on unshielded side.

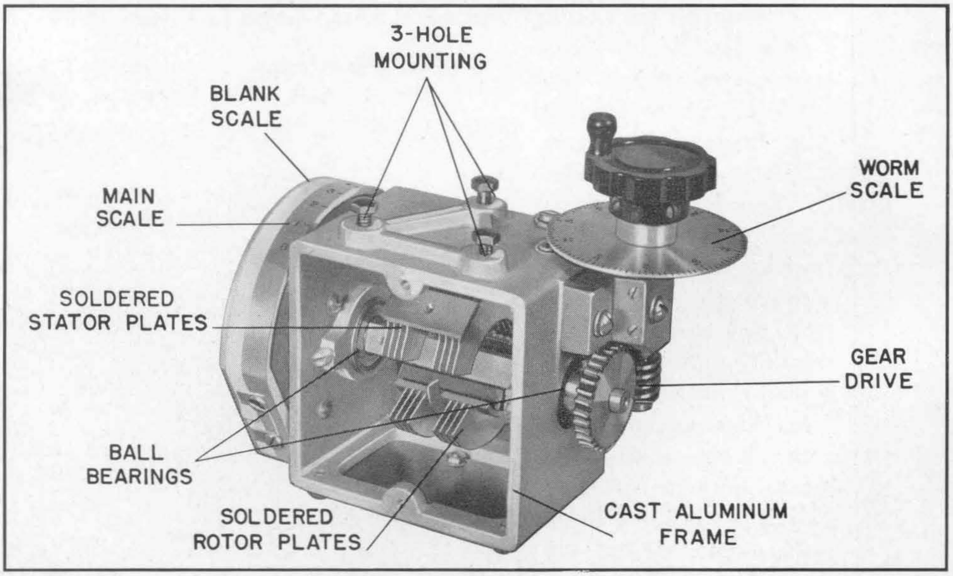
Mounting: The frame is drilled and threaded for a three-hole mounting, $1\frac{3}{4}$ inches on centers. Threads are 8-32.

Dimensions: 6 x $5\frac{1}{2}$ x $4\frac{1}{8}$ inches, over-all, including dial and knobs.

Net Weight: 2 pounds, 10 ounces.

Type		*Code Word*	*Price*
755-A	....	CARGO	

FIGURE 2. View of TYPE 755-A Condenser with base removed.



TYPE 700-P1 VOLTAGE DIVIDER

● **WHEN MEASUREMENTS** of amplifier gain are made, it is often desirable to know the actual magnitude of the input voltage so that the effects of background noise and overloading can be evaluated. In many cases the output voltmeter-potentiometer combination customarily supplied in beat-frequency oscillators yields a sufficiently large voltage range to meet this demand. The small input voltages required for measurements on high-gain amplifiers, however, cannot be read directly with sufficient accuracy and it is desirable to obtain the small voltages from relatively large oscillator output voltages by means of a calibrated attenuator.

The Type 700-P1 Voltage Divider, illustrated in Figure 1, is intended primarily for use with the Type 700-A Wide-Range Beat-Frequency Oscillator to furnish a range of readable output voltage from 100 microvolts to 10 volts.

It consists of a ladder-type resistive network, housed in a shielded container, with a shielded input lead and plug and output binding posts. By means of a rotary switch, multiplying factors of 0.1, 0.01, 0.001, and 0.0001 can be selected. The input impedance is 2000 ohms and the output impedance is 200 ohms. The frequency characteristic is flat within 10%, on all settings, at frequencies up to 5 Mc. A plot of the variation in attenuation with frequency for open-circuit termination is shown in Figure 3.

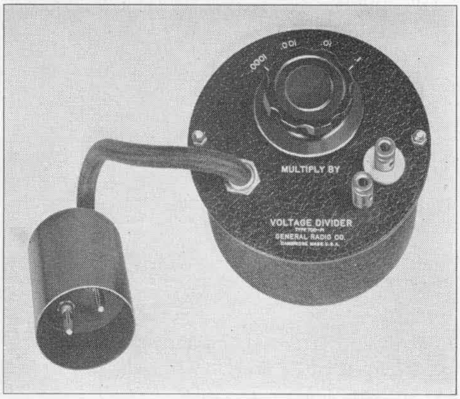


Figure 1. Photograph of the Type 700-P1 Voltage Divider showing scale, terminals, and shielded plug.

While primarily intended for applications involving broad frequency bands, the Type 700-P1 Voltage Divider is suitable for use in audio-frequency applica-

Figure 2. This photograph shows the Type 700-P1 Voltage Divider connected to the Type 700-A Wide-Range Beat-Frequency Oscillator.

tions where an inexpensive attenuator of moderate accuracy is required. It can be connected to any General Radio instrument having output binding posts with standard ¾-in. spacing on centers, and the shielding of the instrument to which it is connected will ordinarily determine the lowest voltage level which can be successfully utilized at the output terminals.

— D. B. Sinclair

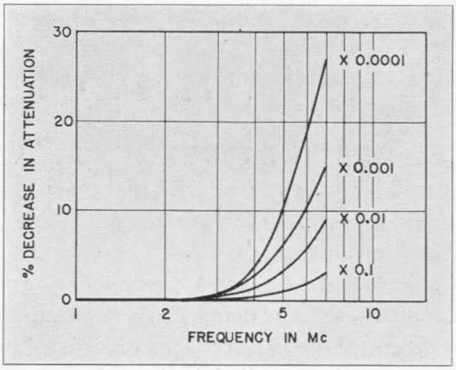


Figure 3. Frequency error in Type 700-P1 Voltage Divider.

SPECIFICATIONS

Accuracy of Attenuation: ± 3%.

Net Weight: 1½ pounds.

Dimensions: (Not including plug and cable) (height) 4½ x (diameter) 4½ inches.

Type	*Code Word*	*Price*
700-P1	OTTER	

MEASURING THE FREQUENCY RESPONSE OF A SOUND SYSTEM WITH THE SOUND-LEVEL METER

● **A UNIQUE FEATURE** of New York's Jones Beach is the Marine Stadium shown in Figure 1. Here the stage is separated from the audience by some 50 yards of water, and a sound-amplification system is used to carry the stage program to all parts of the grandstand.

There are five uni-directional microphones located in the footlight trough of the stage. The sound picked up by these microphones is amplified and drives eight loudspeakers located in front of the stage. The sound then must travel over the 50 yards of water before it reaches the audience in the stands.

When the microphones were first placed in the footlight trough, the amplified

Figure 1. View of a portion of Jones Beach, showing the Marine Stadium.

sound was very unnatural and sounded "boomy." As a result, a variable low-frequency attenuator was installed. Although this eliminated the "boom," the sound still was not natural. Since it was desired to have the volume level at the stands about the same as the volume level at the source of the sound, a linear response was sought. Although each unit of the original amplifying equipment was supposed to have fairly linear response, the over-all response sounded far from linear.

As the first step toward correction, accurate measurements were made of the over-all frequency response. This over-all frequency test included the air-transmission path from origin of sound to microphone and the air-transmission path from loudspeaker to the audience in stands as well as the complete amplifying equipment and transmission lines.

This test was made by placing an artificial voice at the sending position and an artificial ear at the receiving position.

ARTIFICIAL VOICE

The requirements for the artificial voice were that it (1) emit known frequencies at known volumes, (2) have the directional characteristics of the human head, (3) be capable of producing the same power output as the human voice, and (4) be free from distortion.

A theoretical investigation of the diffraction of sound by the human head was conducted by Stewart.* He found that a small source located on the surface of a sphere 19 cm. in diameter approximately represented the human voice in directional characteristics. The placement of a small loudspeaker in a sphere is rather difficult, but it has been found by experiment that the diffraction of sound from an equivalent cube is, for all practical purposes, the same. The

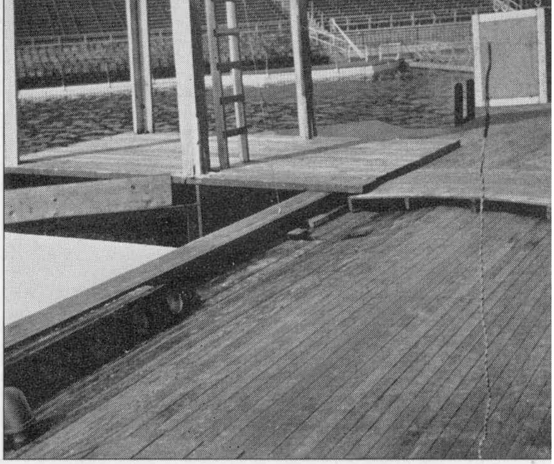


FIGURE 2. This photograph shows the artificial voice suspended before the microphone. The microphone itself is at the extreme lower right.

artificial voice finally used consisted of a box 7 inches x 7 inches x 5 inches with a small dynamic loudspeaker located in the center. The diameter of the opening was 3 inches.

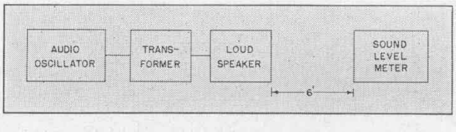
ARTIFICIAL EAR

For the artificial ear a General Radio TYPE 759-A Sound-Level Meter was chosen. This meter was small and compact and could easily be carried around the stadium.

PROCEDURE OF TEST

First it was necessary to calibrate the artificial voice. This was accomplished by using the General Radio Sound-Level Meter, which was already calibrated in decibels. The artificial voice was set up and suspended in the clear. The microphone of the sound-level meter was put on an extension cord and placed six feet from, and in line with, the center of the artificial voice. In order to reduce the

FIGURE 3. Block diagram of method used to calibrate the artificial voice.



Physical Review, 1911, page 476.

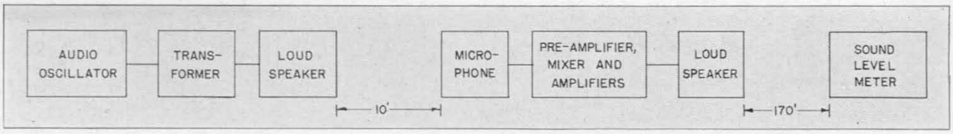
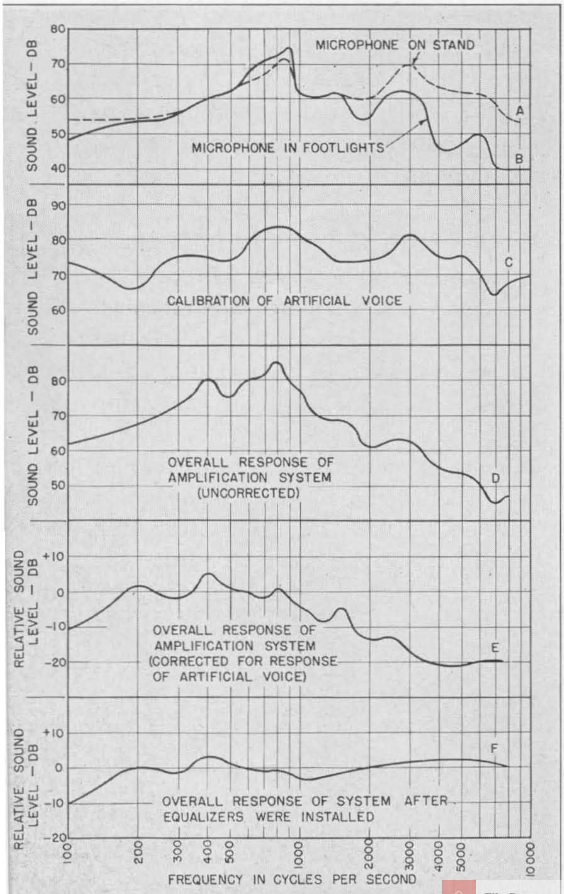


Figure 4. Block diagram of method used to measure the over-all characteristic of the sound system.

influence of reflections to a minimum the calibration test was conducted outdoors.

The volume of the audio oscillator connected to the artificial voice was set so that for 1000 cycles the volume was about 80 db as read by the sound-level meter. The sound-level meter was of course set for a linear response. For various frequencies ranging from 100 to 10,000 cycles per second the reading of the sound-level meter was recorded. A cathode-ray oscillograph was connected to the earphone jack of the sound-level meter, so that the shape of the wave from the artificial voice could be constantly observed. The volume of the audio oscillator was changed, and another set of readings was taken. The frequency characteristic was found to be the same at both levels and is shown in Figure 5c.

Figure 5. The results of each step in the measurement are shown here.



Having the data for a set of calibration curves of the artificial voice, the apparatus was then set up for the over-all frequency response test. The artificial voice was suspended so that it would assume a position similar to that taken by the head of an actor on the stage. Since about 90% of the time the actors on the stage are about two feet in back of the white line and directly in front of a microphone, the artificial voice was placed in the same position. The sound-level meter was placed on one of the front seats of the stadium, and the oscillograph was again connected to the earphone jack of the meter.

The oscillator was turned on so that the output of the artificial voice was about 80 db at the microphone for 1000 cycles per second. The amplifier was adjusted so that the reading of the sound-level meter in the stands was about the same. Readings were taken for various frequencies ranging from 100 to 10,000 cycles per second, and the shape of the output wave was observed. This test was repeated several times.

Other tests were attempted, such as placing the artificial voice further backstage and in between microphones, but unfortunately by this time the wind was quite strong and accurate readings could

FIGURE 6. Showing the sound-level meter and oscillograph as used in measuring the over-all characteristic of the system.

not be obtained. Incidentally, it was necessary to make all the tests between the hours of 11:00 p.m. and 6:00 a.m., as this was the only time of the day that the wind died down at all.

It was interesting to note that for a slight wind, the volume of the sound in the stands varied as much as 10 and 15 db for frequencies above 800 cycles when the volume output of the artificial voice was constant. Below 800 cycles the volume level was quite constant, regardless of the wind. On a very windy night the volume of the frequencies above 800 cycles would vary as much as 25 db — the higher the frequency, the greater the variation.

RESULTS

Subtracting the response curve of the artificial voice from the over-all response curve obtained by the artificial ear, the actual over-all response curve of the Marine Stadium was obtained. As can be seen from this curve, the high frequencies are considerably attenuated.

As a result of the over-all response test a two-section high-frequency equalizer, capable of permitting a maximum equalization of 25 db, was installed in the 250-ohm line output of the stage microphone mixer unit. A control was put on the panel so that the equalization could be varied. The resulting frequency characteristic is shown in Figure 5F.

The improvement in the sound amplification system was very apparent. Speech was much clearer and the music possessed a brilliance that was previously missing.

The text and illustrations of the foregoing article were prepared by Mr. John M. Lester, under whose direction the measurements were made at Jones Beach State Park. —EDITOR

FIGURE 7. View of the grandstand and stage at Jones Beach.

MISCELLANY

● **GENERAL RADIO ENGINEERS** returning from the San Francisco I.R.E. Convention report a large and enthusiastic attendance. Particularly gratifying to us was the interest in the new General Radio instruments on display.

The new CLASS C-21-HLD primary frequency standard will be displayed at the General Radio booth at the Annual Convention of the I.R.E., to be held in New York in September. Same booth, same location as in 1937 and 1938.

● **RECENT VISITORS** to our laboratories included Mr. Henryk Magnuski, Mr. Henryk Lukasiak, and Mr. Artur Hirszbandt, all of the engineering staff of the Tele-Radio-Technical Institute of Poland at Warsaw.

● **THE TABLE** of the properties of insulating materials published in our June issue has aroused considerable interest. Many readers have taken the trouble to send in corrections and additions which will aid in bringing the table up to date. The corrected table will be available some time this fall, and will be published in reprint form as well as in the *Experimenter*.

