the GENERAL RADIO Experimenter

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TO

GENERAL RADIO EXPERIMENTER

VOLUMES XXVI and XXVII

JUNE, 1951 through MAY, 1953

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THE General Radio EXPERIMENTER

VOLUME XXVI No. 8 JANUARY, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VERSATILE RESISTANCE LIMIT BRIDGE DOUBLES AS LABORATORY STANDARD

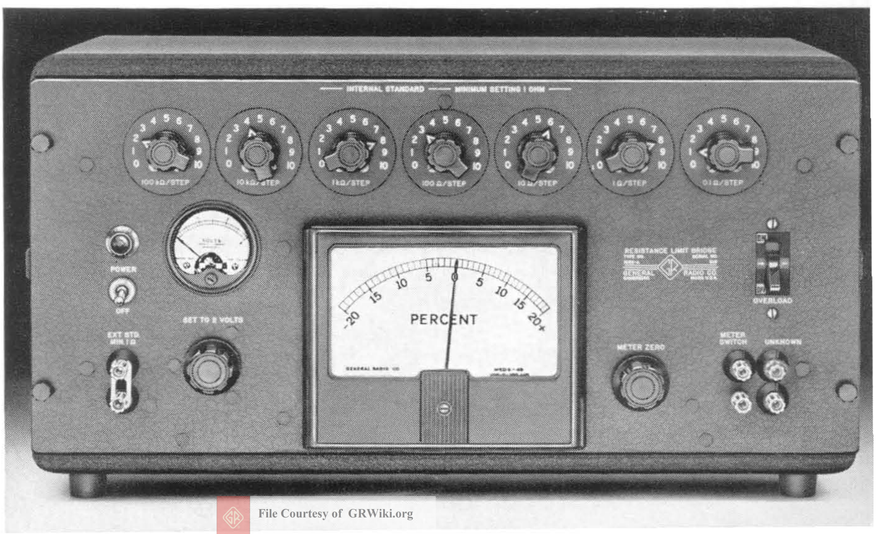
Also

IN THIS ISSUE

● **IN BOTH** the development and the manufacture of electronic equipment, it is frequently necessary to select resistors to close tolerances, to match pairs of resistors, and to make precise measurements of resistance in order to adjust circuit operating conditions. Most Wheatstone bridges, or resistance test sets, are not fast enough for production work, while the simple ohmmeter, although rapid, has insufficient accuracy.

To meet the need for a satisfactory resistance-checking device in our own plant, our Development Engineering Department undertook the design of a resistance limit bridge sufficiently flexible in application to be used in manufacturing, in the model shop, and in the laboratory. The resulting instrument has proved so useful that it is now offered for

Figure 1. Panel view of the Type 1652-A Resistance Limit Bridge. Per cent deviation is indicated on the large meter, with its open, easily read scale.



general sale as the TYPE 1652-A Resistance Limit Bridge.

The versatility of this instrument is best shown by the varied types of measurements for which it can be used. Specifically, it can:

(1) Indicate percentage deviation of the unknown from an adjustable internal standard. Deviation is indicated on a large meter, with the scale from 0% to 5% colored gold and from 5% to 10% colored silver. Maximum deviation is ±20%.

(2) Indicate percentage deviation similarly from an external standard.

(3) Be used to match one resistor to another, the percentage difference being indicated on the meter.

(4) Be used as a conventional decade Wheatstone bridge for resistance measurements by the null method.

(5) Be used with external equipment for automatic sorting by percentage limits.

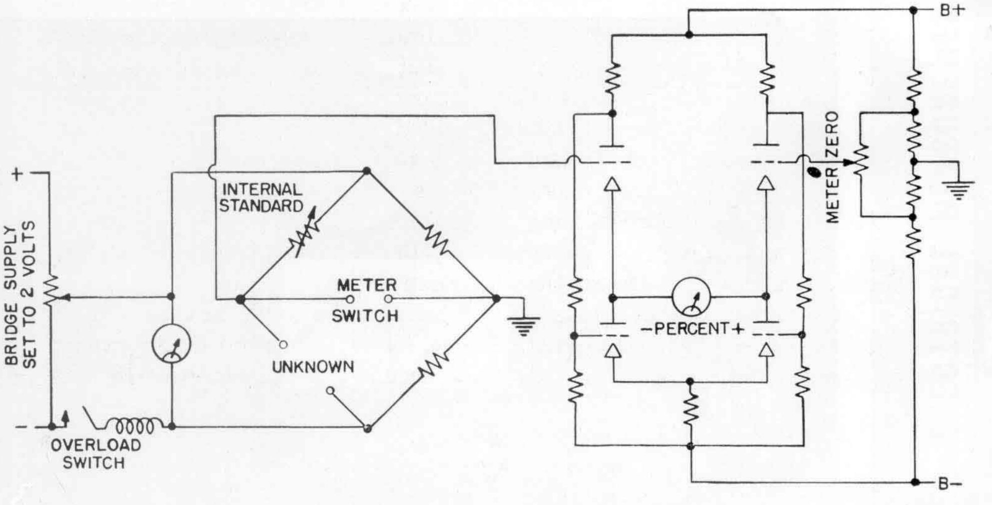
In addition, the internal standard provides a seven-decade resistor that can be used in external circuits, subject to frequency and grounding limitations imposed by the internal circuit configuration.

The range of measurement is from one ohm to above one megohm, with an accuracy between 0.2% and 0.5%, depending on the type of measurement. The bridge is mounted in a metal cabinet and is available for either table or relay-rack mounting. The built-in resistance standard is composed of seven TYPE 510 Decade Resistors, adjustable from 1 ohm to 1,111,111, ohms in 0.1 ohm steps. External standards may be used from 1 ohm to 2 megohms. The internal power supply operates from the a-c power line.

CIRCUIT

The conventional equal-arm Wheatstone bridge circuit, shown in Figure 2, is used. The input voltage E is held constant, and the output voltage is indicated by a high-impedance vacuum-tube voltmeter, whose scale is calibrated in per cent deviation. When the unknown resistor, R_x, differs from the standard resistor, R_s, by P per cent, the bridge output voltage, V, will have the following relation to P: $V = \frac{E}{2}\left(\frac{P}{200+P}\right)$. Since the input voltage, E, is held constant, the output voltage, V, is a function of

Figure 2. Elementary schematic circuit diagram of the limit bridge.



the percentage error of the unknown resistors. The fact that the percentage error, P, appears in the denominator of this expression accounts for the slight deviation from linearity of the meter scale. The d-c vacuum-tube voltmeter, shown at the right of Figure 2, uses a balanced circuit, similar to that in the TYPE 1800-A Vacuum-Tube Voltmeter, to minimize drift. The plate and cathode heater voltages are regulated by a saturable core transformer. As a result of these precautions, the drift due to line-voltage changes is completely negligible.

OPERATION

Limit Testing

For limit measurements, after the preliminary adjustments of internal standard value and meter zero, the meter indicates percentage error directly when the unknown is connected to the bridge. For such operations as acceptance tests on material coming into the plant, the speed and convenience of measurement can be greatly facilitated by the use of a test jig to accept the resistors being measured, and which provides an automatic means of shorting the meter when no resistor is connected. Such a jig is best devised by the user to suit his particular needs.

Matching Pairs

The procedure for matching pairs of resistors is the same as above, except that the internal standard is set to zero and one of the matched resistors is connected to the external standard binding posts. Resistors can also be compared to an acceptable sample by connecting the sample resistor to the external standard binding posts and setting the internal standard to zero.

Null Measurement

When the resistance limit bridge is used as a laboratory instrument to measure resistance, the unknown is connected, and the internal standard is adjusted until there is zero deflection on the meter. Sensitivity is constant for measurement up to several megohms without any additional booster voltage from external batteries.

HIGHER RESISTANCES

For resistors above a few megohms, the grid current drawn through the Wheatstone bridge by the vacuum-tube voltmeter will affect the normal operation of the bridge. However, it is still possible to measure resistors by the null method, using an external standard, providing a slightly different procedure is used. With the standard and unknown resistors connected to the bridge, the meter zero is set with the input voltage removed from the bridge (overload relay turned off). The input voltage to the bridge is then turned on and the external standard adjusted for a null. This procedure must be repeated a few times until the meter indication remains at zero as the voltage to the bridge is turned on and off.

ACCURACY

The basic accuracy of the resistance limit bridge in matching two resistors is $\pm 0.2\%$. When a resistor is being measured, the error of the standard must be added. The internal standard is accurate to $\pm .05\%$ (for values above 10 ohms) so that resistors may be measured to $\pm 0.25\%$. For resistors less than 10 ohms, the accuracy using the internal standard is $\pm 0.4\%$.

When the bridge is used as a limit bridge, for rapid inspection of resistors, finite accuracy of the meter reduces the

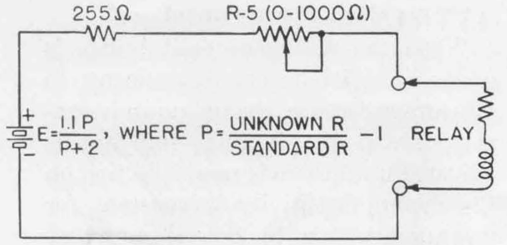


Figure 3. Equivalent circuit of the bridge voltmeter, showing method of connecting on external relay.

accuracy of the instrument to ±0.5%. A control is available on the shelf of the instrument which allows adjustment of the meter sensitivity to remove the meter-calibration error at any one point on the scale. Thus if 5% resistors are always being measured, it is possible to increase the accuracy of the meter indication at the 5% limits with a corresponding decrease in accuracy at other points on the scale.

AUTOMATIC SORTING AND INSPECTION

A relay can be put in place of the meter on the resistance limit bridge for use in automatic equipment. The relay can then be used to control the operation of sorting machinery or rejection equipment. A suitable relay should have a sensitivity in the order of 100 microamperes and an internal resistance of a few hundred ohms. Figure 4 is an equivalent circuit of the bridge voltmeter, in which *R*-5 plus the relay resistance must be 850 ohms.

The Type 1652-A Resistance Limit Bridge is a versatile resistance measuring device, suitable, without additional equipment, for many types of measurement. For specialized applications where speed is essential, it provides a basic measuring circuit of high accuracy, to which automatic handling equipment can be connected.

— W. M. Hague, Jr.

SPECIFICATIONS

Resistance Range: As a limit bridge, 1 ohm to 1,111,111 ohms with internal standard; for null measurement, 1 ohm to 1,111,111 ohms with internal standard; 1 ohm to 2 megohms with external standard.

Limit Range: Meter reads from −20% to +20%, with the standard RTMA tolerance ranges of ±5% and ±10% clearly indicated by gold and silver coloring, respectively.

Accuracy: As a limit bridge, ±0.5% or better; for matching, ±0.2%; for null measurement, with internal standard, ±0.25% above 10 ohms and ±0.4% between 1 ohm and 10 ohms; with an external standard, from 1 ohm to 2 megohms ±(0.2% + accuracy of standard).

Voltage Applied to Unknown: The voltage across the unknown resistor is exactly one volt when the meter indication is zero. As the meter indication varies from −20% to +20% the voltage across the unknown will vary from 0.89 volt to 1.10 volts.

Relay: When a relay is used in place of the meter, the relay resistance should be not more than 850 ohms and its sensitivity 100 microamperes or better. A current of 100 microamperes corresponds approximately to a limit of 20%, 50 microamperes to 10%, and 25 microamperes to 5%.

Power Supply: 105 to 125 volts or 210 to 250 volts, 60 cycles. The power input is approximately 30 watts.

Accessories Supplied: A line connector cord and spare fuses.

Vacuum Tubes: One Type 6X4 and two Type 6SU7-GTY's. All are supplied with the instrument.

Mounting: The bridge is supplied for either relay rack or cabinet mounting. Cabinet has black wrinkle finish.

Dimensions: Over-all, (width) 19 inches x (height) 8¾ inches x (depth) 10½ inches.

Net Weight: 29 pounds.

Type		*Code Word*	*Price*
1652-AM	**Resistance Limit Bridge (Cabinet Model)**	BUXOM	**$365.00**
1652-AR	**Resistance Limit Bridge (Relay Rack Model)**	BADGE	**365.00**

A PORTABLE POWER DISTRIBUTION PANEL FOR TELEVISION STUDIOS

For use in small or temporary television studios, or as an auxiliary switchboard in larger studios, engineers of the Canadian Marconi Company have designed and built the power distribution panel shown in Figure 1. Using Variac® autotransformers for circuits where voltage must be adjustable, this unit provides a convenient means of supplying power to both camera and lighting equipment from any available source of adequate capacity. An important feature of the panel is the simple, yet effective and safe, link system, which permits the panel to be operated from any one of the three common types of building power supply, as shown in the table below.

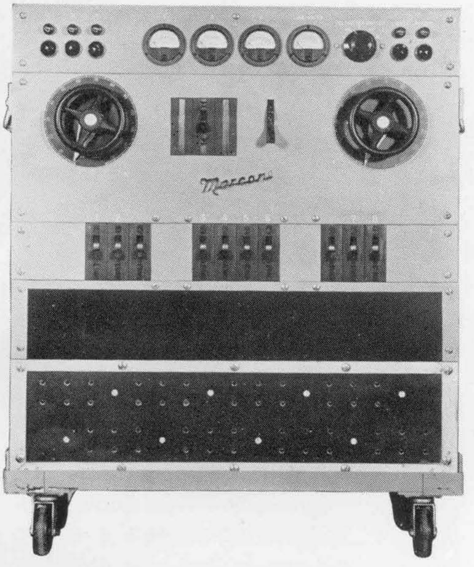


Figure 1. Panel view of the power distribution panel showing controls, pilot lights, circuit breakers, and lighting outlets. The older Type 100-Q Variacs were used on this model. Later models use the modern Type V-20M.

All circuits, including the Board Master, are controlled by circuit-breakers, serving as both switch and overcurrent protection, thereby eliminating fuses and their attendant nuisances and difficulties.

Pilot lights are provided to indicate visually the condition of the panel at all times; a "Lights Master" switch is provided to permit all lighting equipment to be turned off without affecting other apparatus being fed from the board; ammeters facilitate balancing the load, and indicate when the load limit of the panel is approached. A voltmeter is included to permit checking supply voltages under operating conditions.