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 name, company address, type of business company is engaged in, and title or position of individual.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

IMPEDANCE MEASUREMENTS AT HIGH FREQUENCIES WITH STANDARD PARTS

INTRODUCTION

● **THE ADVENT OF COMMERCIAL TELEVISION** and a general increase in interest in high-frequency transmission have greatly stimulated the contemporary demand for precise measurements of impedance at high and ultra-high frequencies. During the past year, the General Radio Company, to meet the need for improved circuit elements, has announced several new units especially designed for high-frequency use. Together with instruments that have been available for a longer period of time, these new units round out the following complete line of components for use in impedance measurements:

Type 700-A Wide-Range Beat-Frequency Oscillator[1]
Type 684-A Modulated Oscillator[2]
Type 516-C Radio-Frequency Bridge[3]

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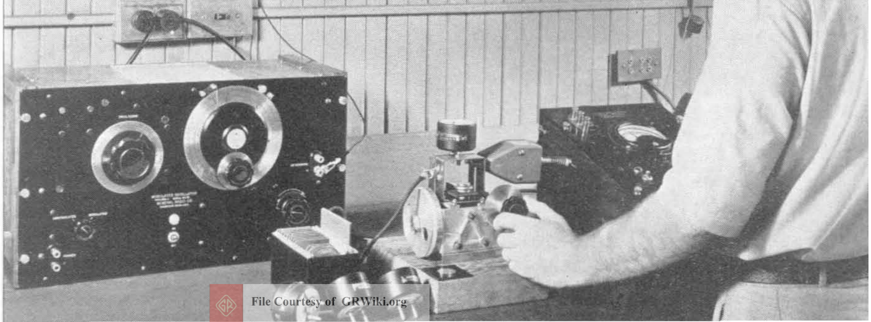
[1] General Radio *Experimenter*, Vol. XIII, No. 8, p. 1, Jan., 1939.
[2] General Radio *Experimenter*, Vol. XII, No. 6, p. 1, Nov., 1937.
[3] General Radio *Experimenter*, Vol. VIII, No. 7, p. 1, Dec., 1933; Vol. XII, No. 9, p. 5, Feb., 1938; *Communications*, Vol. 19, No. 6, p. 5, June, 1939, and Vol. 19, No. 7, p. 5, July, 1939.

Figure 1. Laboratory set-up for measurements of power factor of dielectric samples.



Type 722-N Precision Condenser[4]
Type 500 Resistor
Type 663 Resistor[5]
Type 505 Condenser[6]
Type 670 Compensated Decade Resistor[7]
Type 726-A Vacuum-Tube Voltmeter[8]
Type 493 Thermocouples[9]
Type 755-A Condenser[10]

The need for more accurate measurements at higher frequencies has not only created a demand for better circuit elements but also for better techniques. In particular, the increase in commercial measurements has led to a search for simple and reliable methods and circuits involving, wherever possible, standard parts.

Resonance methods,[11] in general, have been found most suitable for measurements at very high frequencies because of their simplicity, flexibility, and accuracy, and because of the relatively low cost of the necessary components. A practical set-up recently used in the General Radio Company laboratories for measurements of the power factors of small dielectric samples illustrates the ready adaptability of General Radio high-frequency elements to this type of measurement.

METHOD

The photograph of Figure 1 shows the complete set-up which comprises a Type 684-A Modulated Oscillator, a Type 755-A Condenser, and a Type 726-A Vacuum-Tube Voltmeter connected in a susceptance-variation circuit.[12] The circuit diagram is illustrated in Figure 2.

The effective conductance of a parallel-resonance circuit of this type is given rigorously by the expression

$$G_e = \frac{\omega(C - C_r)}{\sqrt{\left(\frac{V_r}{V}\right)^2 - 1}} \qquad (1)$$

where V_r is the voltage occurring across the parallel-resonant circuit at resonance with the variable capacitance equal to C_r, and V is the voltage occurring across the parallel-resonant circuit at any other capacitance setting, C.[13]

The effective conductance, G_e, is easily determined by measuring the voltage at parallel resonance, V_r, and the change in capacitance, $C_1 - C_2$, between the two settings at which the voltage equals $V_r/\sqrt{2}$. For these conditions Equation (1) takes the simple form

$$G_e = \frac{\omega(C_1 - C_2)}{2} \qquad (2)$$

In order to measure a dielectric sample, all that is necessary is to make two conductance measurements, one with the sample disconnected and one with it connected across the tuned circuit. The resonant capacitance must be the same in both cases, so the difference in setting of the standard condenser at resonance is equal to the capacitance, C_x, of the sample. The conductance of the sample is added directly to the effective conductance of the parallel-resonant circuit so the dif-

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[4] General Radio *Experimenter*, Vol. XIII, Nos. 5/6, p. 1, Oct./Nov., 1938.

[5] General Radio *Experimenter*, Vol. XIII, No. 8, p. 6, Jan., 1939.

[6] General Radio *Experimenter*, Vol. VII, No. 8, p. 1, Jan., 1933; Vol. XII, No. 11, p. 4, April, 1938.

[7] General Radio *Experimenter*, Vol. VIII, No. 10, p. 6, March, 1934.

[8] General Radio *Experimenter*, Vol. XI, No. 12, p. 1, May, 1937; Vol. XIII, Nos. 3/4, p. 1, Aug./Sept., 1938.

[9] General Radio *Experimenter*, Vol. XIII, No. 10, p. 5, March, 1939.

[10] General Radio *Experimenter*, Vol. XIV, No. 3, p. 1, Aug., 1939.

[11] For a detailed treatment of resonance methods, see D. B. Sinclair, "Parallel-Resonance Methods for Precise Measurements of High Impedances at Radio Frequencies and a Comparison with the Ordinary Series-Resonance Methods," *Proc. I.R.E.*, Vol. 26, No. 12, p. 1466, Dec., 1938.

[12, 13] Ibid.

ference between the two measured conductances is equal to the conductance, G_x, of the sample. The dissipation factor, D_x,[14] of the sample can be easily computed from the capacitance and conductance by means of the relation

$$D_x = \frac{G_x}{\omega C_x} \qquad (3)$$

CORRECTIONS AND DESCRIPTION OF PHYSICAL SET-UP

The particular feature that distinguishes high-frequency measurements, in contrast with low-frequency measurements, is not any new and strange phenomenon but simply the greater relative importance of residual parameters that are inherent in the impedance standards and in the wiring.

The only impedance standard used in the susceptance-variation method is the incremental admittance of the standard condenser, C, shown in Figure 2. In order to predict the limitations of this method and to compute the corrections that may be necessary, it is essential to analyze carefully the effects of residual parameters in the condenser.

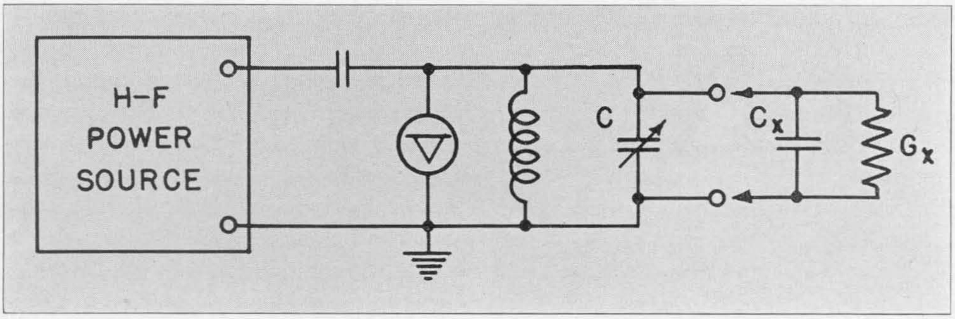
In many applications, it has been found justifiable to treat a variable air condenser as a variable capacitance having no loss and no variation with frequency. At high frequencies, however, especially when used in a measuring circuit, a condenser cannot be considered so nearly ideal a circuit element. The equivalent circuit of Figure 3, to a first approximation, includes the residual parameters that cause the behavior of an actual condenser to depart from that of an ideal capacitance. The conductance, G_c, represents the loss in the dielectric structure, the resistance, R_c, represents the loss in the metallic structure, and the inductance, L_c, represents the inductance caused by magnetic flux set up by currents in the metallic structure.[15] All these residual parameters are nearly constant as a function of dial setting. At high frequencies, where skin-effect is essentially complete, the conductance, G_c, increases nearly linearly with frequency, the resistance, R_c, increases about as the square root of the frequency, and the inductance, L_c, remains constant. In the Type 755-A

---

[14] The term power factor, rather than dissipation factor, is often used loosely to describe the ratio of resistance to reactance, or conductance to susceptance, rather than the ratio of resistance to impedance, or conductance to admittance, because the numerical value for useful dielectrics is so small that there is no significant difference between them.

[15] For a discussion of this equivalent circuit, and methods of measuring the residual parameters, see R. F. Field and D. B. Sinclair, "A Method for Determining the Residual Inductance and Resistance of a Variable Air Condenser at Radio Frequencies," *Proc. I.R.E.*, Vol. 24, No. 2, p. 255, February, 1936.

Figure 2. Susceptance-variation circuit used for the measurements.



Condenser, which has been especially designed for high-frequency service, the residual parameters are very small. At a frequency of 100 Mc, for instance, they are, approximately:

G_c = 0.0055 microhenry
R_c = 0.05 ohm
L_c = 100 micromhos

The effects of these residual parameters depend upon the use to which the condenser is put. In the susceptance-variation circuit only admittance *differences* are used. Since the conductance, G_c, is in circuit at all times, and is constant, it drops out when taking admittance differences and causes no error.

The residual inductance, L_c, causes the effective terminal capacitance, $\hat{C}$, to differ from the static capacitance, C.

$$\hat{C} = \frac{C}{1 - \omega^2 L_c C} \qquad (4)$$

Since the fractional change is a function of the static capacitance, the difference between static and effective capacitance increments is neither zero nor constant, but varies as the absolute capacitances are changed.

The residual resistance, R_c, gives rise to an effective conductance component, G_c'.

$$G_c' \simeq R_c(\omega\hat{C})^2 \qquad (5)$$

Since this conductance component depends upon the capacitance setting, it does not cancel out when taking admittance differences.

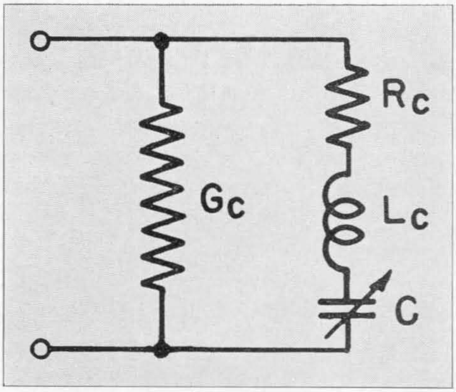


FIGURE 3. Equivalent circuit of a variable air condenser, including residual parameters.

Both the residual inductance, L_c, and the residual resistance, R_c, can therefore cause error in measurement. The inductance, first of all, causes error in the measurement of the circuit conductance, G_e, if static capacitance values are used in Equations (1) or (2). When the effect of the residual inductance, L_c, is considered, these equations become

$$G_e = \frac{\omega(C - C_r)}{1 - \omega^2 L_c(C + C_r)} \cdot \frac{1}{\sqrt{\left(\frac{V_r}{V}\right)^2 - 1}} \qquad (1a)$$

$$= \frac{1}{2}\,\frac{\omega(C_1 - C_2)}{1 - \omega^2 L_c(C_1 + C_2)} \qquad (2a)$$

The inductance also causes error in the determination of the capacitance of the dielectric sample. If C_{r_1} and C_{r_2} are the resonant static capacitances with the sample in and out of circuit, and $\hat{C}_{r_1}$ and $\hat{C}_{r_2}$ the corresponding effective terminal capacitances,

$$C_x = \hat{C}_{r_2} - \hat{C}_{r_1} \simeq \frac{C_{r_1} - C_{r_2}}{1 - \omega^2 L_c(C_{r_1} + C_{r_2})} \qquad (6)$$

The resistance causes the effective conductance of the parallel tuned circuit to change as the condenser setting is altered. While this means that, strictly speaking, the resonance curve is distorted, the effect of the conductance in determining the shape of the resonance curve is small except at settings very near the resonant value and, from a practical standpoint, the residual resistance can be considered as introducing a constant component of conductance equal to the value at the resonant capacitance setting. At the two resonant capacitances, C_{r_1} and C_{r_2}, the conductance components introduced by R_c are different. The difference between the two measured values of conductance, the one with the sample in circuit and the other with it out, is therefore not equal to the conductance of the sample alone but the sum of this conductance and the change in circuit conductance caused by R_c.

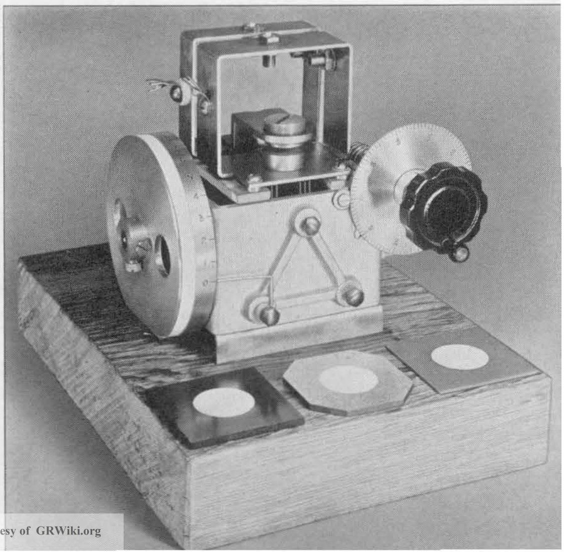
$$\begin{aligned} G_{e_1} - G_{e_2} &= G_x + R_c\omega^2(\hat{C}_{r_1}{}^2 - \hat{C}_{r_2}{}^2) \\ &= G_x - R_c\omega^2 C_x(\hat{C}_{r_1} + \hat{C}_{r_2}) \quad (7) \end{aligned}$$

If no corrections for the residual inductance are used, the capacitance of the sample and the effective circuit conductance will both appear to be smaller than they actually are at very high frequencies. Since the conductance of the sample is found from the difference between the two measured conductances, it will also appear to be smaller than it actually is. If no corrections for the residual resistance are used, the value of the sample conductance will appear even smaller and may even appear to be negative, if the correction becomes sufficiently large.

Satisfactory methods of determining the magnitudes of the residual parameters and of applying the necessary corrections have been worked out and described fully.[16] The application of the corrections, however, is tedious and laborious. The use of a special type of holder for the dielectric sample, which eliminates the error caused by the residual resistance, R_c, is therefore highly desirable. The holder is shown in detail in Figure 4. It consists simply of a brass strap, which is mounted on the ungrounded terminal of the standard condenser and which extends over a brass plate screwed to the grounded terminal. To the grounded plate is attached a disc of brass, above which a threaded rod of the same diameter is tapped into the brass strap. The sample is first placed on the brass disc and the threaded rod screwed down until it touches the electrode, and a conductance measurement is made. The sample is then removed, the threaded rod is screwed down until resonance occurs at the same setting of the standard condenser, and another conductance measurement is made. Since both measurements are made at the same value of resonant capacitance in the standard condenser, the conductance components arising from the residual resistance, R_c, are equal and cancel out when taking admittance differences. The only remaining error is caused by the inductance, L_c, and this error can be corrected for by the use of Equations (1a), (2a), and (6).

The use of the special holder also avoids one of the errors caused by resid-

FIGURE 4. Detail of the condenser assembly. The tuning inductance and the vacuum-tube voltmeter plug into the jacks (TYPE 274-J) mounted on the rectangular straps. These straps are made wide to minimize the resistance and inductance of the leads to the coil, vacuum-tube voltmeter, and coupling condenser. The capacitive coupling to the power source is through the ceramic bushing shown on the left-hand side of the rear strap.



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[16] See footnotes 11 and 15.

ual impedances in the lead from the sample to the standard condenser. This lead necessarily has both resistance and inductance and consequently modifies the admittance of the sample, as measured at the condenser terminals. If, however, the threaded rod is screwed down, as previously described, to give the same resonant capacitance setting with the sample in and out of circuit, the effective conductance component caused by the lead resistance will be the same both with the sample in and with it out of circuit. No correction need therefore be applied for this resistance and the only correction is for the inductance of the lead.[17]

The effect of the lead inductance, L_l, is to make the effective capacitance at the point where the leads are connected to the standard condenser, $\hat{C}_x$, greater than the true capacitance of the sample, C_x, by the factor shown in Equation (8).

$$\hat{C}_x = C_x \left(\frac{1}{1 - \omega^2 L_l C_x}\right) \qquad (8)$$

This correction can be avoided by measuring the capacitance of the threaded rod to the brass disc and deducing the capacitance of the sample from the amount which the rod must be turned to maintain the same resonant capacitance on the standard condenser when the sample is in and out.[18] The gap between the rod and disc, however, becomes so small when the sample is out that the holder must be very carefully made in order to obtain sufficient accuracy. The inductance, L_l, and capacitance, C_x, are both so small in the mechanical arrangement described that the correction is negligible at frequencies up to 100 Mc. The sample capacitance is therefore measured by taking the difference between the two effective resonant capacitances, first with the sample in and, second, with the sample out and the threaded rod screwed up until its bottom face is flush with the bottom of the strap.