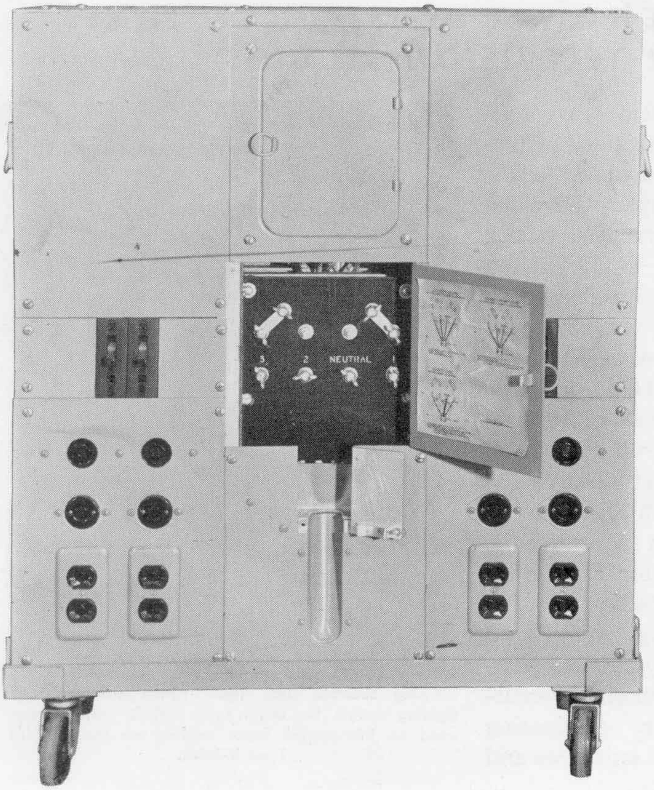
The following output circuits are provided: Four Hubbell 20 amp. 2-wire Twist-Lock receptacles for camera equipment; four Duplex receptacles for auxiliary equipment; eight groups of three receptacles each, for standard 15 amp. Stage Connectors (Kliegl No. 955, or

TABLE I
Summary of Ratings

Supply Volts	*Service Wires*	*Amps. per Leg or Ph.*	*Equipment Amps. (1)*	*Amps. for Lighting*	*Max. Total Output Amps. (2)*
115	2	100	40	60	100
115-230	3	50	40	60	100
115 3 Ph.	4	50	50	100	150

Notes: (1) "Equipment Amps." shown is average for two-camera chain, together with a small amount of auxiliary equipment. Actual current drawn will depend on equipment used.

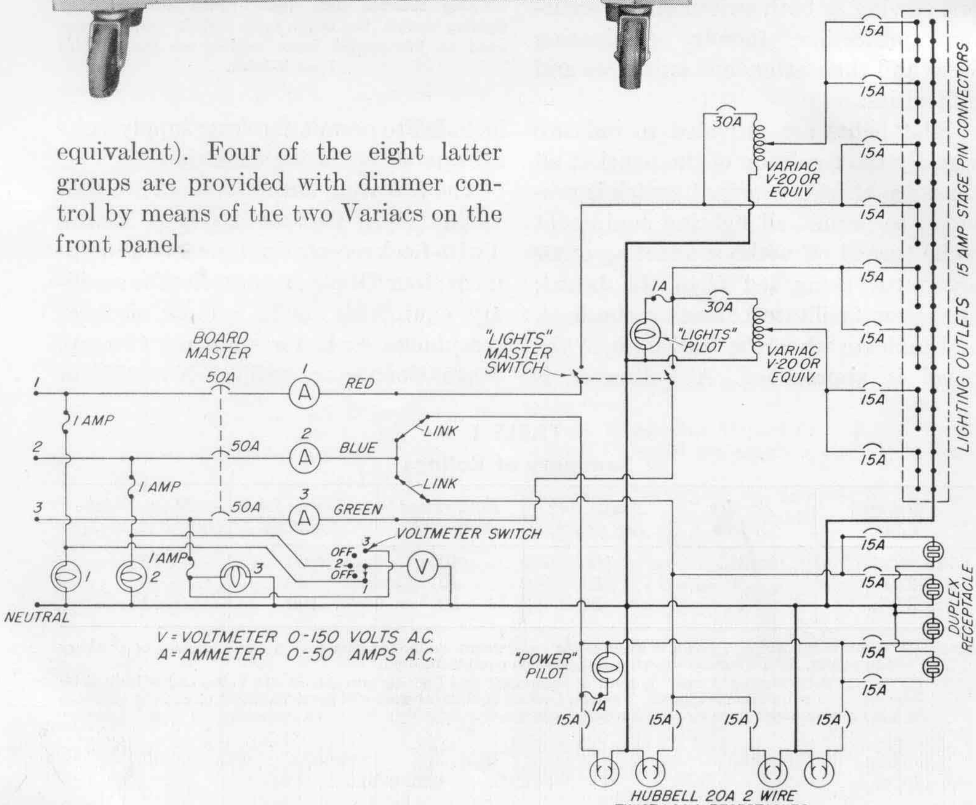
(2) "Max. Total Output Amps." is total of equipment and lighting currents at 115 volts, and is limited by maximum main breaker current. Therefore actual equipment used will govern amount of current available for lighting under some circumstances.



(*Left*) Figure 2. Rear view of the unit showing camera outlets, duplex outlets, and the panel for input connections, with links for adapting the circuit to different types of power supply.

(*Below*) Figure 3. Circuit diagram of the power distribution panel.

equivalent). Four of the eight latter groups are provided with dimmer control by means of the two Variacs on the front panel.



GRAPHIC RECORDER PLOTS LEVEL IN EITHER POLAR OR LINEAR COORDINATES

Sound Apparatus Company's Model PFR Polinear Recorder is an extremely adaptable instrument, particularly suited to the automatic plotting of the directional characteristics of microphones, loudspeakers, antennas, light sources, and other pattern-emitting or -receiving devices. This general-purpose pen-and-ink recorder plots a-c or d-c electrical voltage levels in either polar or rectangular coordinates on linear, square-root, or decibel scales.

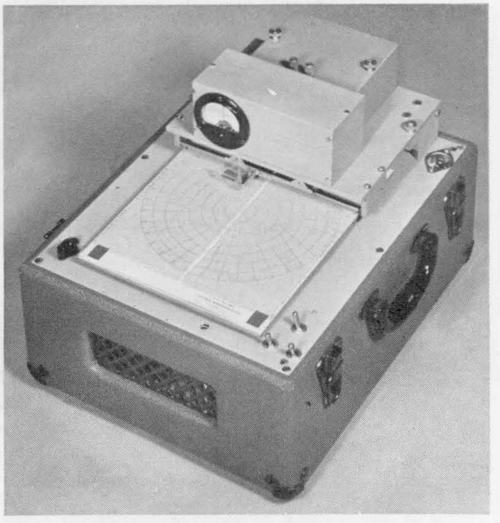


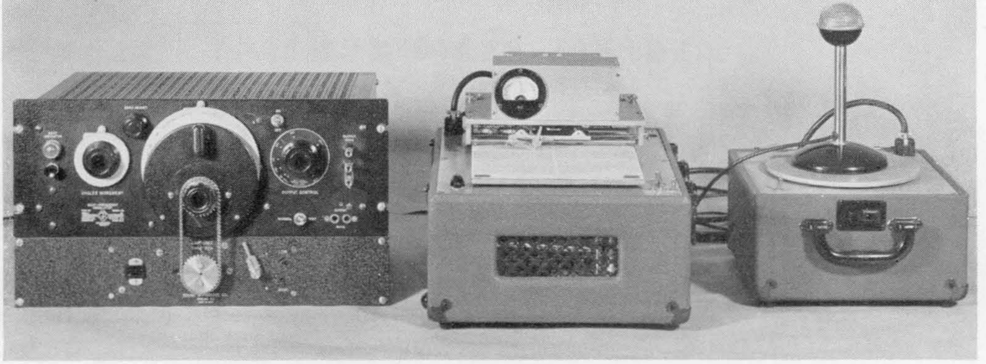
Figure 1. View of the Polinear Recorder.

Frequency response characteristics can be recorded automatically by coupling the recorder drive to the frequency-sweeping dial of an audio-frequency oscillator. For this purpose, the General Radio Type 1304-A Beat Frequency Oscillator is recommended. The beat-frequency oscillator is ideally suited for this type of measurement, since it gives a logarithmic frequency variation over three decades with a single sweep of the dial. In addition, it delivers 0.3 watt into 600 ohms with a total distortion of 0.25% or less.

Figure 1 is a close-up view of the Sound Apparatus Company's Polinear Recorder, and Figure 2 shows a complete setup for measuring frequency response characteristics in either polar or rectangular coordinates. Shown, left to right, are Type 1304-A Beat-Frequency Oscillator coupled with a Link Unit, the Polinear Recorder, and a Test Turntable for the polar recording of directional transmission characteristics. All three units are electrically connected by synchronous motors.

The Sound Apparatus Company manufactures the Link Unit and Test Turntable as well as the recorder. Included with the Link Unit is a sprocket for attachment to the frequency dial of the oscillator.

Figure 2. Complete assembly for measuring frequency response characteristics.



MISCELLANY

RECENT VISITORS to the General Radio plant and laboratories include:

From England:

Lt. Col. Rex Cowley, Leland Instruments, Ltd., London.

From the Netherlands:

Prof. R. M. M. Oberman, Head, Laboratory of Automatic Telephone System, and Prof. G. H. Bast, Director, Netherlands Post, Telegraph, and Telephone Service, The Hague. Both Professor Oberman and Professor Bast are also associated with the Technical University at Delft.

From France:

P. Bourgeas, Textile Engineer, St. Sauveur de Montagut, Ardeche; Fred. Mouraret, Moulinage et Retarderie de Chavanoz, Isere; and Pierre Doublier, M. La Croix, Lyon.

From Norway:

Rolf Olaussen, Engineer, Bergen Fish Industries, Bergen.

From Italy:

Dr. Guido Candussi, Technical Director, Ente Radio Trieste, Trieste; and Bernado Caprotti, Manifattura B. Caprotti, Milan; and Giuseppe Fidecaro, Physicist, Instituto di Fisica, Citta Universitaria, Rome.

CREDIT — The general concept of the Type 1652-A D-C Limit Bridge was suggested by C. A. Tashjian, Foreman of the Variac Department, as a result of experience with a similar development at the Research Construction Company during World War II. Development and design were carried out by D. B. Sinclair and A. M. Eames, mechanical design by H. C. Littlejohn.

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

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THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VOLUME XXVI No. 9 FEBRUARY, 1952

THE UNIT CRYSTAL OSCILLATOR—A SIMPLIFIED FREQUENCY STANDARD FOR THE SMALL LABORATORY

Also

IN THIS ISSUE

● **LATEST ADDITION** to the rapidly growing line of General Radio Unit Instruments is the TYPE 1213-A Unit Crystal Oscillator. Like other unit instruments,[1] this new oscillator is a miniaturized and greatly simplified version of a highly accurate laboratory instrument. The Unit Crystal Oscillator makes available, at low cost, harmonics of one megacycle, 100 kilocycles, and 10 kilocycles, with output frequencies as high as 1,000 megacycles, and with a short period stability of approximately one part per million (0.0001%).

Every electronics laboratory, particularly one concerned with electrical communication systems, needs a means of standardizing and measuring frequency. In the large, well-endowed laboratory, where standard frequencies are in continuous use, and where accuracies approaching one part in 10^8 are required, the TYPE 1100 Primary and Secondary Frequency Standards are used. This equipment, with facilities for distributing standard frequencies throughout the laboratory building, is too expensive for the laboratory with a limited budget, and for the individual experimenter.

[1]Eduard Karplus, "V-H-F and U-H-F Unit Oscillators," *General Radio Experimenter*, May, 1950.
"New Unit Instruments, Power Supplies—Modulator," *General Radio Experimenter*, July, 1951.

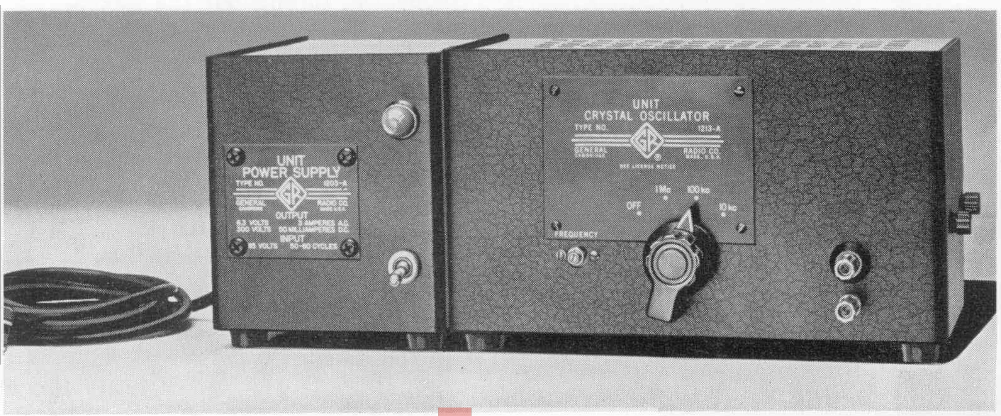
It was particularly to meet the needs of the small organization that the development of the Type 1213-A Unit Crystal Oscillator was undertaken. The oscillator has been proved very useful for receiver and transmitter calibration. The calibration of a good communications receiver can be accurately checked against the harmonic series and the receiver then used as an interpolating device for accurate frequency measurements.

Usable 1-Mc harmonics extend to 1000 Mc, thus covering the new U-H-F TV channels, 100-kc and 10-kc harmonics to at least 250 and 25 Mc, respectively. With good receiving equipment, the 10-kc harmonics can be used up to 30 Mc and higher, thus covering the 28-Mc amateur band. The oscillator, when used in conjunction with the Type 874-MR Mixer Rectifier, can be used as a 1-Mc marker generator up to approximately 250 Mc. A stability of the order of one part per million can be expected for periods of several hours, if the room temperature is constant, and the crystal frequency can be readjusted at any time to agree with standard-frequency transmissions from radio station WWV, operated by the National Bureau of Standards. Daily checking against WWV is sufficient for nearly all ordinary measurements, but still higher accuracy can be maintained by comparison at more frequent intervals, or by continuous monitoring against WWV transmissions.

Circuit

The instrument uses a cathode-coupled 1-Mc crystal oscillator. While the circuit is not new, it is somewhat unconventional. The first half of the twin triode operates as a cathode follower, while the second half is a grounded-grid amplifier. The plate circuit of the amplifier is tuned to 1 Mc, and the voltage appearing across the tuned circuit is fed back to the grid of the cathode follower, thus completing the oscillating circuit. The germanium diode in the plate circuit of the cathode follower is used as a harmonic generator. The 1-Mc crystal and its series capacitor form a series-resonant circuit connected between the two low-impedance cathode circuits; thus the crystal operates at a low impedance and any capacitance across it has only a small effect in determining the frequency. The result is a very stable crystal oscillator with a minimum number of components. The small variable capacitor, accessible from the panel, is connected in series with the crystal to permit setting the oscillator to zero beat with WWV transmissions at 5

Figure 1. Panel view of the Type 1213-A Unit Crystal Oscillator with the Type 1203-A Power Supply. The two units bolt together to form a compact, rigid assembly.



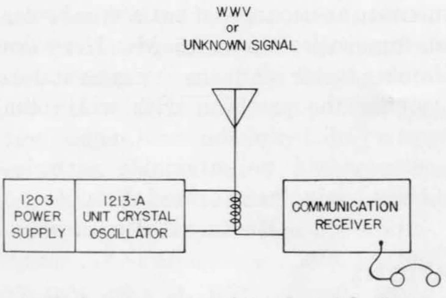


Figure 3. Arrangement of Unit Crystal Oscillator and receiver for standardization and use.

or 10 Mc. Following the oscillator are two 10:1 multivibrators, which provide the 100-kc and 10-kc output frequencies.

Crystal

The crystal is a plated, wire-mounted, hermetically sealed unit with a low temperature coefficient of frequency.

Consideration was given to the use of a small plug-in-type crystal oven, but the cycling of the simple oven tested caused more frequency shift than occurs under normal operating conditions without temperature control. Furthermore, the thermal inertia of the oven was so low that it was very difficult to adjust the crystal to zero beat while the oven was operating. Although satisfactory ovens are available, their cost and physical size are too great for an instrument of this type, and it was therefore decided to omit temperature control.

Power Supply

This oscillator is designed to be operated from a Type 1203-A Unit Power Supply, which is plugged into a convenient connector on the side of the case. Provision is made for clamping oscillator and power supply together in a single unit. The Type 1204-B Unit Variable Power Supply is also satisfactory, and in general any power source capable of supplying the currents and voltages listed under "Power Supply" in the specifications below.

The necessary arrangement for using the oscillator as either a signal source or frequency calibrator is shown in Figure 3. When the 1-Mc output is used to check the oscillator against WWV, it is only necessary to hang an 8- to 12-inch length of wire on the output terminal, and the radiated signal will be sufficient to be heard in a receiver 10 to 12 feet away. However, when the 100- and 10-kc output are used, considerably closer coupling is needed. The output impedance of the oscillator is sufficiently high that it can be connected directly to the antenna terminal of a receiver using an unbalanced transmission line (50-72 ohm coaxial cable). Tests have indicated that, when the oscillator is directly connected to the receiver, there is no appreciable attenuation of the unknown signal at frequencies up through

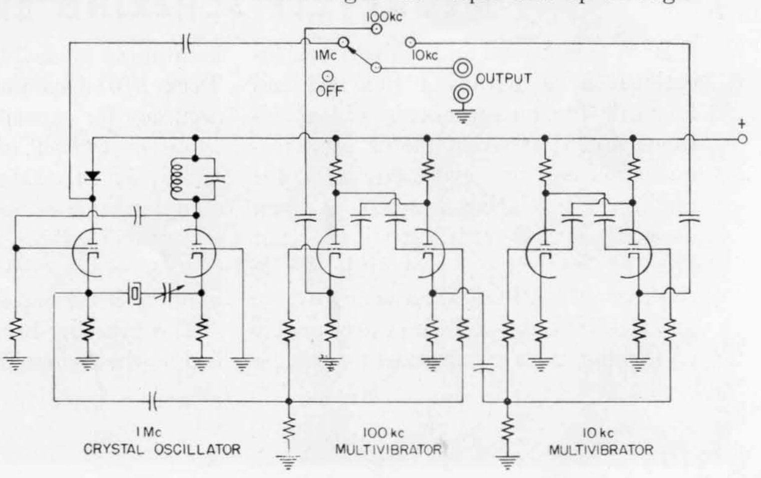


Figure 2. Elementary circuit diagram of the Unit Crystal Oscillator.

55 Mc provided the lead length is kept to a reasonable value. Measurements above this frequency indicate that very close coupling can be used, provided the leads do not become resonant.

The combination of the crystal oscillator and a good communications receiver will permit frequency measurements to an accuracy of 0.002% or better at frequencies up to 15 Mc. Here the limiting factor is not the oscillator stability, but the precision with which the receiver dial can be read. The best accuracy will be attainable with receivers having band-spread dials.

— Robert B. Richmond

SPECIFICATIONS

Frequency: 1 Mc, 100 kc, and 10 kc. The crystal has a temperature coefficient of one part per million per degree centigrade. Under normal operating conditions with a constant room temperature, a stability of approximately one part per million can be obtained for a day's operation.

Output: Greater than six volts for all three frequencies.

Harmonics Available: 1000, 250, and 25 Mc, respectively.

Controls: A ceramic wafer switch to select desired output frequencies.

Terminals: Jack-top binding posts provided with standard ¾ inch spacing.

Vacuum Tubes: Three 12AT7-type.

Power Supply: 300 volts dc, 120 ma; 6.3 volts, 1 ampere, ac.

Power Input: With 1203-A or 1204-A Power Supply, 15 to 31 watts, depending upon switch setting.

Accessories Supplied: One mating multipoint connector.

Mounting Black-crackle-finish panel and sides. Aluminum cover finished in clear lacquer.

Dimensions: (Width) 9⅞ x (height) 5¾ x (depth) 6¼ inches.

Net Weight: 3 lbs. 12 oz.

Type		*Code Word*	*Price*
1213-A	**Unit Crystal Oscillator***	REBEL	**$130.00**
1203-A	**Unit Power Supply**	ALIVE	**47.50**

*Licensed under patents of G. W. Pierce and of the Radio Corporation of America.

General Radio Unit Instruments are basic, general-purpose laboratory instruments, designed for high-quality performance at minimum price. Low cost is achieved through standardized cabinet and chassis construction and by simplified circuit design to use a minimum number of components.

Several other unit instruments will be described in forthcoming issues of the *Experimenter*, among them a null detector, an I-F amplifier, a pulse generator, and other oscillators.

In keeping with the trend toward miniaturized electronic equipment, these instruments have been designed to occupy as small a volume as is consistent with the ability to dissipate the heat developed.

A 1-MEGACYCLE SCHERING BRIDGE

Both commercial and military specifications on capacitors of 1000 $\mu\mu$f and less call for measurements of capacitance and dissipation factor at a frequency of one megacycle. Similarly, the grading of insulating materials is often based on the measured dielectric constant and loss factor at one megacycle. While the Type 916-A Radio-Frequency Bridge and the Type 821-A Twin-T are capable of making such measurements, neither instrument is ideal for the purpose. The Type 916 does not offer the desired accuracy for capacitance measurements while the Twin-T, *although entirely satisfactory for capacitance measurements*, in many instances does not have adequate resolution for the evaluation of the losses of low-loss materials or capacitors, particularly if the capacitance is small.

The Schering bridge circuit, exemplified by the General Radio Type 716, has been widely accepted at lower frequencies for capacitance and dissipation-factor measurements. By appropriate modification it is possible to obtain at one megacycle essentially the same performance as is obtained at lower frequencies with the standard model. Such a modification has been made at the request of leading capacitor manufacturers and is now offered on a semi-stock basis, designated as the TYPE 716-CS1.

Superficially, all that is required to obtain direct-reading operation at one megacycle is the installation of ratio arms of appropriate value to make the dissipation factor read correctly, but actually a number of other changes are necessary. The input transformer must be redesigned in order to obtain satisfactory transfer of energy at the higher frequency. It is also found that multiple sets of ratio arms, as provided in the standard model, produce serious errors caused presumably by the multiple current paths provided through capacitive coupling to the unused elements for any given setting. Accordingly, one set of equal ratio arms only is provided.

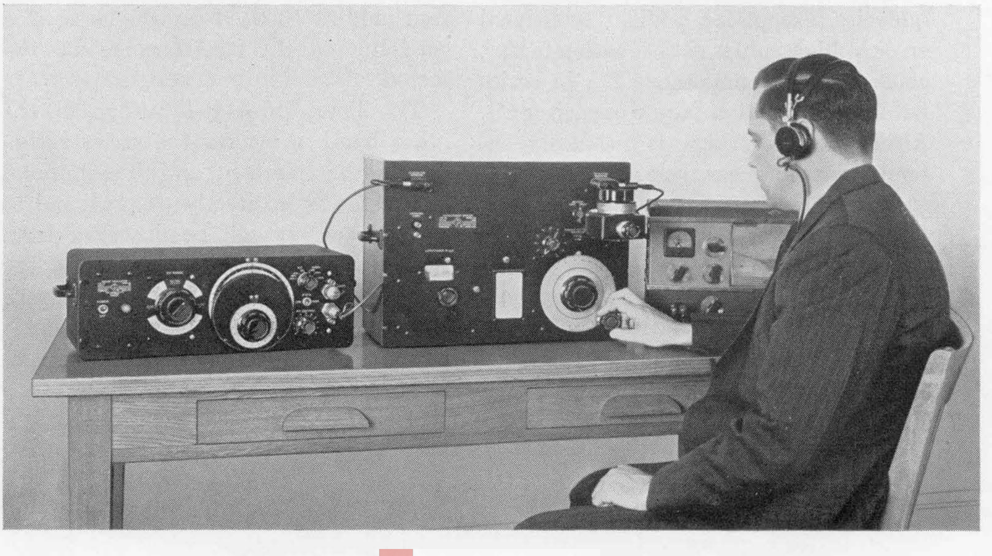
The construction of the precision capacitor used in the standard TYPE 716-C is not entirely satisfactory for use at one megacycle and higher, and a capacitor of the 722-N type is used. This capacitor, designed for *R-F* use, has lower inductance and lower and more nearly constant metallic resistance.

Finally, considerable attention must be given to the location of connecting leads and equalization of lead lengths in order to realize the desired accuracy.

Figure 2 shows the basic circuit bridge circuit, including the residual inductances that are significant in determining performance. Several adjustments are provided to equalize circuit impedances and to provide direct-reading operation.

In order that the static calibration of the capacitor C_N give directly the value of the capacitance C_X connected in the adjacent arm, it is necessary that L_N equal L_P. However, even if this condition is not met, C_N can alternatively be made direct reading for any given frequency by taking the difference of L_N and L_P into account. For a substitution measurement across the UNKNOWN, SUBST terminals, the inductance L'_N

Figure 1. Setup for one-megacycle dielectric measurements. Shown are the Type 716-CS1 Capacitance Bridge, Type 1690-A Dielectric Sample Holder, and Type 1330-A Bridge Oscillator.



introduces an error but in this case there is no opportunity for compensation in the adjacent arm. Actually C_N is calibrated to be direct reading for substitution measurements at 1 Mc, taking into account the inductance L'_N. The values of L_N, L'_N, and L_P are such that this calibration is also correct for direct measurements within the normal calibration accuracy.

The capacitance C_B is adjusted to compensate for the zero capacitance of the dissipation factor capacitor C_A. It also serves to equalize any differences in L_A and L_B, which behave approximately as a negative capacitance in shunt, independent of frequency. The ratio arm resistors themselves are adjusted to equality within ±.05%.

A third adjustment is provided by a differential capacitor connected between the primary shield of the transformer and the junction of the ratio arms. This compensates for any residual leakage capacitance between primary and secondary windings of the transformer[1] and also, in part, for induced voltages in the transformer shields.

With these adjustments properly made, the direct-reading accuracy for capacitance and dissipation factor at one megacycle is the same as at low frequencies, except for a slight additional error at high values of dissipation factor, caused by the inductance L'_A in series with the dissipation factor capacitor C_A. Although the bridge is primarily intended for one-megacycle use, it is useful to about 5 Mc.

RANGE

The introductory paragraph mentioned briefly the Type 821-A Twin-T and the Type 916-A R-F Bridge. A

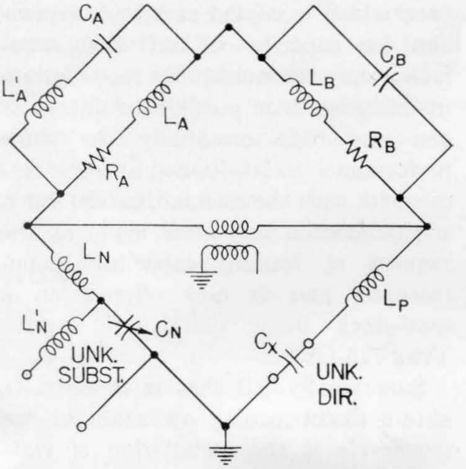


Figure 2. Simplified schematic diagram of Type 716-CS1, showing location of the more important residual inductances.

more detailed comparison between these two and the Type 716-CS1 Capacitance Bridge is in order to point out the area of measurement in which the latter is particularly useful. In Figure 3 is reproduced a plot showing the smallest[2] measurable dissipation factor at one megacycle, as a function of capacitance over the range 1 to 1000 $\mu\mu$f.

The Twin-T is calibrated in terms of conductance, hence the minimum detectable dissipation factor is an inverse function of capacitance. It will be noted that only at 1000 $\mu\mu$f can the losses of a capacitor in the 0.0002 range be detected.

The Type 916-A R-F Bridge, on the other hand, measures the series resistance of the unknown, and the minimum detectable D is directly proportional to capacitance. It will be observed from the plot that below about 500 $\mu\mu$f the Type 916-A R-F Bridge will theoretically measure lower losses, and this is possible, if corrections for residual pa-

[1] R. F. Field and I. G. Easton, "A Wide-Frequency-Range Capacitance Bridge," *General Radio Experimenter*, May, 1947.

[2] In terms of the smallest calibrated scale division. Actually about 1/5 of smallest division can be estimated in most instances.

rameters are established by measurement for the individual bridge used. The accuracy and precision of *capacitance* measurements, however, are not adequate for capacitor checking to close tolerances.

In the Schering bridge circuit, used in the TYPE 716-CS1, the dissipation factor reading is independent of capacitance. Over the direct-reading range of 100 to 1000 $\mu\mu$f, a value of D of .0001 can be observed.[2] When a substitution measurement is made, the dissipation factor, D, of the unknown capacitor is equal to the observed change in D multiplied by the ratio of circuit to unknown capacitance. This accounts for the increase in minimum dissipation factor shown by the curve labeled (SUBST).

The curves plotted in Figure 2 are based entirely on minimum calibration points with no consideration for such factors as balance sensitivity, ease of balance, and signal-to-noise ratio. When such factors are considered, the advantage of the TYPE 716-CS1 for the measurements in question becomes even more pronounced.

It should be pointed out here that the comparisons just made are for a particular measurement at a particular frequency. The Twin-T and the R-F Bridge are general purpose instruments of wide frequency range; the 716-CS1 is a specialized instrument of relatively limited frequency range.