MEASURING TECHNIQUE AND RESULTS

Curves of the capacitance and power factor of five different dielectric samples are shown in Figures 5 and 6. No corrections were made for the residual inductance, L_c, in plotting these points. The effect of inductance can be seen in

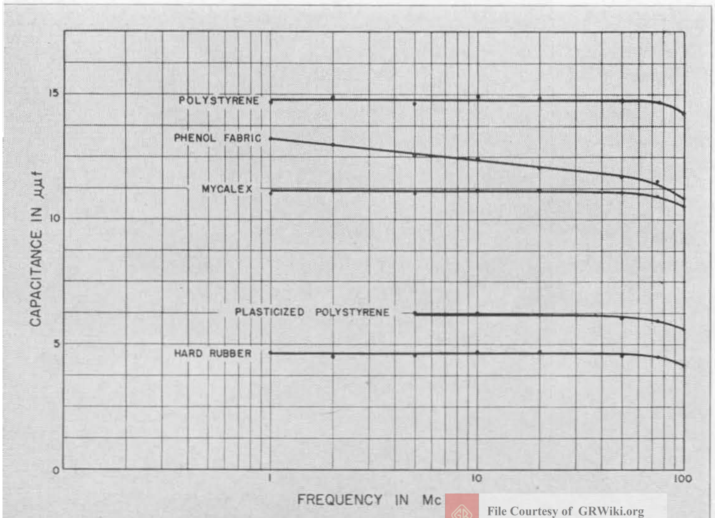

FIGURE 5. Capacitance of dielectric samples as a function of frequency. The falling off of the curves between 50 and 100 Mc is caused by residual inductance in the standard condenser, for which no corrections were made. Corrections can easily be made by the application of Equation (6). The TYPE 684-A Modulated Oscillator was used at frequencies up to 50 Mc. The 75 Mc and 100 Mc points were obtained with the Peterson oscillator described in the October, 1937, issue of the *Experimenter*.

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[17] This procedure for eliminating the corrections necessary for residual resistance in the standard condenser and in the leads to the sample is adapted from a method employing special equipment described in L. Hartshorn and W. H. Ward, "The Measurement of the Permitivity and Power Factor of Dielectrics at Frequencies from 10^4 to 10^8 cycles per second," *Proc. Wireless Section I.E.E.* (London), Vol. 12, p. 6, March, 1937.

[18] See footnote 17.

the droop of the capacitance values between 50 and 100 Mc. It is of little importance in the determinations of power factor, however, because the capacitance increments used to determine both the conductance and capacitance components fall in approximately the same capacitance region. Both are therefore affected by the inductance to roughly the same extent.

There are also corrections for stray capacitances that should be made in order to obtain results of maximum accuracy.[19] These errors are independent of frequency and arise because of the mechanical construction of the holder. The chief error occurs because the stray capacitance of the strap to ground is not the same when the sample is in and when it is out of the holder. The capacitance difference, as read on the standard condenser, is therefore not exactly equal to the capacitance of the sample. Corrections for the stray capacitance were determined from measurements made at low frequencies where the inductance of relatively long leads was not important. Despite the dissimilarity of the samples, these corrections were found to be fairly uniform, ranging from about 0.8 μμf to 1.3 μμf. A small error in conductance also occurs because some of the stray electrostatic field from the strap passes through the sample. The error arising from this source, however, is small because the series air gaps are relatively large.

In order to obtain maximum rapidity, the following measurement routine is convenient:

(1) With the sample in the holder, determine the resonant voltage, V_{r1}, the resonant capacitance, C_{r_1}, and the two capacitance values, C_1 and C_2, at which the voltage is equal to $V_{r_1}/\sqrt{2}$.

(2) With the sample out of the holder, screw down the threaded rod until the resonant point occurs at approximately the same capacitance setting and read the new resonant voltage, V_{r_2}.

(3) With the sample out of the holder, screw up the threaded rod until its lower

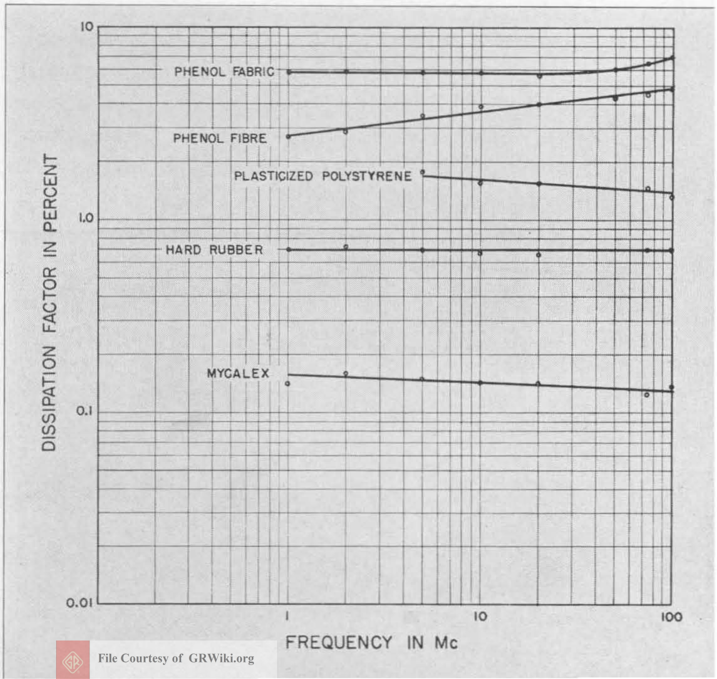

FIGURE 6. Power factor of dielectric samples as a function of frequency. No corrections for residual inductance were necessary in these measurements. Measurements were made of the power factor of the polystyrene sample, the capacitance of which is plotted in Figure 5, but the observations were inconsistent because of the extremely low power factor of this material (less than 0.03%).

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[19] Fringing corrections are not considered in this article, as they do not primarily bear upon the high-frequency measurement problem. The electrodes used on the samples were made of lead foil and were circular in shape. The diameters of the electrodes and the dimensions of the samples were not the same for all samples.

face is flush with the bottom of the strap and read the resonant capacitance C_{r_2}.

The conductance, G_{e_1}, of the parallel-tuned circuit, with the sample in the holder, is found from Equation (2) or (2a). Since the resonant voltage is inversely proportional to the circuit conductance, the conductance of the sample, G_x, is easily found from the following equation:

$$G_x = G_{e_1} - G_{e_2}$$

$$= G_{e_1}\left(1 - \frac{G_{e_2}}{G_{e_1}}\right) = G_{e_1}\left(1 - \frac{V_{r_1}}{V_{r_2}}\right)$$

$$= G_{e_1}\left(\frac{V_{r_2} - V_{r_1}}{V_{r_2}}\right) \qquad (9)$$

The apparent capacitance of the sample is found from Equation (6), and the true capacitance, C_x, found by adding the correction for stray capacitance to the apparent value. The dissipation factor is found from Equation (3).

— D. B. Sinclair

MISCELLANY

● **RECENT VISITORS** to the General Radio plant and laboratories include Mr. G. H. Marchal of the University of Brussels; Messrs. D. Mordossov, A. Vysselski, A. Yurinov, V. Tzvetkov, and P. Kuynetzov of the Glavesprom Commission of the U. S. S. R.; and Mr. R. S. Baldwin of the Bureau of Engineering, U. S. Navy Department.

● **A FEW ERRORS** appeared in the detailed specifications for Type 755-A Condenser, published last month. The gear ratio is 30 to 1, not 15 to 1 as stated. Mounting holes are tapped with a 10-32 thread, not 8-32. Measurements on production units indicate a minimum direct capacitance of less than 5 μμf. Rotor-to-ground capacitance is about 7 μμf, stator-to-ground, about 6 μμf.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also

IN THIS ISSUE

Page

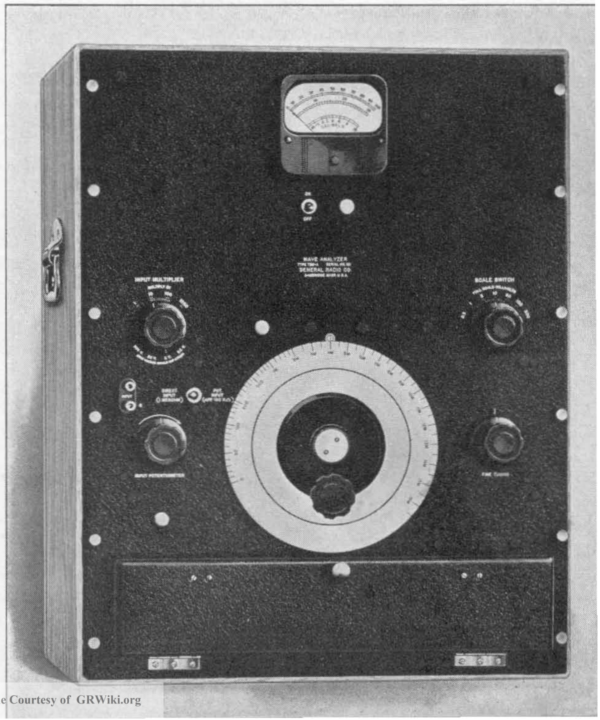
RADIO-FREQUENCY DISTORTION MEASUREMENTS WITH AN AUDIO-FREQUENCY ANALYZER

● **AN IMPORTANT STEP** in the design of the modulator stage of a standard-signal generator is the selection of the proper tubes and operating voltages for maximum output and freedom from distortion. Measurements of power output and distortion are necessary to determine the proper operating conditions.

In the design of broadcast transmitters, the measurements are made by rectifying the carrier with a linear detector and then measuring the distortion in the audio-frequency output. This method is often inapplicable to standard-signal generator measurements because the output voltage may be but a fraction of a volt, and it is practically impossible to make a detector linear at so low a signal level.

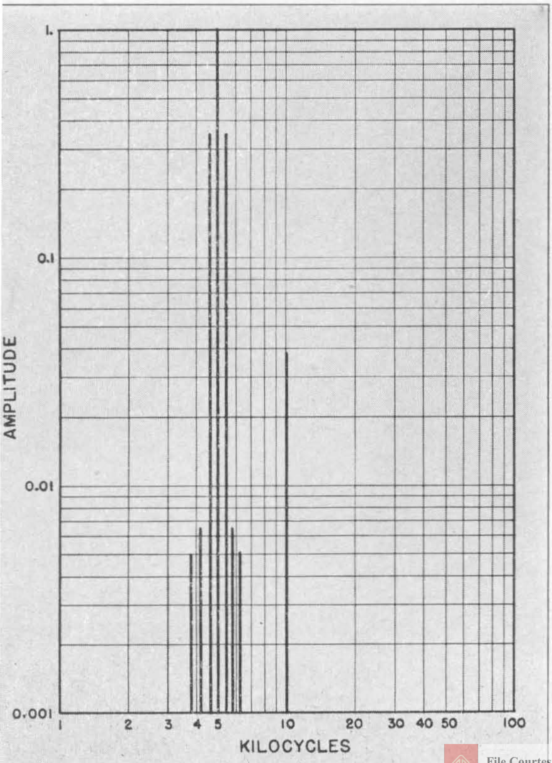
A more laborious method is to measure the radio-frequency output as a function of the

FIGURE 1. TYPE 736-A Wave Analyzer used in the measurements described in this article.



bias on the electrode to which the modulating voltage will be applied. If the characteristic is essentially linear, it is usually assumed that the audio-frequency envelope will be nearly free of distortion. However, it is necessary to measure the output and the bias with a precision of the same order as the minimum percentage distortion and, when the accuracy of ordinary voltage and current meters is not sufficiently good to give the desired accuracy in the result, this method cannot be used. This situation is analogous to that encountered in predicting distortion in amplifiers from measurements of the grid voltage — plate current characteristic.

FIGURE 2. Frequency spectrum for 70% modulation obtained with a low-frequency model of the TYPE 605-B Standard-Signal Generator. The unimportant components $2p \pm q$, $3p \pm q$, etc., have been omitted. While measurable they were not of practical importance. If the signal had been 100% modulated the side-bands $p \pm q$ would have had half the carrier amplitude.



The most direct way of obtaining the results would be to measure the amplitudes of all the products of modulation with a radio-frequency wave analyzer. Unfortunately, wave analyzers for radio frequencies are not available, but the use of an audio-frequency model of the radio-frequency circuit makes it possible to follow the same procedure with an audio-frequency analyzer. In the audio-frequency model, impedances are made the same as they would be at radio frequencies by multiplying the original values of all condensers and inductors by the ratio of the radio frequency to the audio frequency.

An outstanding advantage of this method is that the connection of measuring instruments to the circuit does not appreciably alter the circuit impedances and, therefore, does not affect the operation of the circuit.

If a distorted audio-frequency wave is used to modulate a high frequency in an ideally linear modulator, the resultant signal will be of the form

$$i = [1 + mf(qt)] \sin pt$$

where:

m is the percentage modulation, $f(qt)$ is the audio modulating signal and is assumed to have a peak amplitude of 1, and p and q are the angular velocities of the carrier and audio frequencies respectively.

If this expression is expanded it is found that the spectrum consists of a carrier, first order side-bands $(p + q)$ and $(p - q)$, and higher order side-bands $(p + nq)$ and $(p - nq)$. Each envelope distortion component is proportional to the ratio of the amplitude of $(p \pm nq)$ and $(p \pm q)$.

If carrier distortion is present (corresponding to non-linearity over the high-frequency cycle) there are additional terms containing np. If the high-frequency distortion varies over the audio-frequency cycle, there are still more complex products, such as $(2p \pm q)$, etc.

The above discussion shows that, in aperiodic or broadly tuned circuits, the envelope distortion can be measured by a simple wave analysis of the direct, non-rectified signal. In sharply tuned circuits, other factors may enter the problem, in particular side-band clipping and asymmetrical phase shift in the side-bands, which will introduce envelope distortion, even though no other modulation products are present. Since this article is intended to indicate the method rather than to give a complete treatment of the subject, only the aperiodic case is considered.

Figures 2 and 3 show the results of measurements on an audio-frequency model arranged for studying the modulator of the Type 605-B Standard-Signal Generator. A pure 5-kilocycle signal is used in place of a high-frequency carrier, and this is modulated by a 400-cycle signal. A spectrum for 70% modulation is shown in Figure 2. Figure 3 shows the distortion for various percentages of modulation.

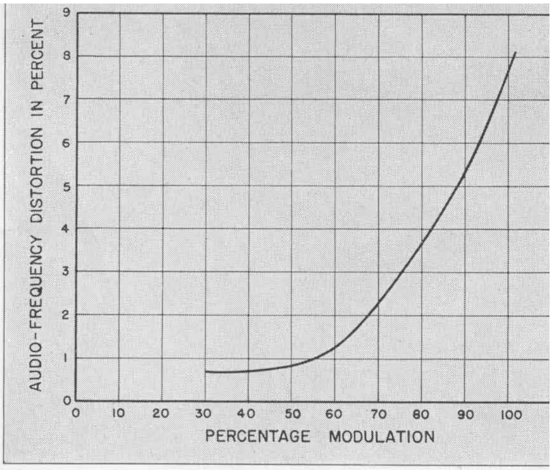


Figure 3. Total distortion as a function of modulation percentage.

Neither the use of a low-frequency model nor the direct analysis of a modulated wave to determine envelope distortion is at all new, but the method has been found so convenient and dependable in designing signal generators that it should find increased usefulness in other non-linear radio-frequency circuits.

— L. B. Arguimbau

EXTENDING THE FIELD OF APPLICATION OF THE VARIAC

● **FREQUENTLY** in attempting to make use of the Variac for voltage control it is found that a particular application involves exceeding in some respect the ratings of the Variac. The voltage may be too high, the frequency of the supply circuit too low, or the current to be handled too great. In some of these instances the method to be suggested may enable one to make use of a standard Variac where it apparently would not be applicable.