DIELECTRIC MEASUREMENTS

In addition to its use for measuring capacitors, the TYPE 716-CS1 Capacitance Bridge will find application in measuring dielectrics at the ASTM test frequency of one megacycle, with the TYPE 1690-A Dielectric Sample Holder.[3]

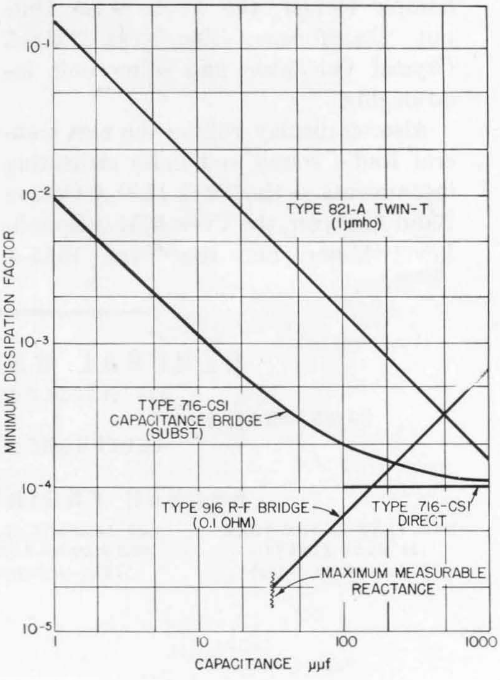
In Figure 3 is shown a sample holder mounted on the TYPE 716-CS1. A TYPE 1330-A Bridge Oscillator provides the test voltage and a commercial radio receiver is used as the null detector.

When the dielectric sample holder is used, the calibration of the precision capacitor in the bridge is not used. Consequently the balance may be made at its minimum setting of about 40 $\mu\mu$f. Under this condition the minimum measurable D is lower than that indicated by the curve of Figure 2. Also, about one fifth division on the D dial can be estimated, and, taking all these factors into account, the ultimate resolution is about 5×10^{-5}, with a 50 $\mu\mu$f low loss specimen.

— IVAN G. EASTON

For Specifications, see page 8

Figure 3. Comparative theoretical minimum ranges of Types 716-CS1, 916-A, and 821-A.



[3]Ivan G. Easton, "A Sample Holder for Solid Dielectric Materials," *General Radio Experimenter*, August, 1951.

SPECIFICATIONS FOR TYPE 716-CS1 CAPACITANCE BRIDGE

Capacitance Range: Direct Method, 100 to 1000 $\mu\mu$f; Substitution Method, 0.1 to 1000 $\mu\mu$f.

Dissipation Factor Range: Direct Method, 0.00002 to 0.56; Substitution Method, 0.00002 $\times \frac{C'}{C_X}$ to 0.56 $\times \frac{C'}{C_X}$, where C' is the capacitance of the standard capacitor and C_X that of the unknown.

Frequency Range: Calibrated for one megacycle, the bridge operates satisfactorily at frequencies between 0.5 and 3 megacycles.

Accuracy: At one megacycle, the bridge is adjusted to have the same accuracy as the standard Type 716-C at low frequencies (see the current General Radio catalog for details). This same accuracy can be obtained at other frequencies between 0.5 Mc and 3 Mc, if correction is made for the effects of residual inductance.

Other specifications are the same as those for the standard Type 716-C.

Type		*Code Word*	*Price*
716-CMS1	**Capacitance Bridge** (Mounted in Cabinet).....	BOGEY	$610.00
716-CRS1	**Capacitance Bridge** (For Relay-Rack Mounting)	BACON	565.00

1952 RADIO ENGINEERING SHOW

When you come to the 1952 Convention of the Institute of Radio Engineers, be sure to look in at Booths 92 and 93 (first floor) in the Radio Engineering Show. General Radio engineers will be glad to show you the new instruments that you have read about in this and other recent issues of the *Experimenter* — the Type 1390-A Random Noise Generator, the Type 1652-A Resistance-Limit Bridge, the Type 1862-A Megohmmeter, the Type 1690-A Dielectric Sample Holder, the Type 942-A Output Transformer, the Type 1213-A Crystal Oscillator, and other unit instruments.

Also on display will be the new General Radio sound and noise measuring instruments — the Type 1550-A Octave Band Analyzer, the Type 1551-A Sound-Level Meter, and the Type 1555-A Sound-Survey Meter. These instruments, embodying the latest circuit and design techniques, are rapidly increasing in importance to industry. An important new use for these basic measuring tools is determining the possibility of ear damage to factory employees from excessive noise levels.

For impedance measurements in the u-h-f and v-h-f ranges, the Type 1602-A Admittance Meter will be set up and operating, so that you can see how quickly and easily it measures, on direct-reading scales, the impedance of resistors, capacitors, inductors, lines, antennas, and cable. If you are working on u-h-f television circuits, this instrument will save you time and money. No calculations, no transmission line charts are necessary.

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VOLUME XXVI No. 10 MARCH, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

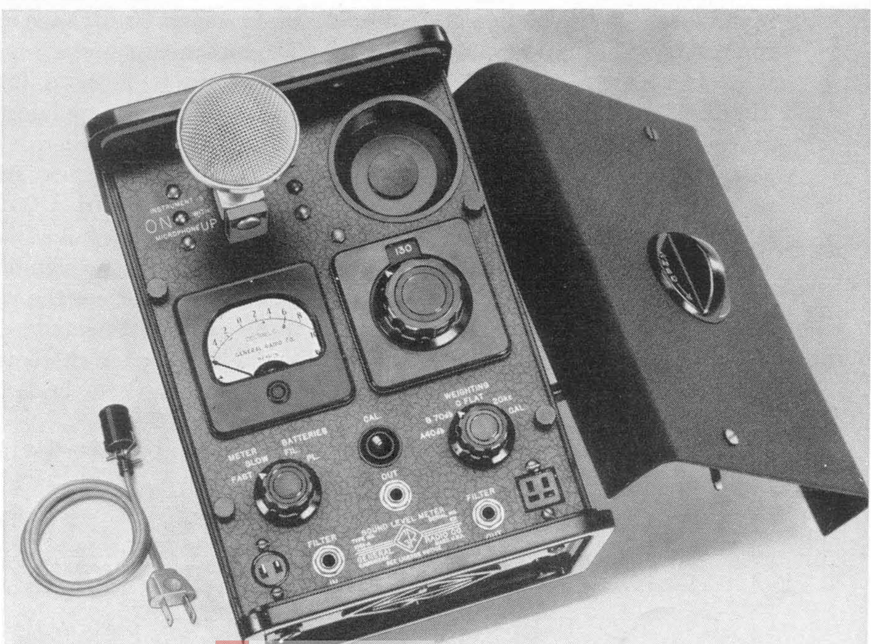
TYPE 1551-A SOUND-LEVEL METER—

A Miniaturized and Improved Basic Instrument for Sound and Noise Measurements

● **THE SOUND-LEVEL METER** is the basic instrument of a sound measuring system. Born in the '30's as a result of the joint effort of several technical societies interested in standardizing[1] acoustic noise measurements, its uses have grown constantly as man's environment has become noisier. Expanding uses inevitably condition the development of a product, and so the first General Radio Sound-Level Meter, TYPE 759-A (1936) was superseded by the TYPE 759-B (1940). New tubes, new components, modern construction methods, and miniaturi-

[1]ASA, American Standard for Sound-Level Meters for measurement of noise and other sounds, Z24.3—1944.

Figure 1. Panel View Type 1551-A Sound-Level Meter.



zation techniques have now made possible a complete redesign, resulting in a smaller, lighter, more useful instrument, the Type 1551-A, shown in Figure 1.

Redesign of the sound-level meter was started with certain definite objectives in mind. These objectives were dictated by users of the sound-level meter and implemented by the desire on our part to provide a sound-level meter with worthwhile improvements in utility and operating characteristics. Compared to its predecessor, the new meter should:

- be considerably *smaller* and *lighter*.
- be more stable.
- cover a wider band of frequencies, so that, with suitable microphones, the complete audio spectrum can be measured.
- be easier and simpler to operate.

The use of sub-miniature tubes and miniaturization techniques readily adapted to a system of relatively small-scale production has resulted in a new high-performance instrument, much reduced in size and weight. The amplifier circuit in the new Type 1551-A Sound-Level Meter uses seven sub-miniature tubes compared with the four tubes used in the older Type 759-B Sound-Level Meter. The added tubes make possible an extended frequency range as well as gain stabilization through the use of negative feedback.

The requirement of increased convenience and simplicity of operation was met by a rearrangement of operating controls and adjustments and by a new cabinet design.

[2]See Figure 7.

CIRCUIT

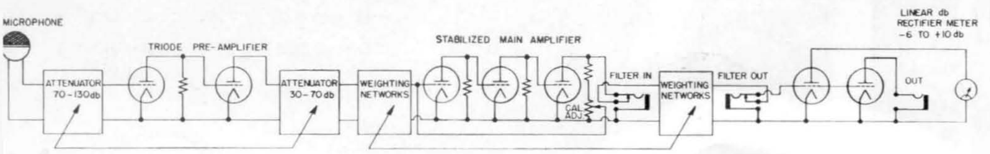
Figure 2 is a functional diagram of the new instrument. A Rochelle-salt crystal microphone is followed by an input attenuator, a two-stage triode-connected pre-amplifier, and a second attenuator. The main amplifier follows with weighting networks inserted at input and output terminals. The circuit is completed by two output amplifiers, an indicating meter, and an output jack. The two attenuators are ganged and operated by a single control, so that the second attenuator operates for dial settings of 30 to 70 db, while the input attenuator operates for settings of 70 to 130 db.

The main three-stage amplifier has a normal gain of 80 db. Under operating conditions the gain of the amplifier is reduced to less than 60 db by means of inverse feedback. Careful choice of circuit parameters and the large amount of negative feedback have made possible an extremely stable and dependable wide-band amplifier. The feedback is adjustable over a limited range to provide calibration adjustment.

The two output stages are also stabilized by negative feedback. One of these is used to drive the rectifier meter. The other supplies a separate output connection to be used for monitoring purposes or for supplying a signal to an analyzer or recorder.

The over-all frequency response of the amplifiers is flat from 20 cycles to 20 kilocycles, so that full advantage can be taken of the new high-fidelity microphones. In addition, the weighting networks provide the standard A, B, and C sound-level meter characteristics[1,2]. A single control selects the desired response.

Figure 2. Elementary Schematic (or Functional diagram) Type 1551-A Sound-Level Meter.



Two telephone jacks labeled FILTER IN and FILTER OUT are connected ahead of the output system so that special networks or filters for altering the frequency response of the instrument may be added ahead of the indicating meter and the output jack. Simple filters for measuring loudness or speech interference level are planned as future accessories.

INTERNAL NOISE LEVEL

Many sub-miniature tube types are being manufactured, but the Type CK512AX tube used in the pre-amplifier of this new sound-level meter has the lowest noise level of any battery type that we have yet found. In the sound-level-meter circuit, the noise output from this tube over the 20 kilocycle band is of the order of 2 microvolts. This is equivalent to the signal level from the microphone placed in a sound field of 18 db,[3] so that measurements to levels at least as low as 24 db are possible, and the over-all gain in the instrument is sufficient to make such measurements. The meter scale is calibrated from -6 to $+10$ db, and the attenuator is calibrated from 30 to 130 db so that direct measurement of sound pressure levels can be made over a range of 24 to 140 db. (A pressure range of over 600,000 to 1 or a power range of 400 billion to 1.)

DESIGN FEATURES

Controls

Much thought and care have been exercised in determining the final location of the panel controls. While simplicity and ease of operation were dominant factors in determining control locations, electrical performance was never sacrificed. As illustrated in Figure 1, the important and most used controls have been placed at the right. The indicating meter and attenuator control have been located side by side and given equal prominence. The mask was added to the attenuator control to reduce the possibility of errors in reading the sound level, which is the sum of meter and attenuator readings. The microphone is shown in operating position. When not in use, it is folded down so that it rests in the small well at the right. The ON-OFF switch is operated by the microphone swivel post so that the instrument is automatically turned on when the microphone is raised to its operating position.

Case

The welded aluminum case designed to house this new meter is light in weight, strong, durable, and attractive. Four large rubber feet mounted on its base serve as a first stage in shock and vibration isolation for the high-gain amplifier carried within. The end frames of the case are molded from high-impact-strength bakelite and serve to protect the panel and controls when the instrument is in use. They make possible a simple U-shaped cover design, which can be attached quickly and securely, and they prevent marring and scarring surfaces when the instrument is set down in other than its operating position.

Interior Construction

Figure 3 is a view of the instrument removed from its cabinet. The amplifier cover has been removed and the amplifier shelf has been raised to show accessibility to all parts of the amplifier. The seven sub-miniature tubes are just visible along the top of the amplifier shelf. Full constructional details of the amplifier shelf are shown in Figure 4. The amplifier case is supported at three points by soft rubber bushings, which make a

[3]Ref. level 0 db = 0.0002 μbar.

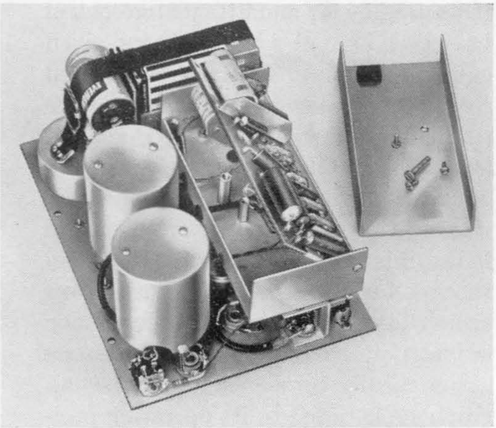


Figure 3. View of Type 1551-A removed from its case. Amplifier cover removed, and amplifier raised to show accessibility.

second stage of shock and vibration isolation. In addition, the input tubes for the pre-amplifier and main amplifier rest between pieces of light cellular rubber when the amplifier cover is in place. The attenuator switch and weighting switch are enclosed in the two cylindrical shield cans at the left of Figure 3.

Batteries

The battery complement for the new instrument is visible at the top of the photograph. It consists of two D-size flashlight cells for the filament supply and one portable radio B battery for the plate supply. Batteries used in this instrument are popular sizes manufactured by a number of battery companies and are readily available at almost any radio store or supply house. One set of A batteries will give 6 to 7 days' operation at 8 hours a day or 30 to 35 days' operation at 2 hours a day. The plate battery will give 18 to 20 days' operation at 8 hours a day or 90 to 100 days' operation at 2 hours a day. Tests to date indicate that over most of the useful life of the batteries, 8-hour stability of the instrument is within 0.5 db and 2-hour stability is within 0.2 db.

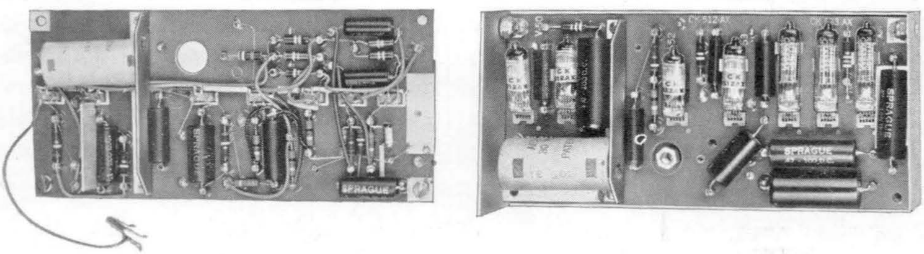
A-C Power Supply

For applications where continuous use of the Type 1551-A Sound-Level Meter is contemplated, a small a-c power supply has been designed. This power unit, the Type 1262-A Power Supply, is so constructed that it will fasten directly to the end plate of the sound-level meter case as is indicated in Figure 5. No regulation is provided in this supply, because the stability of the amplifiers in the sound-level meter is such that variations in line voltage over the range of 105 to 125 volts cause meter reading changes of the order of only 1 db, so that normal line voltage changes have little effect on the meter reading.

MICROPHONE CHARACTERISTICS

The diaphragm-type Rochelle-salt crystal microphone supplied with the Type 1551-A Sound-Level Meter is a good low-cost microphone and serves as a satisfactory pickup for most noises encountered in the home, office, or factory. It has high sensitivity, flat response to sounds of random incidence, from very low frequencies to frequencies well above 1 kilocycle, and good response up to 8

Figure 4. Detail view of panel side and bottom side of Amplifier Shelf.



kilocycles. For sounds arriving at 90° incidence, it is essentially non-directional (in the horizontal plane) for frequencies up to 6 kilocycles. Figure 6 is a group of generalized curves showing the response of this microphone to sounds incident at 0 degrees, 90 degrees, and from random directions in the vertical plane. The upper curve in Figure 7 shows the overall response to sounds of random incidence obtained for a typical microphone used with the TYPE 1551-A Sound-Level Meter. The lower curves show the response characteristics of the electrical circuits in the sound-level meter.

Temperature Effects

The open-circuit voltage of the microphone changes by about 0.02 decibel for each degree Fahrenheit change in temperature as is shown by the dotted curve of Figure 8. This relatively small change in output is accompanied by a rather large change in the capacitance of the microphone.[4] As long as the microphone is connected directly to the input of the TYPE 1551-A Sound-Level Meter, this large capacitance change is of little consequence. The response of the TYPE 1551-A as a function of temperature changes at the microphone for this condition is shown by the upper solid curve in Figure 8. The low input capacitance achieved in the new sound-level meter accounts for the close adherence of the solid curve to the dotted curve. If the input capacitance is increased as, for instance, when a long cable is used, the indicated output of the microphone will vary more widely with temperature as is shown by the middle and lower curves in Figure 8.

[4]E. E. Gross, "A Dynamic Microphone for the Sound-Level Meter," *General Radio Experimenter*, April, 1951.

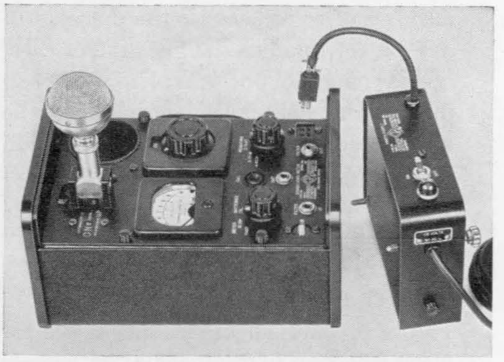


Figure 5. Type 1551-A with Type 1262-A A-C Power Supply.

Microphone Mounting

For convenience in use, storage, and transport, the microphone is mounted directly on the instrument. When sounds of random incidence are being measured, this mounting for the microphone is satisfactory, and the instrument is adjusted to conform to the ASA specifications for such sounds. For sounds of other than random incidence, this mounting can be

Figure 6. *(Below)* Free field frequency response of microphone for sounds incident at 0 degrees, 90 degrees, and from random directions in a vertical plane.

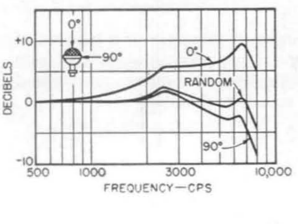
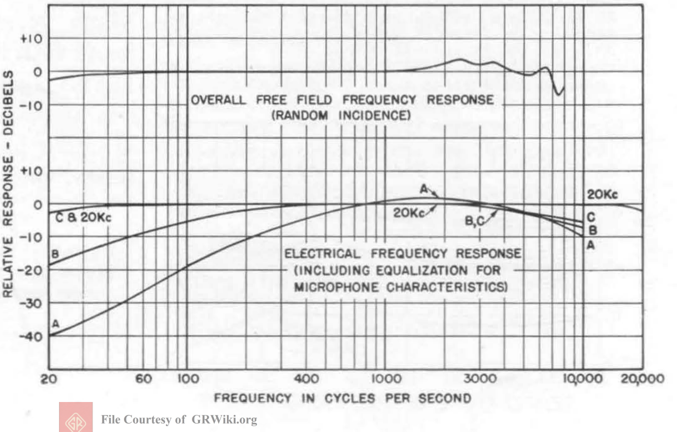


Figure 7. *(Right)* Typical acoustical and electrical calibration curves for the Type 1551-A Sound-Level Meter.



a source of error because the presence of any object, such as the instrument case, in the sound field of the microphone can distort the field and hence affect the meter readings. In addition, the position of the observer relative to the source of sound and the microphone becomes very important. It has been experimentally determined that when the TYPE 1551-A Sound-Level Meter is held as shown in Figure 9, these effects are negligible for frequencies up to 2 kilocycles for sounds in the horizontal direction (90° incidence, Figure 6) which arrive from the left- or right-hand side of the observer. In contrast, the observer will affect meter readings by as much as 3 db at frequencies as low as 200 cycles if he holds the instrument as in Figure 9 and faces the source of sound.

For sounds of random incidence over the frequency range of 20 cycles to 8 kilocycles and for directive sounds from 20 cycles to 2 kilocycles, this sound-level meter with attached microphone is an excellent hand-held instrument, suitable for use in many common noise measurement problems. When directive sounds are involved and good results above 2 kilocycles are required, one should mount the microphone on a tripod and use a cable to keep the microphone well away from the observer and the sound-level meter. The TYPE 759-P25 Dynamic

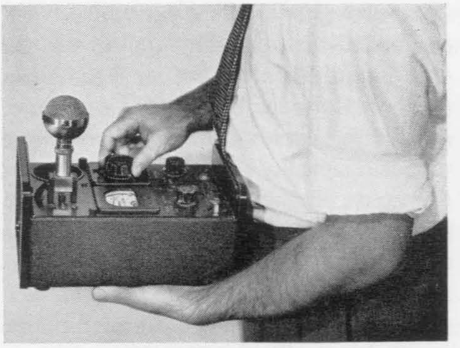


Figure 9. Typical operating position for Type 1551-A Sound-Level Meter.

Microphone Assembly[4] will give better results for measurements above 2 kilocycles. For even better results at high frequencies, a Western Electric Type 640-AA Condenser Microphone or one of the recent high-fidelity microphones, such as the RCA Type BK4A[5] Pressure Ribbon Microphone or the Altec Type 21-B[6] Condenser Microphone should be used. Because good low frequency response is also important in noise measurements, a condenser type of microphone will be offered as accessory for use with the TYPE 1551-A Sound-Level Meter. The development of a battery-operated preamplifier and power supply[7] for this type of microphone will be completed soon.

APPLICATIONS

The sound-level meter is a basic instrument about which a comprehensive sound measuring system can be built. Many types of measurements can be made with it directly, and its usefulness has been extended many-fold by numerous accessories, including a wide range of microphones, vibration pickups, analyzers, and recorders. The sound-level

[5]H. F. Olson and J. Preston, "Unobtrusive Pressure Microphone," *Audio Engineering*, Vol. 34, pp. 18–20 (July, 1950).

[6]J. K. Hilliard, "Miniature Condenser Microphone," *Journal of the Society of Motion Picture and Television Engineers*, Vol. 54, pp. 1–12 (March, 1950).

[7]TYPE 1551-P1 Condenser Microphone System to be described in a forthcoming issue of the *Experimenter*.

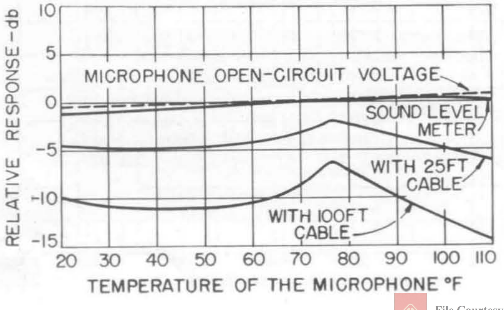


Figure 8. Variation in response as a function of temperature for the microphone alone and with various lengths of cable between microphone and sound-level meter.

meter is commonly used in industry, in schools, and in laboratories to obtain objective measurements of a wide range of noise levels. The list of its applications for the measurement of noise or unwanted sound is growing rapidly. Many measurements are made in the process of reducing the noise in consumer products or in improving worker comfort, safety, and efficiency. With the advent of high-intensity noise makers, such as jet engines, test facilities must be carefully engineered and designed, not only for protection and comfort of test personnel, but to prevent undesirable noise conditions extending to surrounding communities.

Every effort has been made to make the TYPE 1551-A Sound-Level Meter an outstandingly useful instrument. The broad frequency-response characteristic, stability, wide dynamic range, and low noise and distortion level, resulting from careful design of the amplifier, attenuators, and output system, make it an excellent foundation on which to build a comprehensive sound-measuring system. Special microphones can be used to full advantage. The output is adequate to operate many pieces of auxiliary equipment, such as frequency analyzers, graphic level recorders, magnetic tape recorders, or cathode-ray oscillographs. In addition, this new sound-level meter is compact and light in weight, so that it is much easier to carry about than the old TYPE 759-B. Its over-all size is 470 cubic inches, compared to 1200 cubic inches, and its weight is 11 pounds, compared to the 22¼ pounds of the TYPE 759-B.

—E. E. GROSS, JR.

SPECIFICATIONS

Sound-Level Range: From 24 db to 140 db above the standard sound pressure reference level of 0.0002 microbar (a pressure of 0.0002 dyne per square centimeter) at 1000 cycles.

Frequency Characteristics: Any one of 4 response characteristics can be selected by means of a panel switch. The first and second of these are, respectively, the 40- and 70-db equal-loudness contours in accordance with the current standard specified by the American Standards Association. The third frequency response characteristic gives a substantially equal response to all frequencies within the range of the instrument and its microphone. This characteristic is used when measuring extremely high sound levels, when measuring sound pressures, or when using the instrument with the TYPE 760-B Sound Analyzer, the TYPE 736-A Wave Analyzer, or the TYPE 1550-A Octave-Band Noise Analyzer. The fourth frequency response characteristic provides an amplifier which has essentially flat response from 20 cycles to 20 kilocycles, so that full use can be made of extremely wide range microphones such as the W.E. 640-AA or the Altec 21-B Condenser Microphones.

Microphone: The microphone is of the Rochelle-salt, crystal-diaphragm type with an essentially non-directional response characteristic.

Sound-Level Indication: The sound level is indicated by the sum of the readings of the meter and an attenuator. The meter has a range of 16 db, and the attenuator has a range of 100 db in 10-db steps.

Output Terminals: A jack is provided, at which an output of 1 volt across 20,000 ohms can be obtained when the panel meter reads full scale. This output is suitable for use with the TYPE 760-B Sound Analyzer, the TYPE 736-A Wave Analyzer, the TYPE 1550-A Octave-Band Noise Analyzer, a graphic level recorder, or a magnetic tape recorder.

A SLOW-FAST switch makes available two meter speeds. With the control switch in the FAST position, the ballistic characteristics of the meter simulate those of the human ear and agree with the current standards of the American Standards Association. In the SLOW position, the meter is heavily damped for observing the average level of rapidly fluctuating sounds.

Calibration: A means is provided for standardizing the sensitivity of the instrument in terms of any a-c power line of approximately 115 volts.

The absolute level of all microphones is checked at several frequencies against a standard microphone, whose calibration is periodically checked by the National Bureau of Standards.

TYPE 1552-A Sound-Level Calibrator* is available for making periodic checks on the over-all calibration, including microphone.

Accuracy: The frequency response curves *A*, *B*, and *C* of the TYPE 1551-A Sound-Level Meter fall within the tolerances specified by the current ASA standards. When the amplifier sensitivity is standardized, the absolute accuracy of sound-level measurements is within ±1 decibel for average machinery noises in accordance with the ASA standards.

Temperature and Humidity Effects: Readings are independent (within 1 db) of temperature and humidity over the ranges of room conditions normally encountered.

Batteries: Two 1½-volt size-D flashlight cells (Eveready 950 or equivalent); one Eveready 467 B or equivalent battery. Batteries are supplied. The TYPE 1262-A Power Supply is available if a-c operation is desired.

Tubes: Four CK512AX and three CK533AX are required. A complete set is supplied with the instrument.

Accessories Supplied: Power Cord (for calibration check).

Other Accessories Available: Dynamic Microphone, Tripod, and Extension Cable, Vibration Pickup and Control Box.*

Case: Shielded carrying case of aluminum construction.

Dimensions: The over-all dimensions are approximately (height) 6⅝ x (length) 10$^{13}/_{16}$ x (width) 8⅞ inches.

Net Weight: 11 pounds, with batteries.

Type		*Code Word*	*Price*
1551-A	**Sound-Level Meter**† (with batteries)	MIMIC	**$360.00**
1262-A	**Power Supply**	MANLY	**75.00**

* Details on request.
† Licensed under patents of the American Telephone and Telegraph Co.

CREDITS

The TYPE 1551-A Sound-Level Meter was developed by Mr. Ervin E. Gross, Jr., with Dr. Arnold P. G. Peterson as project supervisor. Credit is also due Dr. Leo L. Beranek, of M.I.T., acoustic consultant in the development, to Mr. R. Corwin Crosby for the mechanical design, and to Mr. Robert J. Ruplenas for experimental work on subminiature amplifiers.

ACCESSORIES

A complete line of accessory equipment is available for use with the TYPE 1551-A Sound-Level Meter, including the following:

TYPE 760-B Sound Analyzer.

TYPE 1550-A Octave-Band Noise Analyzer.

TYPE 1552-A Acoustic Calibrator.

TYPE 759-P21 Tripod and Extension Cable.

TYPE 759-P25 Dynamic Microphone Assembly.

TYPE 759-P35 and P36 Vibration Pickup.

Complete specifications will be sent on request.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE SOUND-SURVEY METER

A Simple, Pocket-Size Instrument for Noise-Level Measurements

Also IN THIS ISSUE

MANY SOUND MEASUREMENTS do not require the accuracy and versatility of a standard sound-level meter,[1] and many others are economically feasible only with a low-cost meter. For these applications, the Type 1555-A Sound-Survey Meter, shown in Figure 1, has been developed. It is similar in operating characteristics to the standard sound-level meter and is comparable in accuracy, stability, and frequency response to the commercially available sound-level meters of only one year ago. At the same time it is smaller, lighter in weight, easier to use, and much lower in cost than standard instruments.