The method here proposed is indicated by the diagram of connections shown in Figure 1, and the normal connection that it replaces is shown in Figure 3. It is essential to this method of use that the Variac be used for making adjustments over only a limited range of voltage. The circuit may be used in either direction; that is, to obtain an output voltage variable over a small range with a constant input voltage or to obtain a constant output voltage from an input voltage which varies throughout a small range (or, of course, any reasonable combination of the two). A second requirement is that the transformer primary winding must have three leads instead of the two usually encountered.

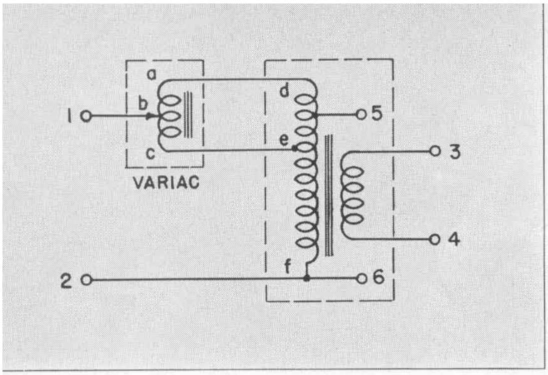


Figure 1. Generalized circuit of the type described in this article.

Figure 1 is almost self-explanatory if it be realized that energy fed to terminals 1 and 2 as input energy can be derived, either autotransformerwise at terminals 5 and 6, or by inductive coupling at terminals 3 and 4. Variations in the voltage of the source may be manually compensated by use of the Variac. Analogous parts of Figures 2 and 3 are designated by the same letters or numbers used in Figure 1.

FIRST APPLICATION

In a typical example, that which first occasioned the use of this method by us, it was desired to use the Variac to compensate for variations likely to be encountered on commercial power lines. The transformer fed from the Variac was to furnish plate and filament power for electronic equipment. For a nominal 115-volt line it was felt that provision for line voltages between 90 and 130 volts would be adequate. Accordingly, the transformer primary, in addition to the common terminal, had leads brought out from turns corresponding to 90 and 130 volts. The extremes of the Variac were connected to the latter two terminals (see Figure 2) and energy fed into the system through the Variac brush and the common terminal of the transformer primary. A number of inductively-coupled secondary loads were to be used, lumped together in the figure as winding 3–4. It will be noted that the voltage drops linearly (with turns or rotation angle) between points *a* and *c* on the Variac and between points *d* and *e* on the transformer primary. In effect then, the Variac provides a vicarious means of moving an input connection up and down on the turns of the transformer primary until a point is found such that the resultant flux density produces the correct voltages in the inductively-coupled windings.

ADVANTAGES

The advantages gained are as follows:

(a) Finer adjustment of voltage because of lower voltage-per-turn of the Variac.

(b) Variac may be used on circuit of higher voltage than would be the case if the connections were made as in Figure 3, that is, with the Variac extremities connected across the full line voltage and with the Variac arm and common point feeding a transformer primary designed for the lowest voltage to which the line might be expected to drop (90 volts in the example given).

(c) As in (b), the Variac could be used on a circuit of lower supply frequency than when using the connections of Figure 3.

(d) In almost all cases, the power-handling ability of the Variac is increased.

(e) A single set of circuit connections in an instrument assembly can be used

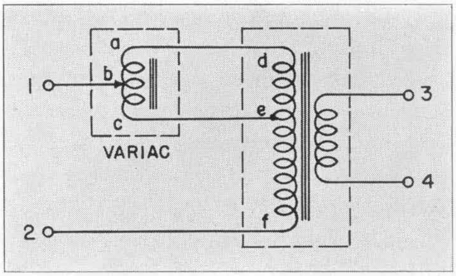


Figure 2. Specific circuit used by the author.

for practically all combinations of supply voltage and frequency likely to be encountered. In the example given, the total voltage across the Variac is only 40 volts whereas ordinarily it would be allowed to go as high as 135 volts, at 50 cycles.[1] This ratio of approximately 3.5 to 1 is available as the approximate maximum for the product of the ratios of supply circuit voltages and frequencies which can be accommodated simultaneously. Actually, if a Variac rated at 135 volts, 50 cycles, be used according to Figure 2, on a supply circuit of 115 volts, 50 cycles, the flux density would be 1/3.5 of the maximum allowable. Using the same Variac at 230 volts, 25 cycles, would result in a flux density four times as great, or only slightly more than the rated value. In practice, the combination of 230 volts and 25 cycles is rarely encountered, but the slightly increased flux density could probably be tolerated because of the lower supply frequency without resulting in excessive no-load losses.

Accordingly, the same Variac could be used in a given instrument for all types of power supply, and the only changes necessary would be those that would have to be made anyway, that is, substitution of a power transformer with the correct windings for the higher voltage and/or lower frequency.

DISADVANTAGES

The disadvantages, less important, are as follows:

(a) The one inherent in the system, namely, that voltage cannot be varied down to zero, but only over a restricted range.

(b) The transformer primary requires three terminals instead of two. To the instrument manufacturer, however, this disadvantage is more apparent than real. If the Variac were used according to Figure 3 for the same purpose of accommodating varying line voltages, the transformer would have to have a special primary suitable for the lowest voltage to be encountered. It is not much more serious to provide a special three-terminal primary when the two-terminal primary would have to be special anyhow.

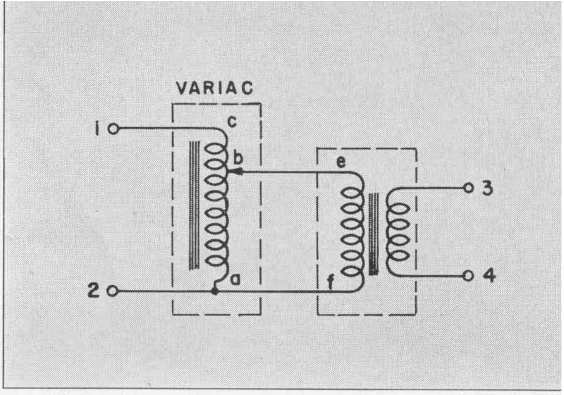


FIGURE 3. Normal method of connection for the Variac.

HOW TO CHOOSE AND APPLY THE CORRECT VARIAC

Selecting the correct size of Variac for use in the circuit of Figure 2 is very little different from the same problem for the circuit of Figure 3. It must be made certain that under the conditions of use the rated and maximum currents of the Variac are not exceeded. The only difference comes about from the fact that the brush carries not the load current but the primary current. With the Figure 3 connection, one usually wishes to derive a certain current on the secondary side, that is, through the brush. The current-rating curves given in the Variac bulletin and in instruction sheets indicate safe conditions of use for this connection. The way they are interpreted must be modified for the Figure 2 type of connection. In this instance, with a given output,

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[1] Note that the TYPE 200-B Variac is rated at 135 volts for 60 cycles line frequency only. At 50 cycles and supplying all the energy allowable, temperature rise would exceed 50° C. on continuous duty. Conditions of use would have to be adjusted if this rise is to be avoided.

the input current through the brush varies inversely with the input voltage, that is, with the position of the brush. The normal brush current should be determined by dividing 115 volts into the secondary volt-amperes (not watts; the Variac rating is in amperes), allowance having been made for the losses in the Variac and the power transformer. This will be the brush current when the line is at normal, 115 volts. If we now refer back to the example given at the beginning of this article, where line voltage may vary between 90 and 130 volts, the brush current will vary respectively from 1.28 times down to 0.88 times the normal brush current. With the normal line voltage about in the middle of the span of the Variac, the normal brush current should not exceed the so-called *rated* current of the Variac. With the line voltage low and the Variac brush rotated to the low-voltage end of the Variac, the brush current is larger and should not exceed the so-called *maximum* current of the Variac. This distinction between *rated* and *maximum* currents is made because, for instance, in the case of the Type 100 Variacs, the rated and maximum currents have the same value, and hence the Variac rating using a Figure 2 connection will be determined by the *maximum* current rating of the Variac. In most other instances, however, the determining factor will be the *rated* current of the Variac.

In wiring up a Variac in this way it must be remembered that the end connections should be reversed from those normally employed. For example, in Figure 3, to produce increasing output voltage with clockwise rotation the clockwise terminal *c* of the Variac should be the *high* one. With this method of Figure 2, however, the clockwise terminal *c* must be the *low* one in order to yield increasing output voltage with clockwise rotation.

—P. K. McElroy

REVISION OF THE SEASHORE MUSICAL TALENT TESTS

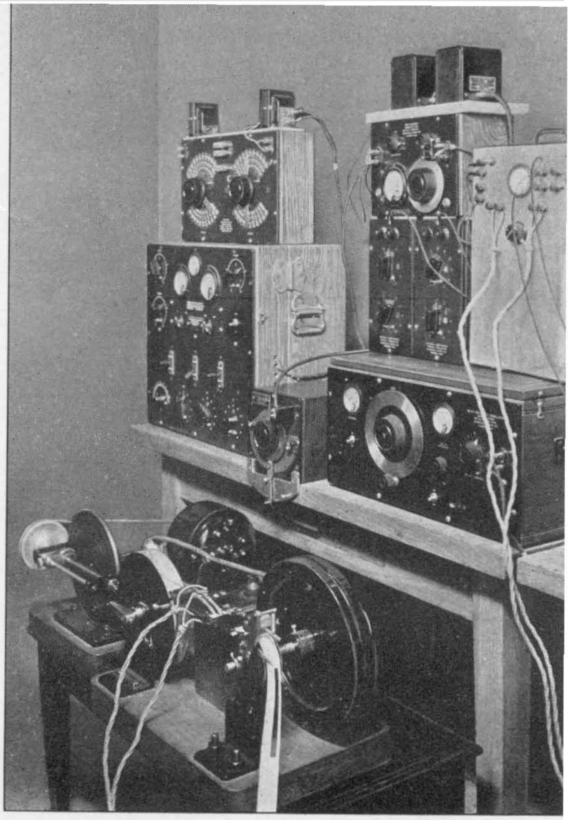
● **SINCE** General Radio instruments are to be found in nearly all college laboratories, it is natural that they are being used continually in new and important development projects in many different fields. Psychological tests and studies always have been among the more interesting applications, and several times unique uses of apparatus in this branch of science have been mentioned in the *Experimenter*.

Recently at the State University of Iowa Psychological Laboratories, General Radio instruments were used in the revision of the Seashore Measures of Musical Talent which have been used internationally by schools, colleges, and universities for the past twenty years. Doctors Seashore, Lewis, and Saetveit revised the tests at the University as to both stimulus sources and values, and the final forms were then recorded on Victor records. Six tests were recorded: pitch, loudness, time, rhythm, tonal memory, and timbre.

The tone source of stimuli for the pitch, loudness, and time tests was a Type 613-B Beat-Frequency Oscillator, which was equipped with a Type 539-P Incremental-Pitch Condenser. Changes in pitch were made with the condenser, and to provide an accurate and rapid means for doing this a special indexing plate was mounted on the condenser. Pegs placed in appropriate holes served as stops for the rotating arm. To obtain the proper timing a special apparatus, carrying paper tape to make and break contacts, was used. The tape was cut to conform with a predetermined schedule of stimulus values, and, once it was inserted and the machine started, the output of the oscillator was started or stopped automatically. Since instantaneous making and breaking of the circuit caused a click, it was necessary to have the contacts control the grid bias on a one-stage amplifier which followed the oscillator and acted as a "transient eliminator." The oscillator output was not varied, but the signal was started and stopped by changing the bias on the amplifier. A condenser in the grid circuit could be adjusted to eliminate all the objectionable clicks.

A 500-cycle band-pass filter followed the amplifier and preceded the TYPE 546-A Microvolter which was used to make changes in signal level. The output of the microvolter was fed through a transformer to a TYPE 329-J Attenuation Box, which was used in the loudness test to change the level by known amounts. From the attenuator the signal went to the recording apparatus.

In running the pitch tests the oscillator and attenuators were set at the beginning, and the only changes that were necessary were made by means of the incremental-pitch condenser. Once the timing tape was started through, it was only necessary for the operator to watch a copy of the test schedule and, acting much as the sound-effect man in a radio broadcast, move the arm and pegs on the condenser according to his cues. Thus the desired stimulus values were produced in the proper order of presentation with the durational factors controlled by the tape timer.



The photograph shows the apparatus used in producing the tones for the revised musical talent tests. On the table at the right are the TYPE 613-B Oscillator and the TYPE 539-P Incremental-Pitch Condenser equipped with the special indexing plate. The TYPE 377-B Oscillator is at the left. In the foreground is the tape timer which controlled the intervals and duration of the tones. The attenuator above the TYPE 377-B was used for varying the loudness. The transient eliminator, coupling transformers, and band-pass filter, together with a TYPE 546-A Microvolter used to vary the output, are atop the TYPE 613-B.

In the loudness tests the pitch was kept constant and the loudness was varied by means of the TYPE 329-J Attenuation Box. The technique for varying the stimulus values and determining the order of presentation was similar to that used in the preceding test — the operator listened to the tones and moved the attenuation dials in accordance with the schedule. Timing was again automatic. The time test required no manipulation of either pitch or loudness controls, and consisted in precutting the tape as before to give the desired time intervals, and then running it through the timer. The same pitch and loudness level were used throughout.

Two oscillators were necessary for the rhythm test, and so a Type 377-B Oscillator was used in addition to the Type 613-B. One oscillator furnished the accented notes and the other the unaccented ones, there being a 4.5-decibel difference in intensity between the two levels. The tape-timing apparatus was arranged with two sets of contacts, and another "transient eliminator" was used with the second oscillator. The tape was punched with holes corresponding to predetermined rhythm patterns. The length of contact was 0.04 second with a tempo of 100 per minute.

For the tonal memory test a Hammond organ was used as the source. Five-hundred-cycle tones from the Type 613-B were used as timing signals for the organist. The oscillator impulses were in turn timed by the tape method. The tempo in the tonal memory test was increased with each succeeding increase of melodic span. In the sixth test, for timbre, a specially constructed electrostatic tone generator was used to produce the desired stimuli, which could not be obtained from an ordinary oscillator.

MISCELLANY

ERRATA

● **THE** following typographical errors occurred in the September *Experimenter:*

Page 4, column 1, should read:

$G_c = 100$ micromhos
$R_c = 0.05$ ohm
$L_c = 0.0055$ microhenry

Page 4, Equation (6) should read:

$$C_x = \hat{C}_{r_2} - \hat{C}_{r_1} \simeq \frac{C_{r_2} - C_{r_1}}{1 - \omega^2 L_c \,(C_{r_1} + C_{r_2})}$$

● **MR. L. B. ARGUIMBAU** has been granted a one-year leave of absence from the General Radio Engineering Department and has joined the staff of the Department of Electrical Engineering at the Massachusetts Institute of Technology, where he is engaged in research in high-frequency measurements.

● **DON'T FORGET** the Second Annual Instrumentation Contest sponsored by the Industrial Instrument Section of the Scientific Apparatus Makers of America. A total of 12 prizes, ranging from $200 to $10, is offered for the best papers on either of the two following themes:

(1) Instruments Save Money
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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also

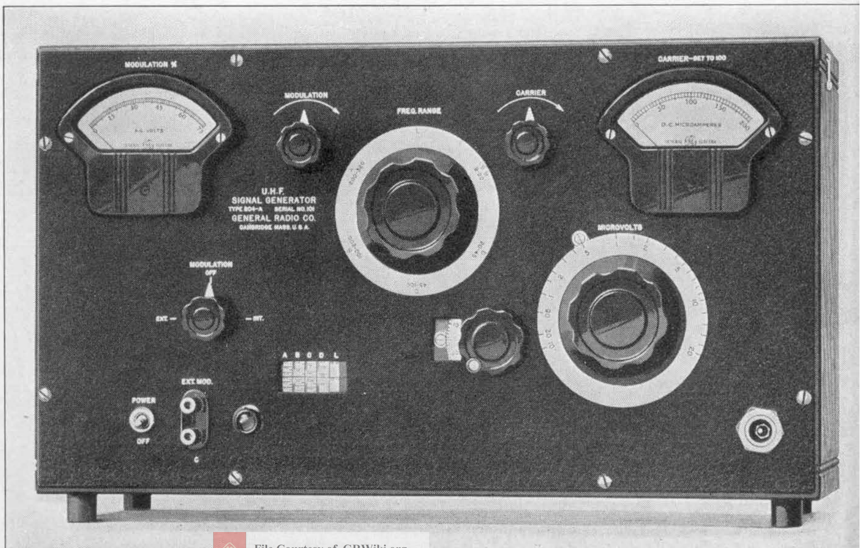
IN THIS ISSUE

A SIGNAL GENERATOR FOR THE ULTRA-HIGH FREQUENCIES

● **RESEARCH** in radio transmission and reception at the ultra-high frequencies continues to foster an increased use of these frequencies for practical radio communication. In addition to their usefulness for television and frequency modulated transmissions, the ultra-high frequencies have an increasing importance for civil and military aircraft communication and for commercial radio service.

Receiver measurements in the high- and ultra-high frequency ranges have been handicapped by lack of testing equipment, particularly signal generators. The Type 804-A U-H-F Signal Generator, shown in Figure 1, is designed for use at these frequencies.

Figure 1. Panel view of the Type 804-A U-H-F Signal Generator.



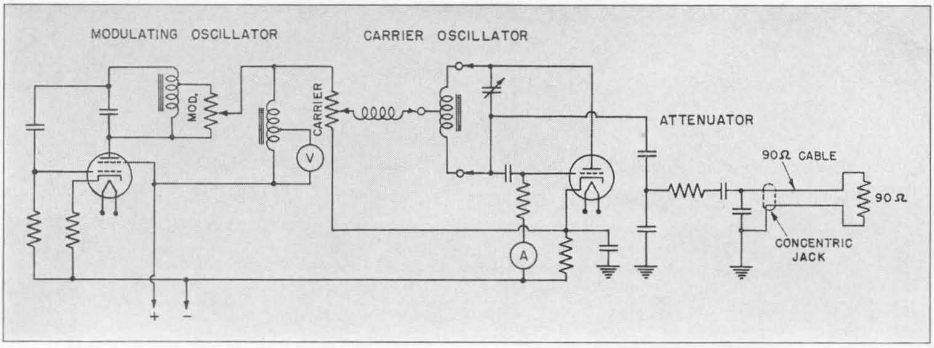


FIGURE 2. Schematic circuit diagram of the signal generator. The a-c power supply is not shown.

GENERAL PERFORMANCE

An important feature of this instrument is its capability of being set accurately to any frequency between 7.5 and 330 megacycles. This wide frequency range is covered by a worm-drive condenser and coil switching system, described below. The output voltage range is from 10 microvolts to 20 millivolts. Internal 400-cycle modulation is provided. An external source of modulating voltage can also be used. Detailed specifications are given on page 5.

CIRCUIT

Both the carrier and modulating oscillators use a conventional Hartley circuit. Carrier level is indicated by a grid current meter, so arranged as to give an indication of oscillator amplitude. The carrier is modulated directly in the oscillator plate circuit, and modulation percentage is indicated by a rectifier-type voltmeter connected across

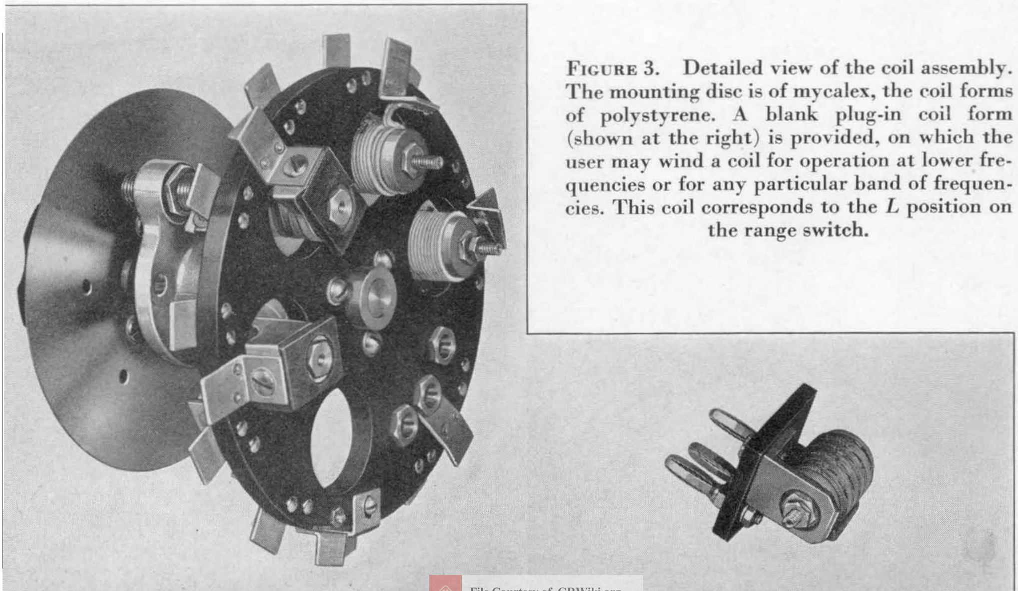


FIGURE 3. Detailed view of the coil assembly. The mounting disc is of mycalex, the coil forms of polystyrene. A blank plug-in coil form (shown at the right) is provided, on which the user may wind a coil for operation at lower frequencies or for any particular band of frequencies. This coil corresponds to the *L* position on the range switch.

a portion of the modulating choke. Because the plate voltage of the carrier oscillator is held constant by a voltage regulating system, this meter is direct reading in modulation percentage, with a range of 0 to 60%. Both meters are the new fan-shaped models with open, easily read scales.

STABILITY

Through the use of a large tuning capacitance and a voltage-regulated power supply, good frequency stability has been achieved in the carrier oscillator. Since modulation is accomplished in the plate circuit of the oscillator, however, an appreciable degree of frequency modulation occurs when the oscillator is modulated. Allowance should be made for this in testing receivers designed to pass the relatively narrow audio-frequency band.

TUNED CIRCUIT

The tuned circuit is an outstanding feature of this generator. The entire oscillating circuit is compact and has unusually short leads. The condenser is a Type 755-A*, designed especially for ultra-high frequency work.

The main condenser dial has 1500 easily read divisions for a frequency spread of about 2.5:1, so that a setting can be made with a precision of considerably better than 0.1%. A frequency calibration is provided directly on the main drum dial. The absolute accuracy of this calibration is ±2%.

The coil assembly is shown in Figure 3. Coils are mounted on a mycalex disc which is rotated from the panel. As each coil is moved into position, its silver contacts are engaged by brushes mounted on the condenser frame. These and the 955-type oscillator tube are shown in Figure 4. In the rear view of the instrument, Figure 5, the entire assembly can be seen.

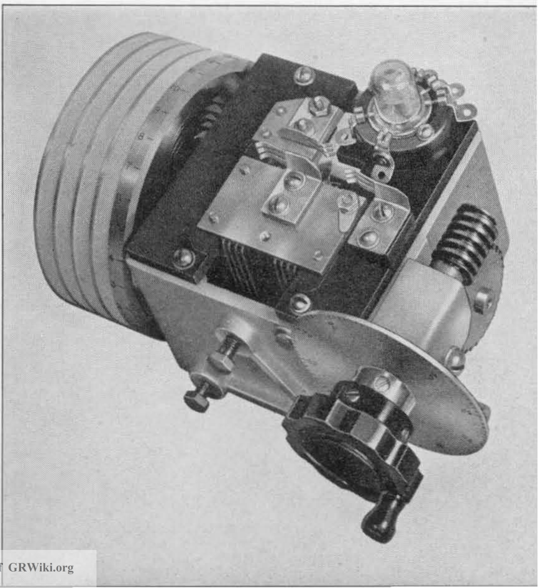
A blank plug-in coil form is furnished for the *L* position of the range switch. This can be wound by the user to operate at any desired frequency in or below the calibrated range of the instrument, or to cover a specific frequency band such as the intermediate frequencies used in television or frequency-modulated reception.

OUTPUT SYSTEM

The output of the Type 804-A U-H-F Signal Generator is continuously variable between 10 microvolts and 20 millivolts. The output is determined by the reading of the output meter and the setting of the attenuator dial.

The capacitive attenuator is shown in Figure 6. To obtain smooth operation, and to facilitate precise settings, the moving element is driven through a reduction gear train. The alignment screws shown in the photograph are so adjusted

Figure 4. Close-up view of the tuning condenser, showing the vacuum tube and the brushes which engage the contacts on the coil mounting. A direct-reading frequency calibration is provided on the drum dial. These scales are shown blank in the photograph.



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*"A New Condenser for High-Frequency Circuits," *Experimenter*, Vol. XIV, No. 3, August, 1939.

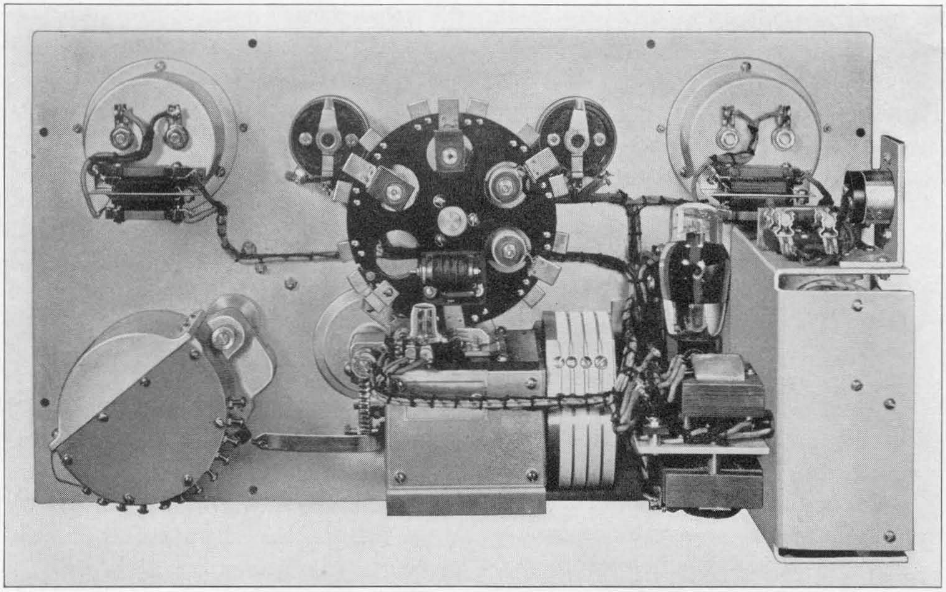


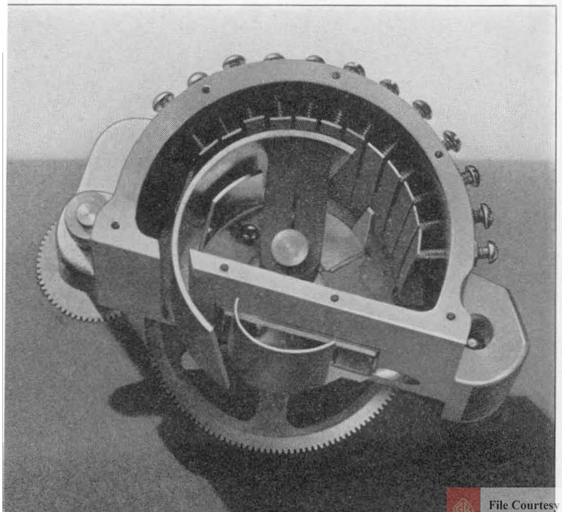
FIGURE 5. Rear view of the signal generator. The coils and condenser are shown in the center, the attenuator at the lower left, the power supply at the extreme right.

that the attenuator presents a constant capacitance to the oscillator circuit, thus eliminating changes in carrier frequency with attenuator setting.

Output voltages are obtained at the output jack at the lower right-hand corner of the front panel. The voltage is developed across a 100-$\mu\mu$f condenser built into the attenuator housing. The output impedance, therefore, varies between 5 ohms at 320 Mc and 200 ohms at 8 Mc.

A 90-ohm concentric shielded cable with a 90-ohm terminating resistance is furnished. At high frequencies, the voltage at the end of the cable is substantially the same as that at the panel jack. A correction is supplied for use at low frequencies.

FIGURE 6. View of the attenuator with cover removed.



POWER SUPPLY

The power supply operates from the a-c line, 105 to 125 volts, 40 to 60 cycles, regulated to eliminate voltage fluctuations. As with most other General Radio instruments, a 210- to 250-volt winding is provided on the power transformer.

SPECIFICATIONS

Carrier Frequency Range: 7.5–330 Mc in five ranges — 7.5–22, 22–50, 50–120, 120–240, 240–330 Mc.

Frequency Calibration: Direct reading within 2%.

Output Voltage Range: 10 microvolts to 20 millivolts for frequencies between 7.5–120 Mc. Above 120 Mc, the maximum output is less.

Output System: 100 $\mu\mu$f output capacitance. 90-ohm cable with 90-ohm termination furnished.

Modulation: Continuously adjustable 0–60%. Internal: 400 cycles ±5%. External: Flat within 2 db from 200 to 20,000 cycles. Five and one-half volts are required for 50% modulation. The input impedance is 0.5 megohm.

Stray Fields: Stray fields will not be noticeable with receivers of less than 10 microvolts sensitivity.

Power Supply: 105–125 (or 210–250) volts, 40–60 cycles, 24 watts.

Tubes: 955, 6G6G, 6X5G, VR150.

Accessories Supplied: Three-foot output cable, 90-ohm impedance. Six-foot cable for line connection. One blank coil form for additional frequency range.

Mounting: Black crackle aluminum panel, walnut cabinet, hinged cover.

Dimensions: (Length) 19½ x (depth) 9 x (height) 11⅝ inches.

Net Weight: 32 pounds.

Type		*Code Word*	*Price*
804-A	....	DENSE	

INDUCTANCE MEASUREMENTS ON LOOP ANTENNAS

● **THE LOOP ANTENNA,** a familiar sight in the early days of factory-built receivers, is with us again. Completely encased, no longer the unsightly hat rack of 1924, it is now used in all portable receivers and many of the newer home models.

Today's loop is usually smaller than its progenitor, because today's receivers are more sensitive than yesterday's, but it still must be tuned. The tuning condenser for the modern loop is ganged with the other tuning condensers and, in order to make the tuning track with

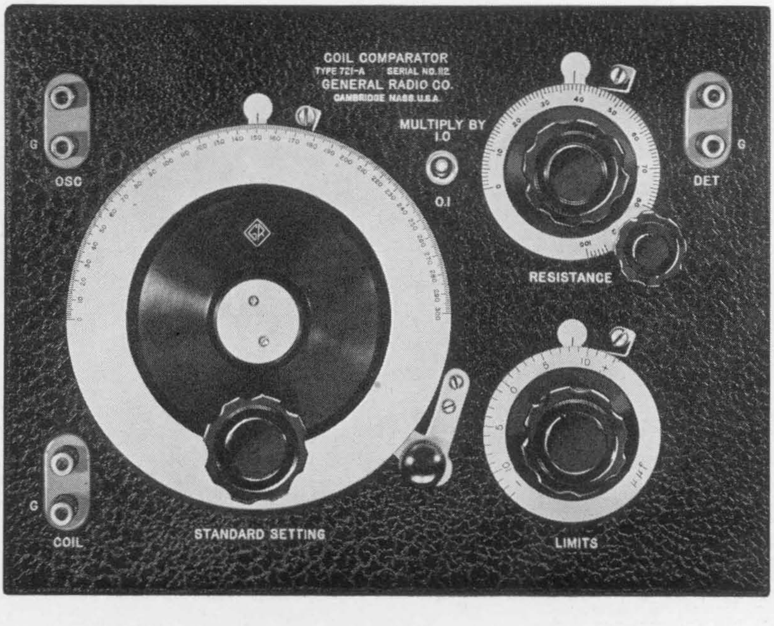


FIGURE 1. Panel view of the coil comparator. For production testing, the main dial is locked at the standard setting and deviations are read on the LIMITS dial.

that of the other circuits, the antenna inductance must be known and kept within close limits. Hence, the need for measuring these loops and making sure that their constants are close to those of a standard which has been especially designed for the receiver.