The Sound-Survey Meter has a wide range of applications in nearly all fields of sound measurement. For example, it can be used for determining the noise level from machinery, for preliminary surveys of environmental

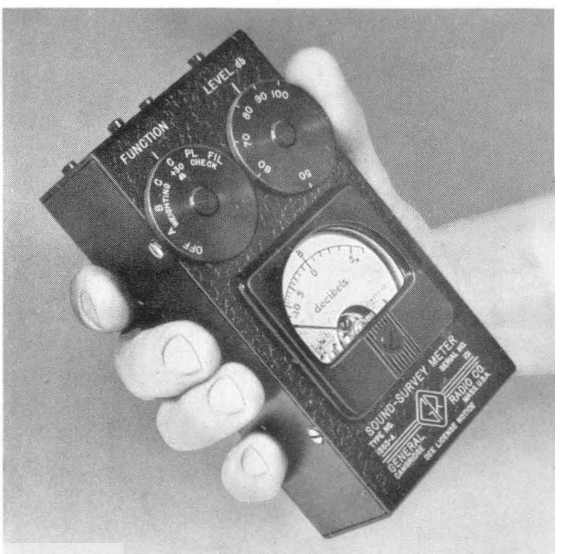


Figure 1. View of the Sound-Survey Meter, held in hand, with thumb in position to operate level control.

[1]E. E. Gross, "Type 1551-A Sound-Level Meter," *General Radio Experimenter*, XXVI, 10, March, 1952.

noise levels, for simple acoustic measurements, and as a teaching and laboratory aid in education.

Description

The photograph of Figure 1 shows that the instrument has been designed particularly for ease of use. It is shaped to fit the hand but can also be set on a table or mounted on a tripod. The indicating meter is large for a hand-size instrument, so that it can be easily read. The controls and the meter are all on the face of the instrument. Controls are simple, a function switch at the left and a continuous level control at the right, both arranged for easy, finger-tip operation. Total weight with batteries is only 1 pound, 14 ounces.

Although the instrument is small enough to be carried in the coat or trousers pocket, many users will find it convenient to have the carrying case shown in Figure 2, which is available as an accessory.

The Sound-Survey Meter is shown partially disassembled in Figure 3. The entire unit is mounted in a simple, two-piece, aluminum case. The microphone cartridge is visible at the top, fastened to the case. The amplifier chassis is in the middle, showing the four sub-miniature tubes, and this chassis is readily removed from the case for ease in servicing. The batteries are one size-C flashlight cell and one 30-volt hearing-aid B-battery.

Figure 2. Convenient carrying case is made of brown, blister-proof, top-grain cowhide and has a shoulder strap. Space is provided for two spare flashlight cells and one spare plate battery.

Circuit

As shown by the simplified schematic of Figure 4, the instrument consists of a microphone, a calibrated potentiometer, a four-stage amplifier with weighting networks, and an indicating meter. A voltage proportional to the current in the meter circuit is returned to the grid of the second stage as negative feedback, which maintains the gain of the amplifier reasonably independent of normal changes in battery voltage and aging of tubes. This stabilization makes it practical in this simplified instrument to dispense with the usual front-panel gain adjustments. An internal adjustment is provided, however, which can be used if tube replacements make it necessary.

Components

While low price was an important objective in the design of this instrument, high-quality components have been used throughout. For example, the capacitors are hermetically-sealed units; low-noise, low-microphonic tubes are used in the first two stages; the meter is rugged, accurate, and comparatively large; the switch used is a high-quality miniature one; and the potentiometer is of a type well known for stability and long life.

Level Control

The calibrated potentiometer is a continuous level control, which is an innovation in commercial noise meters. It permits one, when measuring noise, to adjust the level control so that the fluctuating reading of the meter balances about the zero-decibel mark on the meter. Then the level is given directly by the setting of the attenuating potentiometer, which covers the most often used range of from 50 to 100 decibels.[2] An additional 30-decibel attenuation is also provided, and this with the −10 to +6 decibel range of the meter makes the total sound-pressure-level range of the instrument from 40 to 136 decibels.[2]

The continuous level control also permits the full 16-decibel dynamic range of the meter to be utilized. For example, some noises have a fairly steady background level with occasional bursts to higher levels. The level control can then be set so that the background level is at −10 decibels on the meter, and bursts of noise up to 16 decibels higher can be observed directly on the meter. This freedom of adjustment is not possible with the usual 10-decibel step control.

Meter Characteristics

The negative feedback from the meter circuit to the second stage provides a high-impedance source for the rectifier-type meter. The resultant meter current is very closely proportional to the average value of the rectified signal, over the full calibrated range of the meter, with little dependence on temperature and individual rectifier characteristics. The scale distribution on the meter is correspondingly appreciably better than that obtained when a low-impedance source is used for driving the rectifier.

The metering system fails to meet the requirements of the two-signal test[3] for r-m-s reading by only ½ decibel. An investigation made during the development of this instrument showed, however, that this discrepancy is not important for a simple Sound-Survey Meter. It was checked experimentally that for almost all sounds the difference in reading that could be ascribed to the rectifier characteristic compared to that in standard sound-level meters was less than one decibel.

The meter meets the ballistic characteristics specified for sound-level meters, which includes a limit of one decibel on the overshoot. The speed of response is only slightly faster than a VU meter,[4] so that those familiar with the behavior of that instrument will find this one very similar.

Frequency Response

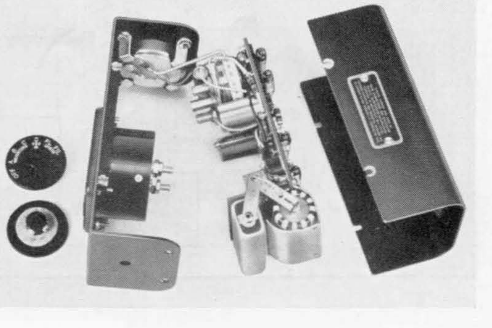
Typical over-all frequency response curves of the instrument are shown in Figure 5. These curves show the relative meter reading as a function of frequency for constant free-field sound pressure produced by a plane-wave source. The response curves include the diffraction effects of the instrument, but not those of the observer. Results are shown for two different angles of incidence and for the three different weighting networks. Those who are familiar with the usual microphone characteristics will realize that this over-all response is remarkably good.

[2]re 0.0002 μbar.

[3]American Standard for Sound-Level Meters, Z24.3 (1944), American Standards Association.

[4]A. S. A., "Volume Measurements of Electrical Speech and Program Waves," C16.5 — 1942.

Figure 3. View of Sound-Survey Meter partially disassembled to show construction.



The weighting characteristics are intended to approximate the relative response of the ear to pure tones at three different levels: the A network corresponding approximately to a 40-decibel level, the B network to a 70-decibel level, and the C network to a 100-decibel level. In this Sound-Survey Meter the minor differences at high frequencies have been ignored, and the weighting networks affect only the low-frequency response.

Maintaining uniform response at high frequencies for the different networks makes the instrument more suitable for preliminary surveys for determining possible hearing damage. It also makes it possible to estimate better the nature of the frequency spectrum being measured. For example, if a marked reduction in reading occurs when switching from the C to the B and from the B to the A networks, then most of the energy is concentrated at low frequencies. The extent of the reduction sometimes permits one to estimate the approximate frequency at which the energy is concentrated. In contrast, the usual weighting networks modify the high-frequency response as well, and this modification makes the estimate of the spectrum more uncertain.

Comparative Measurements

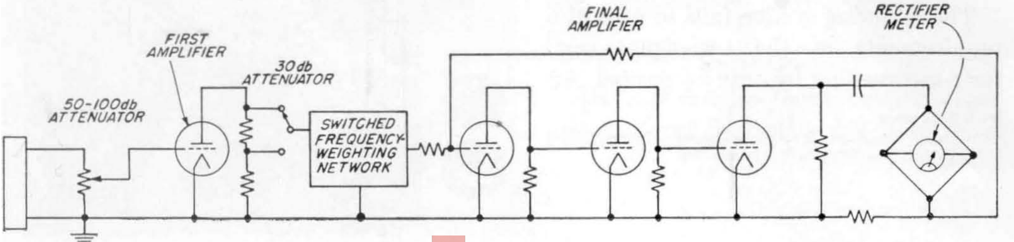
One important question that should be considered is: How does the noise-level reading as measured by the Sound-Survey Meter compare with that measured on a sound-level meter? There are many factors that enter into the answer to this question. The most important are the frequency spectrum of the noise and the frequency response characteristic of the instruments being compared. When these two factors are known, a fairly good estimate of possible differences can be made. This effect is important, not only when the Sound-Survey Meter is compared with a sound-level meter; it also is important when comparing two different types of sound-level meters that use different microphones.

For example, when the TYPE 759-P25 Dynamic Microphone is used with the TYPE 1551-A Sound-Level Meter to measure a 30-cycle signal, the reading will be about 7 decibels lower than when the Rochelle-salt microphone furnished with the instrument is used. For this frequency and the C network, the TYPE 1555-A Sound-Survey Meter reading would tend to be near that obtained when the TYPE 759-P25 Dynamic Microphone is used on the TYPE 1551-A Sound-Level Meter. Differences of similar magnitude can occur at the very high frequencies, while the differences will be appreciably less in the range from 100 to 2,000 cycles. That such differences are normal can be verified by checking the tolerances allowed in the ASA Specification on sound-level meters.[5]

Because of the limitations imposed by small size and low cost, more variation can be expected in the low-frequency response for the different networks in this simplified instrument than occur in the TYPE 1551-A Sound-Level Meter.

[5] See footnote 3.

Figure 4. Elementary schematic circuit diagram.



On the whole, however, the differences between readings taken on the Sound-Survey Meter and a commercial sound-level meter are not significantly greater than the differences that can be expected between sound-level meters of different manufacture.

Microphone

The microphone used in the Sound-Survey Meter is a Rochelle-salt-crystal diaphragm type similar in characteristics to the one supplied as standard with the TYPE 1551-A Sound-Level Meter. It operates into a high impedance, which limits the variation of sensitivity with temperature to about 0.03 db per degree F. Like all Rochelle-salt devices, it is limited to a maximum safe operating temperature of 46°C. or 115°F.; and the crystal is destroyed if kept above 55°C. or 131°F. Long exposure to extremes of humidity should also be avoided.

Maintenance

Routine maintenance checks are easily made. A battery check position is provided on the function switch. The plate battery is a 30-volt hearing-aid B-battery, which lasts for about 100 hours at two hours per day, while the filament battery operates for 20 hours at two hours per day. The filament battery is a size-C flashlight cell available in many local stores. The marked discrepancy in life of the two batteries serves to make less costly any oversight in failing to turn off the instrument. The inexpensive, readily-obtained filament battery runs down first and saves the plate battery.

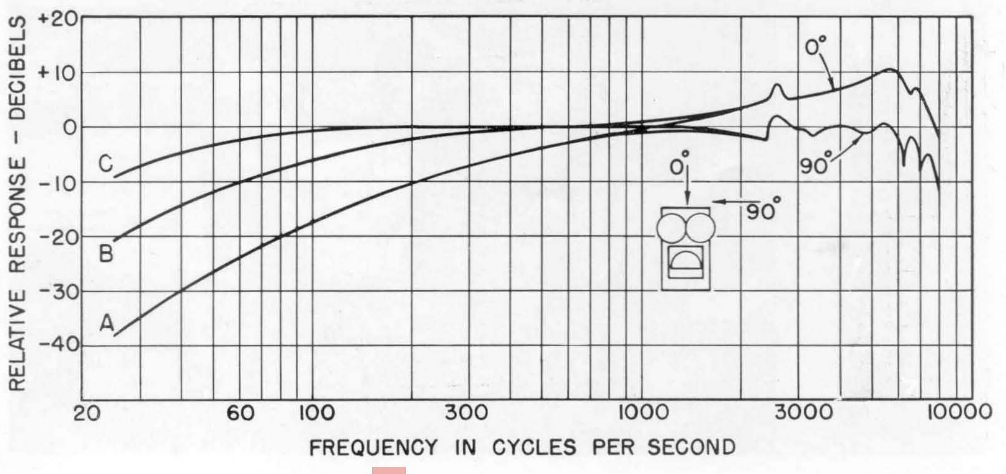
When necessary, the over-all calibration can be checked accurately with the TYPE 1552-A Sound-Level Calibrator[6] as shown in Figure 6.

Applications

The Sound-Survey Meter can be used in many measurements that have hitherto been made by the more expensive sound-level meter. For example, many noise surveys, appliance noise tests, and frequency response tests can be made satisfactorily with this new instrument. Some of these tests, however, must still be made with an instrument like the TYPE 1551-A Sound-Level Meter. When the noise must be analyzed or recorded, when a wide-frequency range system is necessary, or when a product-acceptance test requires the use of a standard sound-level meter, the

[6] E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

Figure 5. Typical frequency-response curves.



Type 1551-A Sound-Level Meter is recommended. In addition, some noise levels are beyond the range of measurement of the Sound-Survey Meter. For example, quiet electric clocks have a noise level well below 40 db, and the background level in a broadcast studio is usually in the range from 20 to 30 db on the A-weighting network. But these low levels are exceptional, and the usual noise levels to be measured are well within the operating range of the Type 1555-A Sound-Survey Meter.

In addition to these generally accepted applications for a noise meter, the low cost of the Sound-Survey Meter makes it economically practical to use for many applications that were not so feasible before. Some of these will be discussed briefly, and, because of its importance, the application of this meter for preliminary noise surveys with regard to deafness risk will also be considered.

Deafness-Risk Surveys

Much work is being done at present by industrial hygienists, otologists, psychologists, physicists, engineers, and others on the problem of hearing loss from long-period exposure to excessive noise.[7] This work will lead to essential information for judging when ear protection is necessary. Some preliminary conclusions have been reached, but, because the problem is very complicated and adequate data are not available, the present conclusions are tentative and will be modified when a better understanding of the problem develops. Some of the factors that make the problem difficult are (1) the large differences between individuals in their susceptibility to damage by noise; (2) the normal loss in hearing with age; (3) the effects of some diseases on hearing; (4) the much higher level of noise that can be tolerated without permanent damage for short exposures than for repeated long-time exposures; and (5) the higher levels that can be tolerated when the noise is dominated by low-frequency components rather than components in the higher audio-frequency range.

[7] Karl D. Kryter, "The Effects of Noise on Man," Monograph Supplement 1, September, 1950, American Speech and Hearing Association.