These measurements are important to the loop manufacturer as a production test in order to avoid rejections by the customer, and to the receiver manufacturer as an acceptance test. For both, a rapid and accurate means of test is desirable.

The TYPE 721-A Coil Comparator* meets these requirements of speed and accuracy. Its usefulness for testing r-f antenna, oscillator, and other coils has been proved many times in manufacturing plants where each part must be tested accurately but rapidly at the normal operating frequency. It has also been used for checking tuning and trimmer condensers and low resistances at radio frequencies, and now is finding wide application by parts and set manufacturers for the checking of loop antennas.

The coil comparator combines the simplicity of a resonance method with the precision of setting of a bridge method. Like a bridge, it is capable of being balanced for a perfect null indication, but unlike a bridge, one side of the generator, of the detector, and of the coil under test is connected to a common grounded point. This simplifies considerably the whole arrangement, and the stray capacitance from generator to ground, or from the detector to ground, does not have to be balanced out or otherwise compensated for. Readings are completely independent of both generator and detector impedances. The effective low impedance of the circuit, moreover, makes other effects such as capacitance between input and output and capacitance to the operator's body almost unnoticeable.

The method of using the coil comparator for this new application is the same as for coils and condensers. First a standard loop is set up, and the comparator is adjusted until a null is obtained at the desired frequency. The standard is then removed, and the production units are next set in place in the test jig. There are two methods of noting the allowable deviations from the standard. The first consists in rapidly adjusting the balance for each loop by means of the LIMITS dial, on which the tolerances can be marked directly. The second method is to replace the

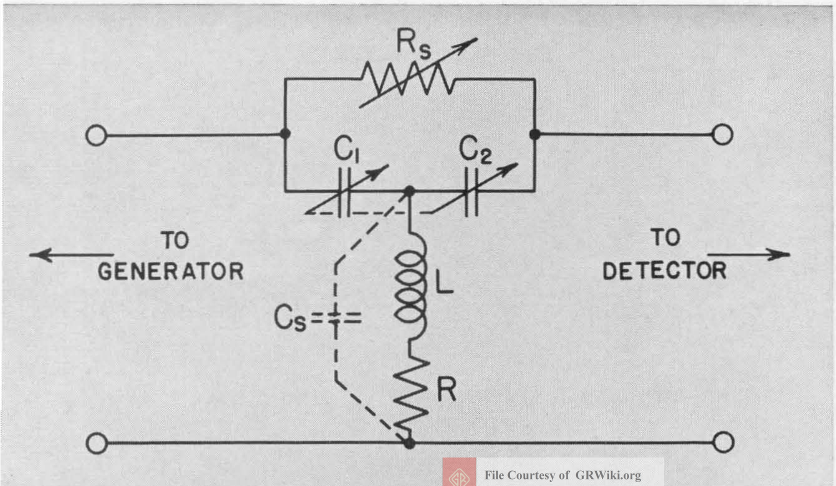


FIGURE 2. Circuit of the TYPE 721-A Coil Comparator. C_1 and C_2 are ganged and operated by a single control. L and R are the inductance and resistance of the coil under test, and C_s is the stray capacitance of the measuring circuit.

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*W. N. Tuttle, "A New Instrument and a New Circuit for Coil or Condenser Checking," *General Radio Experimenter*, Vol. XII, Nos. 3 and 4, August-September, 1939.

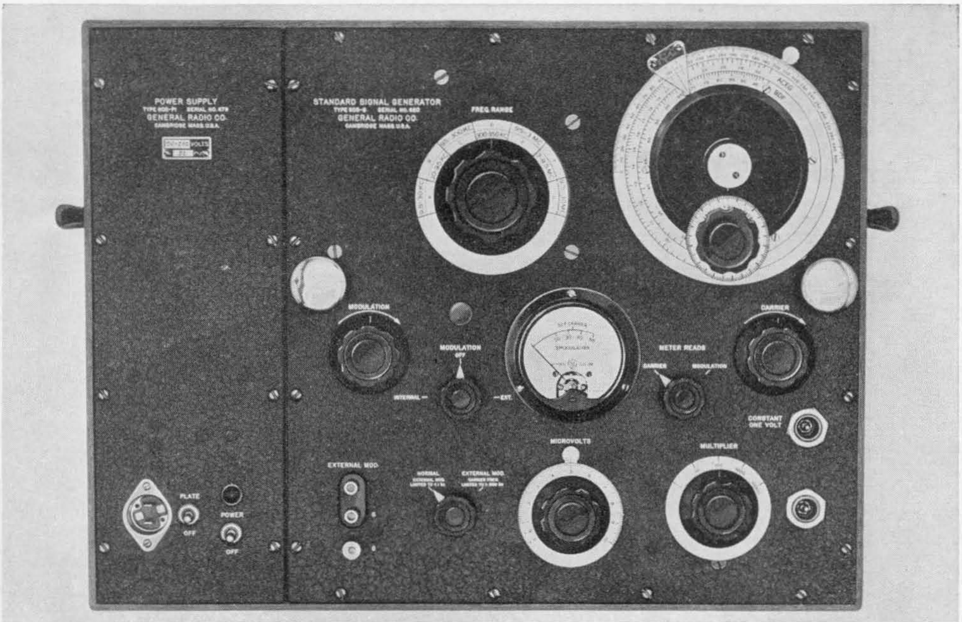
speaker or headphones by a voltmeter on whose scale marks may be placed corresponding to limits that can be tolerated. Of course, it will often be desirable to adjust the loop until it is satisfactory, while it is being checked, rather than have the two operations separate. — MARTIN A. GILMAN

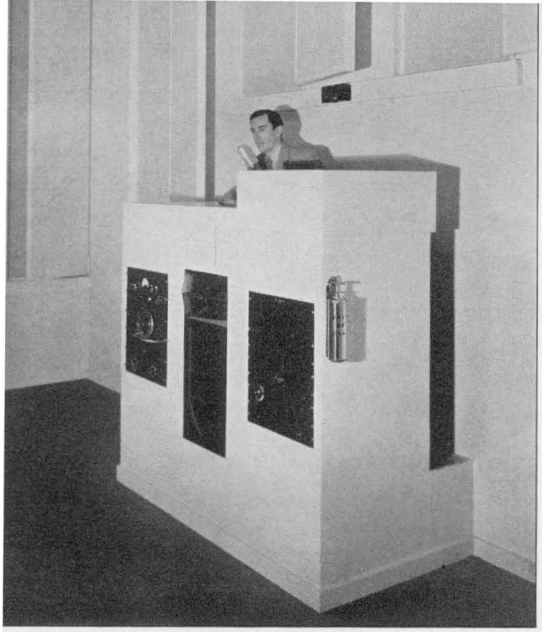
MODERNIZATION OF TYPES 605-A AND 605-B STANDARD-SIGNAL GENERATORS

● **PRICES FOR REBUILDING** old TYPE 605 Standard-Signal Generators to include later design features were listed in the *Experimenter* for December, 1938. Several months' experience with these reconditioning jobs has indicated that the prices originally set were too low, chiefly because of the testing and recalibration time and necessary replacement parts not contemplated when the price was originally set. New prices are as follows:

(1) Addition of 1-volt output jack
(2) New ball-bearing condenser and gear drive dial } . . . . . .
(3) 80% modulation
If change (1) has already been made, deduct . . . .
If (1) and (2) have already been made, deduct. . . . .
If (1) is made separately, the charge is . . . .
If (2) is made separately, the charge is . . . .
If (3) is made separately, the charge is . . . .

(*Continued on next page*)





MISCELLANY

● **THE ACCOMPANYING PHOTOGRAPH** shows the equipment used for the demonstration in acoustics at the University of California Exhibit, Hall of Science, Golden Gate International Exposition. The demonstration contrasted the effects of highly reflective and highly absorbent walls, and gave spectators an opportunity to measure their high-frequency and low-frequency cut-offs. A Type 713-B Beat-Frequency Oscillator was used as the tone source.

● **RECENT VISITORS** to the General Radio laboratories included Messrs. W. E. Jackson, H. I. Metz, and J. C. Hromada of the Civil Aeronautics Authority; Dr. H. C. Hayes of the Naval Research Laboratory and Mr. John Sasso, Assistant Editor of *Product Engineering*.

● **AT THE FALL** lecture series, "Modern Methods for Communications Measurement," conducted by the Communications Group of the New York Section of the A. I. E. E., Mr. A. E. Thiessen of the General Radio engineering staff delivered the lecture on "Measuring Circuits."

MODERNIZATION OF STANDARD-SIGNAL GENERATORS

(*Continued*)

Prices are f.o.b. Cambridge. They include *complete reconditioning, replacement of tubes as necessary, and recalibration.* These reconditioned instruments carry the same one-year guarantee as a new instrument against defects in material and workmanship.

— H. H. Dawes

GENERAL RADIO COMPANY

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BRANCH ENGINEERING OFFICES

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also

IN THIS ISSUE

NETWORK TESTING WITH SQUARE WAVES

● **THE THEORY OF THE RESPONSE OF NETWORKS** to transient impulses has been known and discussed for many years, and from time to time various individuals, particularly those familiar with operational calculus, have used square waves in testing networks. This test method has not been widely applied to communication circuits until quite recently* when its obvious applicability to television circuits has attracted attention to it. Its application to audio-frequency circuits has received little, if any, attention.

The entire behavior of an amplifier or other circuit to applied signals is completely determined by a knowledge of its response to sinusoidal signals in phase and amplitude over the frequency scale. Similarly, its performance is completely determined once its transient response to a so-called unit function, or abruptly steep wave front, is known. It is very likely that similar theorems could be derived for many other functions. The testing method to be chosen depends upon the ease of application and the directness of the information obtained. The waveforms of television images, of speech, and of music are very complicated and

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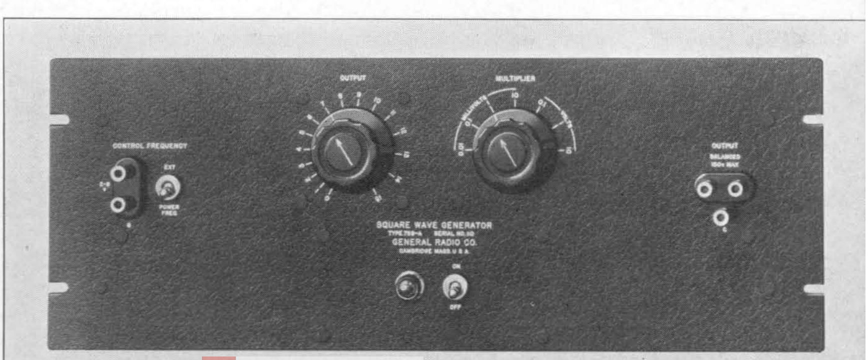
*Gilbert Swift, "Amplifier Testing by Means of Square Waves," *Communications*, Vol. 19, No. 2, February, 1939.

*A. V. Bedford and G. L. Fredendahle, "Transient Response of Multistage Video-Frequency Amplifiers," *Proc. I.R.E.*, Vol. 25, No. 4, April, 1939.

FIGURE 1. Panel view of the TYPE 769-A Square-Wave Generator.



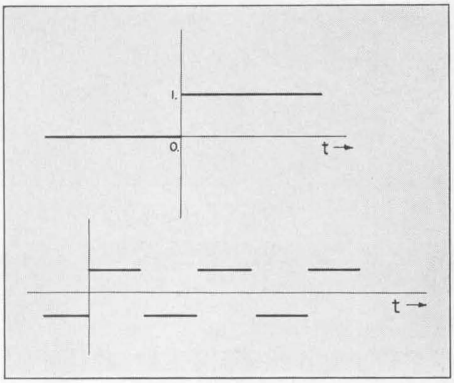


FIGURE 2. At the top is shown a so-called unit function which consists of a suddenly applied voltage. The response of a network to such a signal completely determines the properties of the network. For practical purposes such a transient can be replaced by a square wave of appropriate frequency, like that shown in the lower sketch.

in testing amplifiers it becomes desirable to make use of sinusoidal, square, or other easily reproducible disturbances rather than to use the complicated signals met in practice. Fortunately, the theorems concerning sine waves and unit functions form a good basis for such testing methods.

TELEVISION APPLICATIONS

In television transmitters and receivers it is necessary that the wave shape of a signal be faithfully reproduced. When large black or white areas are scanned, a long uniform voltage pulse must be passed through a condenser-leak coupling network without having appreciable leakage take place during the cycle. On the other hand, when an abrupt transition from black to white is scanned, it is necessary that the voltage change without appreciable time delay and without an oscillating transient.

Some engineers working on television are of the opinion that square-wave testing is of no great value "except to a service man" because they feel small improvements in a single component of a complicated system can be more readily followed by means of phase and amplitude characteristics than by transients. It is true that in complicated cases cumulative effects are not simply additive in transient response, although in some cases they are approximately additive. Others argue that for television the phase and amplitude curves are so artificial that they are of little use, that one should speak and think in terms of time delays and of "over-shoot ratios" and ignore the rest. Certainly in television the square-wave technique is more direct and gives the answer that is fundamentally required. The phase-amplitude method is difficult to interpret and is at best an intermediate tool of no final significance. Square waves are very easy to use and lead to usable results more rapidly than do other methods.

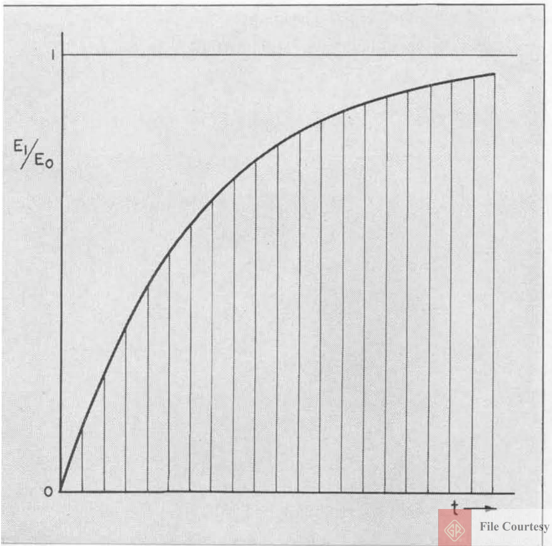
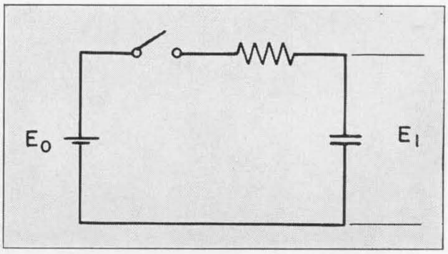


FIGURE 3. Plot of the voltage across the condenser during charge in the circuit shown below.



AUDIO-FREQUENCY APPLICATIONS

As is well known, the sounds of music and of speech are usually formed by the interaction of intermittent vibrators (the saw-tooth motion of a violin string, for example) and resonant cavities. The ear distinguishes one sound from another by the wave shape of the quasi-transients set up. One might expect that an amplifier would have to reproduce this waveform accurately in order to lay claim to "high fidelity." Those who are familiar with the strict requirements placed on video amplifiers will realize that acoustic waveforms are certainly not preserved by ordinary audio equipment. For many years, however, it has been the practice to rate the performance of audio equipment on the "frequency characteristic" by which is usually meant the over-all amplitude response as a function of frequency. To be sure, a system which is "flat" from 50 cycles to 10,000 cycles is almost certain to sound better than a system which is only moderately "flat" from 300 to 3000 cycles, but in less obvious examples mere flatness is not necessarily a measure of fidelity. Although little data are on hand, it has been reported that listening tests do not always agree with over-all electrical tests. This is rather to be expected, since the behavior of a network is measured not only by its amplitude response but also by its phase response, and it should not be surprising to find that in some cases the remark, "it sounds terrible" may be more scientific than the statement, "it is flat from 50 to 5000 cycles." Square waves offer a simple and rapid method of including both phase shift and amplitude response in a single test.

SQUARE-WAVE RESPONSE OF SIMPLE CIRCUITS

Tests made by means of square waves on a wide variety of circuits indicate that the nature of the circuit may be fairly accurately determined without elaborate computation by observation of the transient response. Fortunately, many of the circuits met with in practice give very simple and easily recognized transient response curves, which can be used as a guide for other more complicated cases.

In order to give an idea of this simplicity a single case is treated here. Figure 3 shows the familiar exponential rise of the condenser voltage when a condenser is charged through a resistor. (The curve is drawn for a circuit in which $\frac{1}{2\pi\ x\ 1\ x\ C} = R$; in other words one in which the condenser reactance at 1 cycle is equal to the resistance.) For other values of the time constant, *CR*, the resultant curves are exactly the same except for the horizontal scale which is

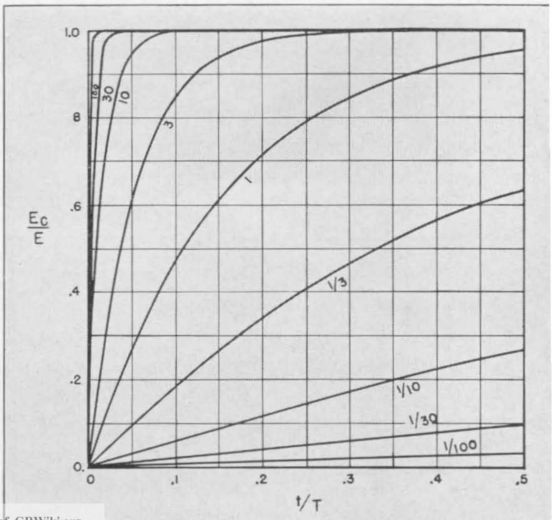


FIGURE 4. Curves of the voltage across a condenser during charge for different values of n, where n is $\frac{1}{2\pi CR}$, which is the ratio of reactance to resistance for the frequency at which the curve shown is the wave shape of the response over a half cycle.

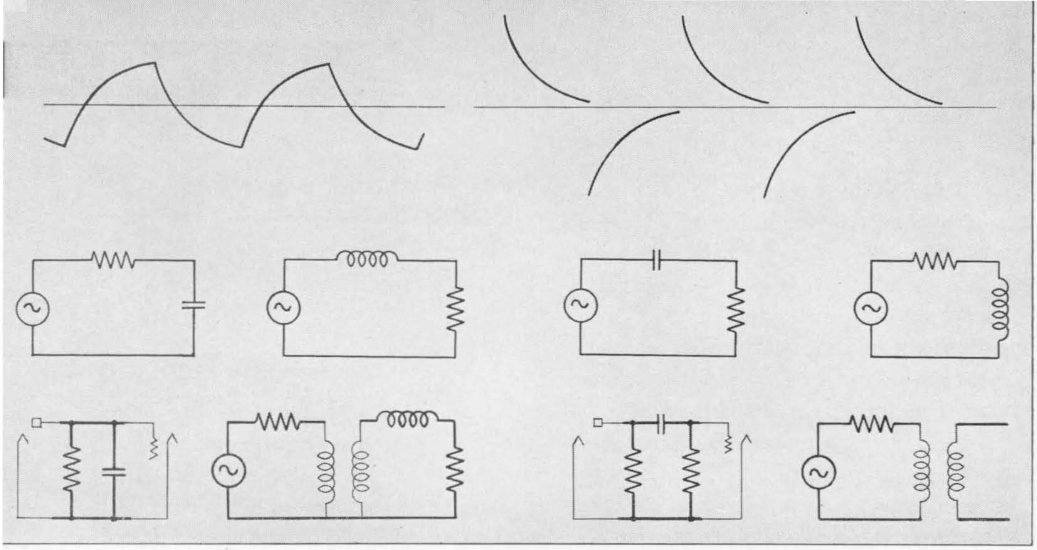


FIGURE 5. The curve at the upper left shows the voltage across the condenser in a series RC circuit when a square wave is applied. Below the plot are shown several circuits giving this type of response. At the right is shown the voltage across the resistor under the same conditions, together with circuits giving a similar square-wave response.

multiplied or divided by a constant factor. Several such curves are shown in Figure 4. If a square wave of unit period is applied to such a circuit the voltage wave across the condenser will be as shown at the left in Figure 5, which is made up of a series of segments each similar to the curve of Figure 3.

The voltage across the resistor is the difference between the applied unit voltage and the condenser voltage. In other words, it is given by the white area above the shaded area of the condenser charge curve. This response is shown at the right in Figure 5.

This same series of curves also applies to the case of inductive circuits where capacity effects are negligible. A group of such circuits is shown in Figure 5 which shows some of the practical cases covered by this one series of curves.

Another article in this month's issue of the *Experimenter* shows the transient curves obtained for a variety of transformers. In a later issue we hope to publish some over-all transient responses for broadcast transmitters and receivers.

In the case of the simple circuits outlined above, it is relatively easy to derive the over-all amplitude-frequency characteristic from the transient response (the converse is not true). In such cases it would seem quite clear that a knowledge of the transient response is more valuable than a knowledge of the amplitude characteristic, because the latter does not necessarily imply a knowledge of the phase response. In very poor, narrow-band, amplifiers it is more difficult to apply square-wave methods because it is difficult to separate the low-frequency cut-off effects from the high-frequency effects. This results in both ends of the characteristic being badly scrambled in a single square wave. In such cases, however, the amplitude response is itself difficult to evaluate in terms of fidelity.

TYPE 769-A SQUARE-WAVE GENERATOR

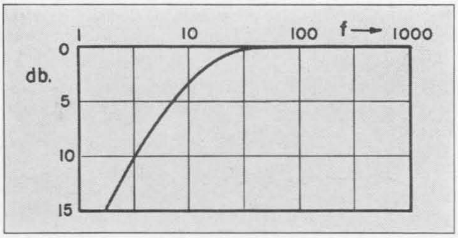
With this issue the *Experimenter* is announcing a square-wave generator which is primarily intended for audio-frequency testing. As will be noticed by reference to Figure 7, the circuit consists essentially of an amplifier which is so arranged that it overloads with extraordinary ease. A voltage of 2–8 volts from the power line or an external source is amplified to about 75 volts and it then has both sides of the wave clipped off by a double diode. This squared signal is re-amplified and carefully clipped by a pair of cascaded diodes. Finally, this signal is amplified and attenuated to any desired level.

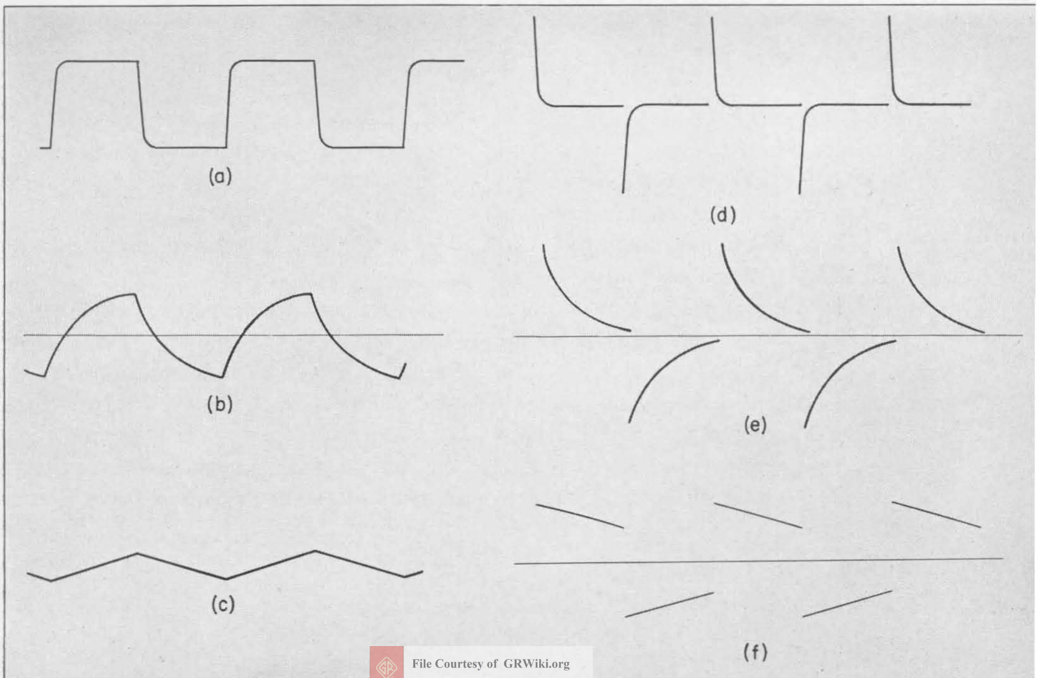
The generator is not arranged for use at video frequencies but can be used to test the low-frequency response of a video amplifier and is entirely adequate for all audio-frequency use. The internal dynamics of the generator itself are roughly those which would result from an amplifier having a "flat response" from about 1/10 of a cycle to about 250 kc. Complete specifications are given on next page.

The problem of getting quantitative data on the fidelity of amplifiers is a very important one, and it is likely that the customary amplitude rating is insuf-

FIGURE 6. The curves below, left, show the voltage across the condenser in the circuit of Figure 3 when a square wave is applied. Curves (a), (b), and (c) correspond to reactance-to-resistance ratios of 10, 1, and 0.1, respectively. These curves are characteristic of the high-frequency response of fully damped amplifiers. The curves at the right show the voltage across the resistance. Curves (d), (e), and (f) correspond to reactance-to-resistance ratios of 10, 1, and 0.1, respectively. They are characteristic of the low-frequency response of amplifiers.

At the right is shown the amplitude response for a single-stage amplifier. A response of the type of (d) corresponds to a frequency of 1 on this curve, (e) to 10, and (f) to 100. It will be noticed that the amplitude response curve is almost entirely flat at 100, although the response to a square wave of this frequency is by no means square. This illustrates the necessity of considering phase shift as well as amplitude response.





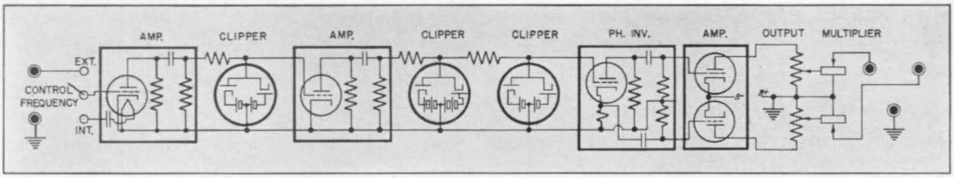


Figure 7. Schematic circuit diagram of the Type 769-A Square-Wave Generator.

ficient. It would seem highly desirable for someone to make an attempt to correlate transient response with listening tests. In any case, square waves appear to offer a new possibility of improving high-fidelity performance.

— L. B. Arguimbau

SPECIFICATIONS

Frequency Range: Square waves with fundamentals from approximately 10 cycles per second to 5000 can be produced. The output circuit will pass frequencies between 0.1 cycle and 250,000 cycles.

Output Voltage: Peak-to-peak, 150 volts on balanced output; 75 volts unbalanced. The minimum output voltage is 10 microvolts.

Attenuator: A slide wire and a 6-step multiplier are used. The frequency characteristic (wave shape) is not affected by the attenuator setting.

Squareness of Waveform: At low frequencies, the entire rise in voltage takes place in 0.001 cycle.

Output Impedance: 500 Ω, balanced; 250 Ω unbalanced for low-voltage output. The impedance is independent of frequency down to d-c. No condenser is used in the output. $B+$ is grounded.

External Oscillator: An oscillator capable of delivering 6 volts, open circuit, is required to excite the square-wave generator. A 60-cycle control system is built in.

Power Supply: 105–125 volts, 50–60 cycles. The power input is 60 watts.

Mounting: 19-inch relay-rack panel.

Dimensions: Panel, 19 x 7 inches; depth behind panel, 8½ inches.

Net Weight: 22 pounds.

Type		*Code Word*	*Price*
769-A	....	ASPEN	

HIGH QUALITY AUDIO TRANSFORMERS

● **SQUARE - WAVE TESTING,** the theme of the preceding article in this month's issue of the *Experimenter*, affords an excellent means of reviewing twenty years of audio-transformer history. Figure 1, which shows square-wave patterns for four types of transformers ranging from the early Type 231 to the current Type 641, is an index of the improvement in the frequency range of reproduced speech and music that has taken place in those twenty years.

Fidelity requirements on audio-frequency systems have constantly increased and, with them, the performance requirements of equipment and circuit components.

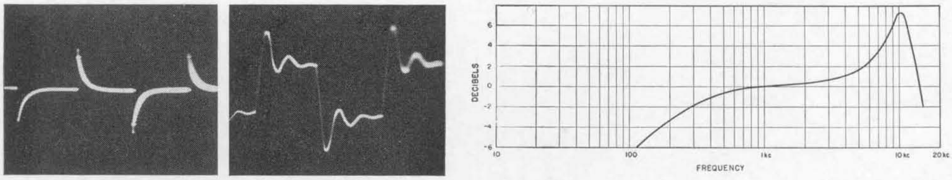
The new Type 641 Transformers are designed and constructed to meet the exacting requirements of high quality audio systems. Electrically, they have a wide frequency response, they have electrostatic and electromagnetic shields, and accurately balanced windings. Mechanically, they are so designed that the cases can be mounted in several different ways with terminals easily accessible for wiring.

FREQUENCY RESPONSE

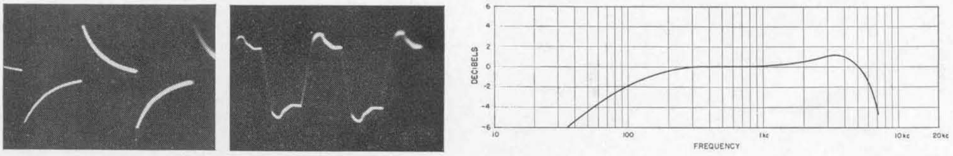
Present-day broadcast equipment uses an audio-frequency band of about 30 to 10,000 cycles, sound-recording systems a slightly narrower band. To maintain a flat amplitude response over this range for a whole system requires a far better response of the individual circuit elements.

In an amplifier using three transformers, if each is down 2 db at 10,000 cycles, the over-all response is down 6 db at that frequency, or 2 to 1 in voltage. Obviously, the transformer characteristic should show no appreciable dropping off at 10,000 cycles. Similar considerations hold for the low-frequency end.

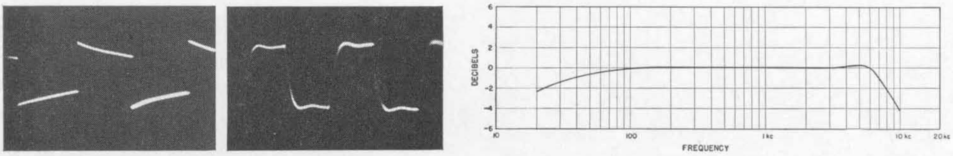
Type 641 Transformers are designed for use in high-quality systems, and, for most models, the response is down only 1 db at 20 and 20,000 cycles. Consequently, several units can be cascaded in an audio system without appreciably



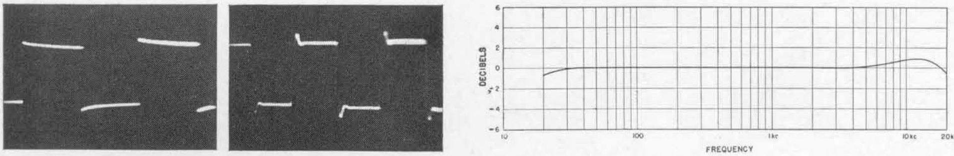
(A) 60~ 2000~ Type 231 1920



(B) 60~ 2000~ Type 285-A 1924



(C) 60~ 2000~ Type 585-H 1928



(D) 60~ 2000~ Type 641-E 1939

Figure 1. Square-wave response patterns and amplitude-frequency characteristics for the transformers indicated in the captions above. The oscillogram at the left is the response to a square wave of 60 cycles fundamental, and the right-hand oscillogram is for a wave of 2000 cycles fundamental. These oscillograms should be compared with the curves on page 5. The 60-cycle response shown above is similar to curves (d), (e), and (f) on page 5. The 2-kilocycle pattern is basically the same as that of curve (a), but there is superposed on the curve a damped oscillation of a frequency corresponding to that of the resonant point in the amplitude-frequency curve. This transient could be suppressed by increasing the secondary damping.