Leo L. Beranek, "Noise Control in Office and Factory Spaces," Transactions Bulletin 18, 1950, Industrial Hygiene Foundation, pp. 26-33.

Proceedings of the Second Annual National Noise Abatement Symposium, October 5, 1951, Technology Center, Chicago 16, Illinois.

Proceedings of the Course on the Acoustical Spectrum, February 5-8, 1952, School of Public Health, University of Michigan, Ann Arbor, Michigan.

(*Left*) Figure 6. Sound-Survey Meter with Sound-Level Calibrator in position for over-all calibration check.
(*Right*) Figure 7. Sound-Survey Meter being used to measure noise level produced by pneumatic rock drills.

Because of the importance of the problem, however, even the tentative conclusions available now are of value; and the Sound-Survey Meter is most helpful for preliminary surveys to determine if operating personnel need to wear ear defenders or if effort to reduce the noise level is justified. If the levels are sufficiently low, a check by the Sound-Survey Meter could be all that is needed. Otherwise, it can show whether or not detailed investigation using the TYPE 1551-A Sound-Level Meter and the TYPE 1550-A Octave-Band Noise Analyzer is necessary.

Sound Reproduction

The audio engineer should find the Sound-Survey Meter very useful for custom audio installations. Typical uses here are the following: adjusting the relative levels of the different speakers in a two or three-way speaker system; checking the dynamic range; setting the initial reference level for a compensated volume control; checking and adjusting low-frequency response to avoid boominess.

Speech Classes

The deaf person is obviously unable to judge the relative loudness of his own speech and that of others. A visible indication of level, such as that provided by the Sound-Survey Meter, can be a useful aid to the instructor of the handicapped in showing the student how to adjust this level. Training in adjusting the level of speaking is also needed when a hearing aid is first used, because this aid upsets the apparent balance of level between the user's voice and the background noise or other voices.

Even a person with normal hearing cannot correctly compare on a subjective basis his own voice level with that of others, because of the inherent difference between listening to himself and listening to others. The instructor in speech and drama classes may find the Sound-Survey Meter useful here for demonstrating to the student on an objective basis how his level compares with other voices, and it might be used as an aid to develop the ability of the student to project his voice to cover a reasonable audience without speech reinforcement.

After experience has been obtained with the instrument, it can be used as a guide at rehearsals. It can help in determining whether or not a given performer needs a close microphone pickup, or it may be useful in demonstrating to the performer and the director that such a pickup is necessary.

Physics Laboratories

While many college physics laboratories have sound-level meters, large numbers of high-school physics laboratories and even some of the smaller colleges have not been able to afford one. Now these can consider this new, low-cost meter. It can replace or supplement

Figure 8. Measuring the level of reproduced sound in a theatre.

some of the classical powder or flame experiments. For example, standing waves in rooms, the effects of baffles or obstructions, the attenuation of doors and partitions, the comparative intensity of various noise sources as well as other phenomena can be demonstrated.

When schools have a serious noise problem, this instrument can help in determining how to correct it. Simple sound surveys will indicate quickly which classrooms are too noisy and likely to affect the efficiency of the teachers. Experience has indicated that when the noise level exceeds 45 db on the A-weighting network, the students are likely to have difficulty in understanding the teacher.

Architects

The architect can use the Sound-Survey Meter in the study of sites for office buildings, homes, and factories. The builder often considers noise in his selection of a proper place to put a building, in the same way that he considers other environmental factors such as prevailing winds, smoke, and schools.

Field Engineers

The instrument is so convenient to carry that sales engineers of some products should find it a useful accessory on their field trips. For example, the applications engineer for acoustical materials can determine with this instrument much about the nature of any noise problem. He can determine the levels involved, and, by using the weighting networks, he can also learn something about the spectrum, which is often a crucial factor in the problem.

— Arnold Peterson

SPECIFICATIONS

Range: From 40 db to 136 db above the standard sound-pressure reference level of 0.0002 μbar.

Frequency Characteristic: Three different frequency characteristics can be selected by the main control switch. (See Figure 5.) In the *C* and *C* +30db weighting positions substantially equal response to all frequencies between 40 and 8000 cps is obtained. This characteristic is ordinarily used for all levels above 85 db.

The *B*-weighting position is used for levels between 55 and 85 db. Its response follows the 70 db contour established as the standard of weighting for sound-level meters. The *A*-weighting position is usually used for levels between 40 and 55 db. Its response follows approximately the 40-db contour established for sound-level meter weighting. In addition to providing means for making the usual weighted level measurement, these characteristics permit one to estimate, by comparative measurements with different weighting characteristics, the relative importance of low-frequency components in the sound being measured.

Microphone: The crystal diaphragm-type microphone cartridge is mounted at the top of the instrument. Temperature coefficient of sensitivity is about 0.03 db per degree F.

Meter and Attenuator: For levels below 100 db the noise level is given by the sum of the readings of the meter and attenuator.

For levels above 100 db the main control switch is set to "*C* +30db." Then the noise level is given by the sum of the readings of the attenuator and the meter plus 30 db.

The ballistic characteristics of the rectifier-type meter simulate those of the human ear and agree with those for standard sound-level meters.

Stability: The amplifier and level indicator are stabilized by feedback. The change in gain with battery voltages is thereby reduced to moderate values.

The behavior of the instrument is not noticeably affected by temperature and humidity over the ranges of room conditions normally encountered. The maximum safe operating temperature is 115° F. Temperatures above 130° F. will permanently damage the Rochelle-salt crystal in the microphone cartridge.

Accuracy: The gain of the amplifier is set initially so that the sensitivity of the instrument is correct at 1000 cps within ±1 db. The *B* and *C* frequency characteristics are essentially within the tolerances allowed by the American Standards Association specification on Sound-Level Meters. The *A* frequency characteristic is similar to that required by the ASA specification, but it provides only the low-frequency roll-off below 1000 cps.

When the *B*- and *C*- weighting networks are used, the reading of this meter for most types of sounds does not differ from that of a meter meeting the ideal characteristics given in the ASA specification on sound-level meters by more than the standard ASA tolerances increased by 1 db.

Batteries: One 1½-volt size-C flashlight battery (Eveready 935 or equivalent) and one 30-volt hearing-aid battery (Eveready 413E or equivalent) are supplied.

Tubes: Two CK512AX and two CK533AX tubes are supplied.

Case: Aluminum, finished in organic black, with standard ¼-20 tripod socket. Aluminum panel is finished in black crackle lacquer.

Dimensions: 6 x 3⅛ x 2½ inches, over-all.

Net Weight: 1 pound, 14 ounces, with batteries.

Type		*Code Word*	*Price*
1555-A	**Sound-Survey Meter***	MISER	**$125.00**
1551-P1	**Carrying Case**		**10.00**

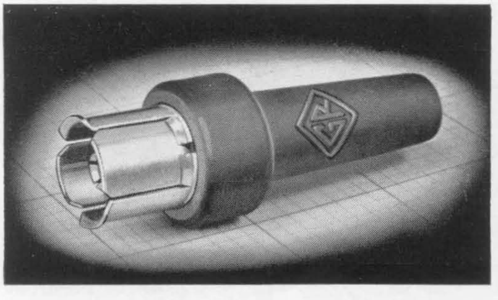
*Licensed under patents of the American Telephone and Telegraph Co.

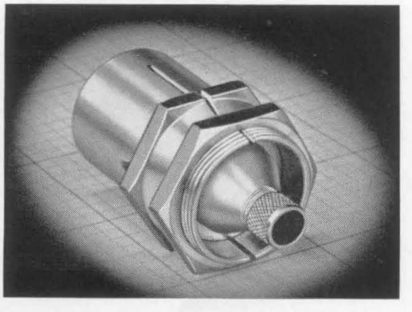
CREDITS — The development of the Sound-Survey Meter was carried out under the direction of Dr. Arnold P. G. Peterson. Credit is also due to Henry C. Littlejohn for the mechanical design, to Robert J. Ruplenas for his assistance in the electrical development, and to Dr. Leo L. Beranek, Dr. Donald B. Sinclair, and Ervin E. Gross for their many helpful suggestions.

COAXIAL CONNECTORS FOR RG-58/U AND OTHER CABLES

We have recently had several requests for a TYPE 874 Connector for use with RG-58/U and other cables of small diameter. Accordingly, we are making available the TYPE 874-C58 Cable Connector and the TYPE 874-P58 Panel Connector for this purpose. A complete list of TYPE 874 Cable and Panel Connectors, with the coaxial cables for which they are suitable, is given on page 10.

(*Left*) Cable Connector; (*right*) Panel Connector.





Type		*Code Word*	*Price*
874-C	**Cable Connector**	COAXCABLER	**$2.00**
874-P	**Panel Connector**	COAXPEGGER	**2.50**
874-C8	**Cable Connector**	COAXCORDER	**2.00**
874-P8	**Panel Connector**	COAXPUTTER	**2.50**
874-C58	**Cable Connector**	COAXCALLER	**2.00**
874-P58	**Panel Connector**	COAXPANNER	**2.50**

AN Number	Impedance in Ohms	Jacket Diameter-inches	Shields	O.D. of Dielectric	Inner Conductor	Capacitance μμf/foot	Maximum Operating Volts-rms	ATTENUATION DB/100 FT. MEGACYCLES 100	300	1000	3000	Cable Connector	Panel Connector
GR 874–A2 CABLE	50	.365	DOUBLE SHIELD TINNED COPPER	.244	41/30T	32	3500	2.6	5.1	10.5	20.5	874–C	874–P
RG–8/U	52	.405	COPPER	.285	7/21	29.5	4000	2.1	4.2	9.0	18	874–C8	874–P8
RG–29/U	53.5	.184	TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–55/U	53.5	.206	DOUBLE SHIELD TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–58/U	53.5	.195	TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–58A/U	50	.195	TINNED COPPER	.116	19/.0068	29	1900	5.3	9.6	22	45	874–C58	874–P58

A NOTE ON THE SINGLE-ENDED PUSH-PULL AMPLIFIER

Much interest has been shown in the article on the push-pull amplifier circuit in the October, 1951, issue of the *Experimenter*. Some of our correspondents have cited earlier work in which series-connected output tubes have been used. Since others may also be interested, we reproduce here their combined references, all of which are U. S. Patents.

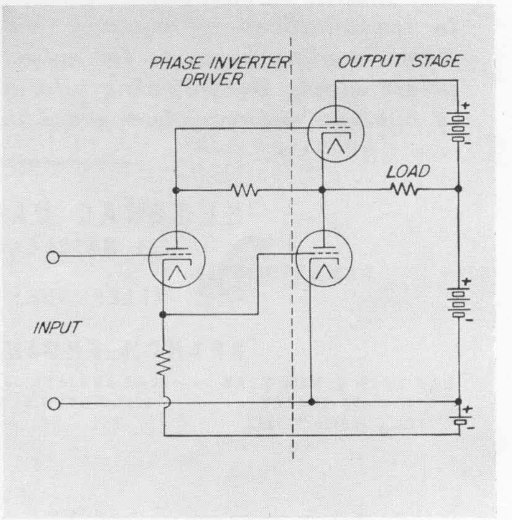
Holden	1,999,327
Gubin	2,235,677
Smith	2,247,316
Artzt	2,310,342
White	2,358,428
Etter	2,423,931
Rockwell	2,446,025
Stodola	2,488,567
Stachura	2,561,425

A study of these patents appears to show that none of them have anticipated the basic circuit of Figure 1 of the October, 1951, *Experimenter*, which is reproduced here. The essential element of this circuit is the symmetrical drive of the series output tubes without the use of a transformer. Each output tube is driven with a voltage from cathode to grid so that the two tubes operate in the same fashion. The usual attempts at driving these series tubes without a transformer result in one being driven as a cathode follower, while the other is driven as a straight amplifier or in the drive of one tube by some portion of the output voltage. With either of these systems the true push-pull symmetry of Figure 1 is lost.

Another point raised by several of our correspondents concerns the heater-to-cathode voltage of the upper output tube. When the series circuit is used, this voltage is usually so high that a separate heater winding must be used for the upper output tube. This winding should then be connected to a d-c potential corresponding to the average potential of the upper cathode. Sometimes, because of the high a-c voltages developed, this separate winding must be connected directly to the cathode rather than to a derived d-c potential. Then it is desirable to use a shielded, twisted pair for the connection from the transformer to the heater. When tubes like the Type 6AS7 Twin Triode are used in the output, however, this separate heater winding is not usually necessary.

The connection of one side of a separate heater winding to the cathode adds a capacitance across the output load. The effect of this capacitance is usually insignificant. For example, it can usually be kept to less than 200 $\mu\mu$f; and then for two Type 6L6 Pentodes as output tubes the frequency at which the reactive current is equal to the load current is 500 kc. This figure applies for a 1650-ohm load and, if lower-impedance tubes

Figure 1. The basic single-ended push-pull amplifier circuit, showing the series-connected output tubes supplying a common load and driven by a cathode-follower phase inverter.



are used or if more care is exercised in reducing the stray capacitance, the effect is even less important.

Those who want additional information on the amplifier should find the paper on "A Single-Ended Push-Pull Audio Amplifier" in the January, 1952, issue of the *Proceedings* of the Institute of Radio Engineers helpful. Reprints of this paper are available on request from the Editor of the *General Radio Experimenter*.

MISCELLANY

ELECTED — Kipling Adams, Manager of our Chicago office, has been named Chairman of the Board of the 1952 National Electronics Conference. Mr. Adams is also Secretary of Region Five of the Institute of Radio Engineers.

William M. Ihde, of our Chicago office, has been elected Secretary of the Chicago Audio and Acoustic Group.

RECENT VISITORS: Mr. E. Garthwaite, Chief Engineer, Marconi Instruments Co., St. Albans, Herts., England; Mr. Jurg Keller, Manager, Seyffer and Co., our representatives for Switzerland; Prof. Andrea Pinciroli, National Electrotechnical Institute, Turin, Italy; Mr. Giuseppe Fidecaro, Physicist, Instituto di Fisica, Universitaria Rowe, Italy; Prof. E. W. Kimbark, Instituto Technológico de Aeronáutica, Sao Paulo, Brazil; and Dr. Hideo Seki, Radio Regulatory Administrative Office, Tokyo, Japan.

PUBLICATIONS AVAILABLE

The series of articles entitled "The Versatile Voltage Divider," which appeared in the *Experimenter* in 1950, is now available in reprint form with some new material. These articles discuss the design, characteristics, and applications of variable three-terminal resistors, commonly called "potentiometers."

Reprints are also available of "Apparatus for Noise Measurement" by Leo L. Beranek. This paper describes a sound-measuring system and discusses the various components.

We shall be glad to send you a copy of either paper on request.