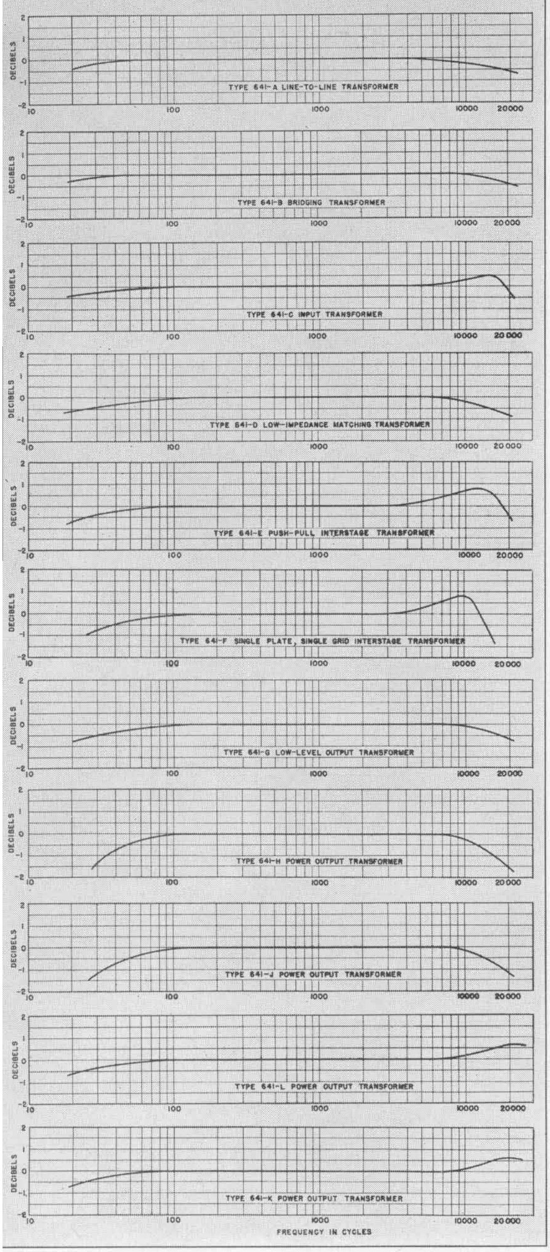


Figure 2. Typical amplitude-frequency curves for all models of Type 641 Transformer.

affecting the frequency characteristic. Of equal importance is the transient response of the transformer as measured by an applied square wave. As the oscillogram of Figure 1 shows, very little distortion of the square wave occurs in Type 641 units.

Frequency response curves for all models are shown in Figure 2. Since the apparent low-frequency response of a transformer can be varied by a number of factors, such curves are of little value unless the conditions under which the measurements are made are completely stated. Two things are important with regard to the curves shown here:

(1) The low-frequency response data are taken, not under the most favorable conditions, but under the *least* favorable ones.

(2) The measurements are accurate.

A characteristic of high permeability alloy cores is that the permeability at very low levels is considerably below the maximum value. Tests on the output models are made with 0.1 volt applied to the primary; normal operating level is, of course, much higher. In order to assure accurate measurements at low levels, the low-frequency response is measured with a Type 736-A Wave Analyzer. This also eliminates all errors caused by hum and by harmonics in the test oscillator. The general method of measurement has been covered in a previous article.* It can be seen from the curves of Figure 2 that the response at 20 cycles for many of these transformers is down less than 1 db, necessitating an accuracy of measurement of about .2 db or 2%. Without the wave analyzer, using a good beat-frequency oscillator and a vacuum-tube voltmeter, the error at 20 cycles may be considerably greater than this, both because of oscillator harmonics and because of waveform error in the voltmeter. When the wave analyzer is used, the waveform of the oscillator is unimportant.

CONSTRUCTION

Careful design and construction account for many of the excellent charac-

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*A. E. Thiessen, "Waveform Errors in the Measurement of Filter Characteristics," *General Radio Experimenter*, March, 1935.

teristics of these transformers. The core is made up of thin laminations of high-permeability alloy. Windings are in two symmetrical sections to assure accurate balance to ground. An electrostatic shield between primary and secondary isolates the two circuits so that the transformer can be used between a grounded circuit and a balanced circuit.

Low-loss insulating material tested on 1000 volts is used between windings and between winding and core. Coils are wound in layers insulated from one another with less danger of breakdown and shorted turns than occurs in random-wound coils. Input, interstage models and impedance-matching, which operate usually at low levels, are provided with a high-permeability magnetic shield which attenuates a-c hum by about 50 decibels. Outside the magnetic shield is the aluminum case. Terminals are brought out at one end.

BALANCE

Excellent shielding and balance-to-ground is obtained in these transformers.

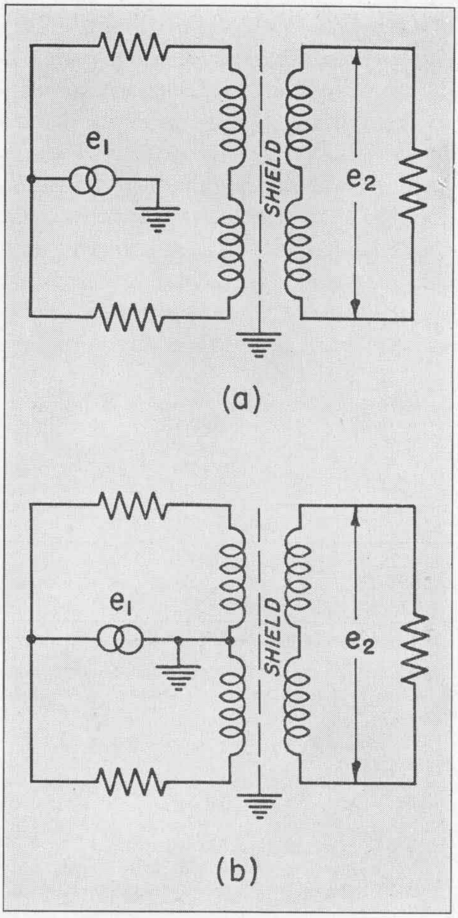
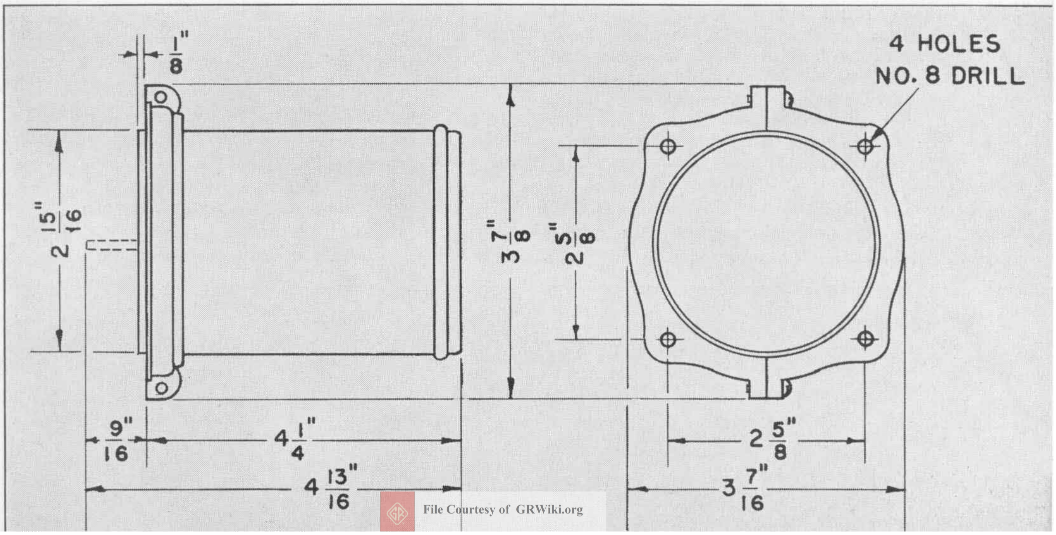


FIGURE 3. (a) Circuit for measuring longitudinal transmission; (b) circuit for measuring longitudinal and unbalance transmission.

FIGURE 4. Over-all dimensions of TYPE 641 Transformer.



For the types used in broadcasting and sound-recording service, the balance is sufficiently good to balance out all pickup from hum or other sources on the lines to which they are connected. Figures for longitudinal and unbalance transmission for these models are given below.

The so-called longitudinal transmission, measured as indicated in Figure 3a, is a measure of the electrostatic shielding. By introducing e_1 as shown in Figure 3b, the sum of unbalance and longitudinal transmission is obtained.

MOUNTING

Not least among the features of these transformers is the method of mounting. The case is clamped in a metal ring, which is in turn attached to baseboard or shelf on which the transformer is to be mounted. The case can be mounted either above or below the shelf, with terminals projecting in either direction. Figure 5 tells the story completely.

— L. E. Packard

SPECIFICATIONS

Type	*Longitudinal and Unbalance Transmission (Decibels Below Test Voltage)**			*Longitudinal Transmission (Decibels Below Test Voltage)**		
	100~	1 kc	10 kc	100~	1 kc	10 kc
641-A	72	55	40	95	105	81
641-B	87	58	47	85	79	61
641-C	68	39	17	85	65	57

*One volt applied as shown in Figure 3.

Uses: See table. Numbers refer to the more common types of tubes with which the model can be used.

Frequency Range: The table gives the frequency range over which the voltage ratio is less than 1 decibel below its value on the flat portion of the characteristic, and the operating conditions for this performance. Sample frequency curves are given in Figure 2.

The frequency range naturally holds only when the primary source has an internal impedance equal to that specified under "Out of (ohms)," and the load is as specified under "Into (ohms)." In several of the output transformers the source impedance from which they are to work is different from the impedance which should be reflected back to the tube by the transformer. The table gives the proper source impedance (the plate resistance of the tubes), while the footnotes give the load impedance as seen by the tube.

The column headed "Pri. DC" gives the maximum direct current which can be handled by each section of the primary winding under balanced conditions, while the "Unbalance DC" column gives the maximum allowable current unbalance for the stated frequency range, and the allowable direct current when the unit is operated single-ended.

Maximum Level: Under the column "Max. Level" is given the audio power or primary voltage which each transformer will handle with negligible distortion. At higher values some low frequency distortion occurs.

Turns Ratio: The ratio of turns of the whole primary winding to the whole secondary winding is given in the "Turns Ratio" column.

Electrostatic Shielding: The line-to-line, bridging, input, and low-impedance matching transformers, Types 641-A, -B, -C, and -D, respectively, all have an electrostatic shield to assure isolation between the primary and secondary windings.

Magnetic Shielding: The line-to-line, bridging, input, low-impedance matching, and interstage transformers, Types 641-A, -B, -C, -D,

Figure 5. Several ways of mounting Type 641 Transformers. From left to right: above shelf with terminals at top, above shelf with terminals below, below shelf with terminals at top (clamping ring can be below shelf, if desired), and below shelf with terminals at bottom.

-E, and -F, respectively, all have a high permeability magnetic shield which introduces about 50 decibels of attenuation to hum pickup.

Terminals: Soldering lugs are provided.

Mounting: Each transformer is mounted in a cylindrical aluminum case. The base clamps on and is arranged so that the unit can be mounted above or below the mounting shelf with the terminals either up or down.

Dimensions: See FIGURE 4.

Net Weight: 3 pounds, all types.

Type	*Uses*	*Out of*[1] *(ohms)*	*Into*[1] *(ohms)*	*Pri. DC (bal) (ma)*	*Un-balance DC (ma)*	*Freq. Range Down 1 db*		*Max. Level*	*Turns Ratio*	*Code Word*	*Price*
						From (cycles)	*To (cycles)*				
641-A	Line, Mixer to Line, Mixer[5,6]	50 to 60 125 to 150 200 to 240 500 to 600	50 to 60 125 to 150 200 to 240 500 to 600	—	—	20	20,000	6 watts	1 to 1	UDDER	
641-B	Bridging 500 to 600Ω Lines[5,6]	10 to 1000[2]	50 to 60 125 to 150 200 to 240 500 to 600	—	—	20	20,000	20 watts in line	4.1 to 1	ULCER	
641-C	Line, Mixer[5,6] to P-P or Single Grids	50 to 60 125 to 150 200 to 240 500 to 600	P-P Grids or Single Grid (Class A)	—	—	20	20,000	30 volts across total primary	1 to 8.9	UMBER	
641-D	Low-Impedance Matching[5,6]	1.2, 2.5, 5, 7.5, 10, 15, 20, 30	50 to 60 125 to 150 200 to 240 500 to 600	—	—	20	20,000	6 watts	1 to 4.1	UNDER	
641-E	P-P Plates (6C5, 6J5, 6L5-G, etc.) to P-P Grids	16,000 to 24,000 plate-to-plate	P-P Grids	40	—	20	20,000	120 volts, plate-to-plate	1 to 2.1	UNION	
641-F	Single Plate (6C5, etc.) to Single Grid	9000 to 13,000	Single Grid (Class A)	—	10	30	14,000	70 volts across primary	1 to 3	UNITY	
641-G	P-P Plates (6C5, 6J5, etc.) to Line[5]	10,000 to 40,000	50 to 60 125 to 150 200 to 240 500 to 600	40	—	20	20,000	6 watts	6.3 to 1	UNCLE	
641-H	P-P or Single Plates (2A3, 6A3, 45, etc.) to Speaker	800 to 2200[7]	1.2, 2.5, 5, 7.5, 10, 15, 20, 30	95	60	30[3]	20,000[3]	20 watts	12.9 to 1	VIZOR	
641-J	P-P or Single Plates (2A3, 6A3, etc.) to Line	800 to 2200[7]	50 to 60 125 to 150 200 to 240 500 to 600	95	60	30[3]	20,000[3]	20 watts	3.1 to 1	VOCAL	
641-K	P-P Plates (6L6, etc.) to Speaker	20,000 to 40,000[4]	1.2, 2.5, 5, 7.5, 10, 15, 20, 30	90	5	20	20,000	20 watts	14.3 to 1	WEARY	
641-L	P-P Plates (6L6, etc.) to Line[5]	20,000 to 40,000[4]	50 to 60 125 to 150 200 to 240 500 to 600	90	5	20	20,000	20 watts	3.5 to 1	WINDY	

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[1] These limits may be changed by as much as 10% without causing appreciable changes in the transformer characteristics.

[2] This transformer places a load of 5000 or 20,000 ohms across the line, depending on which tap is used. To do this and still match output impedances, series resistors are built into the unit.

[3] Response is down 2 db at these frequencies except on 2.5 Ω and 10 Ω taps of TYPE 641-H where response is down 2 db at 14,000.

[4] This transformer places a load of 6000 ohms across the tubes. This is the proper load for 6L6's operating CLASS A or AB.

[5] 240 Ω and 600 Ω taps can be used either balanced or single-ended.

[6] These transformers have electrostatic shielding between windings.

[7] This transformer places a load of either 3000 or 5000 ohms across the tubes. These are the proper loads for 2A3's operating with fixed or self-bias respectively.

MISCELLANY

● **AN EXHIBIT** of General Radio apparatus will be held at the Stevens Hotel, Chicago, from February 12 to 17, 1940. This is to be a working display of equipment as it is used in typical applications and will include many new instruments. *Experimenter* readers are cordially invited to attend.

● **"ENGINEERING ADMINISTRATION** in a Small Manufacturing Company" was the title of a [illegible] delivered by C. T. Burke at I.R [illegible] onvention, New York, Septemb [illegible], at the Philadelphia Section, I.R.E., on November 2, and at the Emporium (Pennsylvania) Section, November 10.

● **DESIGNERS** of the instruments described in this issue:

TYPE 769-A Square-Wave Generator, L. B. Arguimbau; TYPE 641 Transformers, L. E. Packard.

● **AT THE ROCHESTER** Fall Meeting of the I.R.E. and R.M.A., E. Karplus delivered a paper on "Standard-Signal Generators" and L. B. Arguimbau spoke on "Square-Wave Testing," accompanying his talk with a demonstration. At the banquet, H. B. Richmond, treasurer of the General Radio Company, spoke on the subject of co-operation between the I. R. E. and R. M. A.

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