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

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VOLUME XXVI No. 12 MAY, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A THREE-QUARTER HORSEPOWER VARIAC® MOTOR SPEED CONTROL

Also

IN THIS ISSUE

●**THE VARIAC SPEED CONTROL** provides adjustable-speed operation of d-c motors from a-c power lines. This control uses no electronic tubes, so is capable of instant starting, without warm-up. Its basic simplicity makes possible a compact, single-unit construction with the ruggedness and reliability needed in industrial applications.

Since the Variac Speed Control was first introduced, there has been a persistent demand for a unit large enough to handle light production machine work. The one-third horsepower rating of the Type 1700-B Variac Speed Control is insufficient for this duty, although it has proved ample for many special applications such as toroidal winding machines, resistance-card-winding machines, and for lathes used in finishing small parts. It has been apparent that a unit of about three-quarter horsepower rating

Figure 1. Panel view of the Type 1702-A ¾-hp Variac Speed Control.

would greatly extend the field of application of controls of this type. The TYPE 1702 Variac Speed Control shown in Figure 1 is now offered to meet this need.

Characteristics

The circuitry, construction, and performance of the new three-quarter horsepower control are all practically identical with those of the one-third horsepower TYPE 1700-B Variac Speed Control recently announced.[1]

Figure 3 is a schematic circuit diagram. An adjustable armature voltage is supplied by a bridge-connected selenium rectifier fed by a Variac® autotransformer. A fixed shunt-field voltage is supplied by a separate transformer and rectifier system. The base speed of the motor can be increased if desired by about 15 per cent by shifting the output lead of the field-supply transformer to the low-voltage tap provided.

Some of the important features of this control are:

(1) The use of selenium rectifiers eliminates tube replacement and the warm-up time delay when the unit is first turned on. The rectifiers adopted for these controls are of a type having long life even when operating in high ambient temperatures.

(2) The control is simple and rugged and is easy to install and maintain. A compact, single-unit construction is employed, including dynamic braking and a manually operated starting and reversing switch. The size of the three-quarter horsepower control is not proportionately larger than that of the one-third horsepower unit and is still small enough, 15 x 13 x 5³⁄₁₆ inches, so that it can be mounted beside a machine within convenient reach of the operator.

(3) An isolated field supply permits the use of compound-wound motors with their greatly improved starting characteristics. Since the control has very large short-period overload capacity, this means that heavy loads can be started or reversed quickly and often, without damage to the control system.

(4) The choke (L_1 in Figure 2) reduces the a-c ripple in the armature circuit, thus lowering motor losses and eliminating torque pulsation at the ripple fre-

[1] W. N. Tuttle, "An Improved Variac Speed Control," *General Radio Experimenter*, Vol. 25, May, 1951, pp. 1-5.

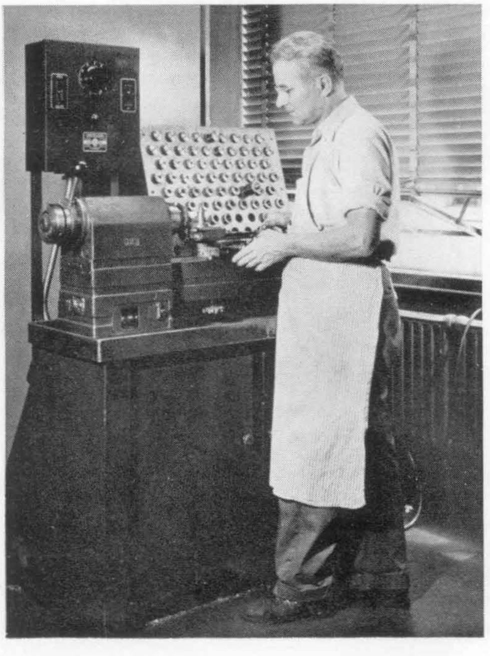


Figure 2. Typical installations of the ¾-hp Variac Speed Control, *(left)* on a lathe, and *(right)* on a toroidal winder.

quency. This feature is particularly important in precision grinding operations where other types of controls are unsatisfactory.

(5) The armature voltage source has a low internal impedance so that the inherently good regulation characteristics of shunt or compound-wound motors are largely preserved. The regulation with a standard compound-wound motor is about 24 per cent at base speed. Speed-torque curves are given in Figure 4.

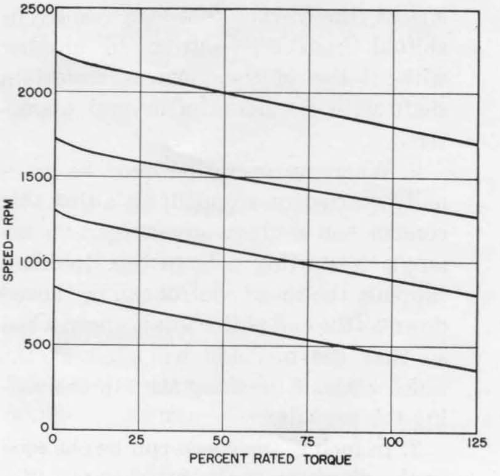


Figure 4. Typical speed-torque curves for the Type 1702-A Variac Speed Control operating a ¾-hp compound motor.

Motors

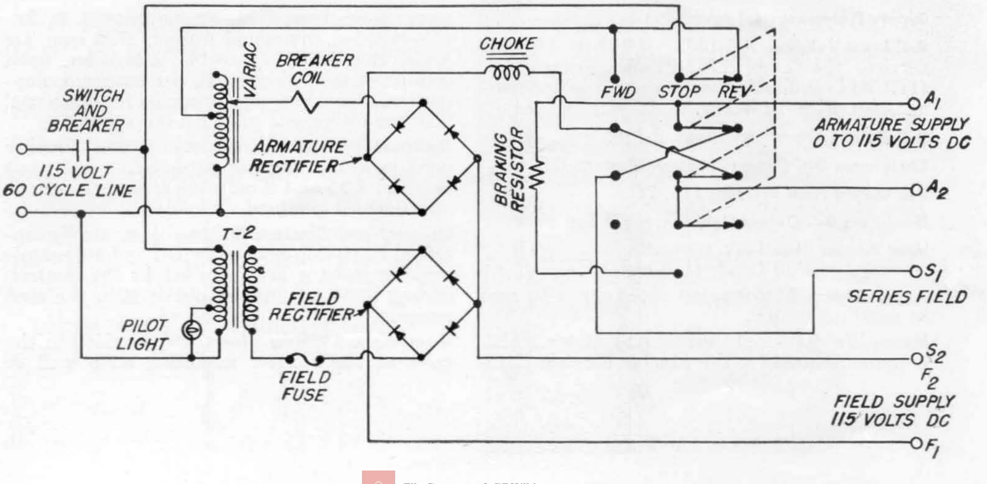
Motors can be purchased directly from the motor manufacturer or from the General Radio Company. In the selection of motors, armature currents should be checked to determine that full-load ratings conform to the output rating of the Variac Speed Control as listed in the specifications, page 4.

Applications

Experience with the three-quarter horsepower controls in our own production work has shown that their characteristics are excellent for a wide range of applications. These include not only a large proportion of the cases where some sort of continuously adjustable speed control is obviously required, but also many applications where conventional step-pulley drives were formerly employed and where increased production efficiency has been found to result from substitution of the Variac Speed Controls. The reaction of the operators has been that this drive is the best that they have ever used. A few situations in which the new controls have saved production time are the following:

1. Where several lathe operations are done on the same piece at different

Figure 3. Schematic circuit diagram of the Type 1702-A Variac Speed Control.



speeds, the Variac knob can readily be shifted from one setting to another without loss of time. An example is a shaft with shoulders of several diameters.

2. Where an operation must be gradually started or stopped, an adjustable control has a great advantage. An example is starting a large tap. In blind tapping, the speed control can be turned down as the end of the hole is approached so that the machine will stall at the finish without breaking the tap or spoiling the threads.

3. In facing, the speed can be changed as the diameter of the cut changes.

4. Since speed can be changed quickly and easily, certain operations such as withdrawing a tap are naturally speeded up to the limit, with appreciable saving in production time.

5. Some operations require rapidly repeated starts, stops, and reversals. Since an induction motor starts very inefficiently, such service may cause overheating and short motor life in conventional drives. A compound-wound motor, as used with the Variac Speed Controls, has much better starting characteristics, so starts faster and heats up less.

6. Since the optimum speed for a given operation can be quickly determined with an adjustable control, faster production is frequently obtained than with conventional drives which provide only three or four fixed speeds.

In many of the lathe installations made in our shops, the three-speed step-pulley drive of the original equipment has been retained, only the motor and control being changed. In these cases, it has been observed that the operator usually shifts the belt only when increased torque is required at low speeds. An installation has recently been made with the motor belted directly to a back-geared lathe at a fixed speed ratio. This has proved entirely satisfactory, there being plenty of overlap between the minimum useful speed with direct drive and the maximum speed using the back gears. This is a particularly simple and satisfactory installation.

This new three-quarter horsepower unit extends the application of the Variac Speed Control to light production operations, where its many advantages are even more evident than in the specialized jobs for which the lower-power models are suited.

— W. N. Tuttle

SPECIFICATIONS

Supply Frequency: 60 cycles.

A-C Input Voltage: 105-125. For 210- to 250-volt service, the Type 1702-P1 Autotransformer (1KVA) is available to step down the line voltage. See price list below.

D-C Output Armature Voltage: 0-115.

Continuous D-C Output Armature Current: 6.5 a.

D-C Output Field Voltage: 115, 75.

Maximum D-C Output Field Current: 0.4 a.

Input Power: Stand-By, 65 watts.
Full Load, 1150 watts.

Speed Range: Motor rated speed down to zero at constant torque.

Motor: We can supply our MOD-6 motor, which is manufactured by the Master Electric Company: their Type DM, Frame No. 66, ¾ hp, 115-volt d-c, compound wound, 1725 rpm, six leads, electrically reversible, interpoles, open drip-proof mounting, 40°C. rise continuous operation, sleeve bearings, arranged for horizontal floor mounting. See price list on page 5.

Overload Protection: Magnetic circuit breaker permits heavy starting current but will open between 7.25 and 9 amperes armature current on sustained overload.

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

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

Dimensions: Box, 13 x 15 x 5$\frac{3}{16}$ inches; overall, including knobs, 13$\frac{9}{16}$ x 15 x 6$\frac{5}{8}$ inches. TYPE 1702-P1 Autotransformer, 3$\frac{1}{2}$ x 4$\frac{1}{4}$ x 5$\frac{9}{16}$ inches.

Net Weight: TYPE 1702-A Variac Speed Control, 41 pounds; TYPE 1702-P1 Autotransformer, 20$\frac{1}{4}$ pounds.

Type		*Code Word*	*Price*
1702-A	**Variac® Speed Control* — ¾ hp**	AMAZE	**$230.00**
1702-P1	**Autotransformer, 230 to 115 volts**	WOVEN	**27.50**
MOD-6	**¾ hp Motor**	MOTOR†	**80.90**

*U. S. Patent No. 2,009,013.
†To order speed control with motor, use compound code word AMAZEMOTOR.

PRICE REDUCTION ON MOD-4 MOTOR

The price of the TYPE MOD-4 universal motor, $\frac{1}{15}$ hp, for use with the TYPE 1701-AU Variac® Speed Control** is reduced from $29.85 to $17.50. This new price is effective on all orders now on hand, as well as those received in the future.

**W. N. Tuttle, "A Smaller Variac Speed Control," *General Radio Experimenter*, XXIV, 5, October, 1949.

USES OF VARIACS IN ELECTRICAL ENGINEERING POWER LABORATORIES

by Abraham Abramowitz††

Variac® autotransformers have been widely used in communication and electronics laboratories. Because of their relatively late arrival on the equipment scene, particularly in the larger sizes, they are less commonly found in the power laboratory. For many purposes, they can take the place of large, costly, adjustable-voltage sources. In addition, they offer the advantages of simple installation and complete portability.

For example, transformers are always tested by means of standard no-load tests, namely the open- and short-circuit tests. For these tests 220- to 110-volt transformers of 1- to 5-kva capacity are commonly used. A 115-volt Variac in conjunction with a step-down autotransformer is ideal for this test. Fortunately, the Variac required can be considerably smaller than the transformer rating.

Let us take, for an illustration, a 220- to 110-volt, 3-kva transformer. Reference to tables of representative losses in transformers such as "Electrical Engineering Laboratory Experiments," fourth edition, by C. W. Ricker and Carlton E. Tucker, yields the following data: Exciting current, 4.5 per cent of load current; impedance voltage, 3.4 per cent. At rated low-voltage input, the no-load current will be $\frac{3{,}000}{110} \times 0.045 = 1.23$ amperes. For test purposes, it is desirable to overvoltage the transformer say 10 per cent. If this is done, the transformer becomes saturated, and the no-load current will rise approximately 2.5 times. Thus a 5-ampere (V-5) Variac will more than suffice. For the short-circuit test (input on the high side), the voltage will be $0.034 \times 220 = 7.48$ volts at $\frac{3{,}000}{220} =$ 13.65 amperes. In order to overload the

††Professor of Electrical Engineering, College of the City of New York.

transformer, about 15 volts should be provided. This can be done by using a 110-volt to 20-volt step-down transformer of 500 volt-ampere capacity. The Variac will be called upon at maximum to furnish $\frac{500}{110} = 4.54$ amperes. Thus, a 5-ampere Variac will be more than ample. The step-down transformer does more than cut the required Variac capacity, since it permits much better control than an appropriate large Variac.

We see that a 5-ampere Variac is sufficient for testing a 3-kva transformer. For use in the power laboratory, the Variacs should be ordered for the largest unit to be tested, if the test transformers can be used to change the voltage available from the Variac.

Three-phase ganged Variacs also have a place in the power laboratory. Three-phase variable voltage is commonly used for running-light and blocked-rotor testing of induction motors and for the slip test on salient-pole alternators. Here, too, the Variacs can have smaller capacity than the machines to be tested.

View of the three-gang Variac assembly used in the electrical engineering laboratories of the College of the City of New York.

(Photo by McManus Studios)

In the electrical engineering laboratories of the College of the City of New York, two three-gang 20-ampere Variacs have been employed for several years for testing a 15-horsepower, 220-volt, 39-ampere, wound-rotor induction motor and for performing the slip test on a 15-kva, 39-ampere, 220-volt, salient-pole alternator. The results have been extremely satisfactory. The unit has become so popular that an auxiliary variable-voltage a-c motor-generator is rarely used.

The Variac is supported on an angle-iron frame mounted on casters to insure portability. Two-to-one step-down autotransformers are mounted integrally with the Variac. A three-pole double-throw switch permits the selection of either 0-220 volt or 0-110 volt output (actually due to the voltage available in the laboratory, 0-208 volts and 0-104 volts are obtained). The Variac and autotransformers are both "wye" connected. A 40-ampere unit has been built with delta-connected autotransformers. The Variac is not connected for output voltages higher than the input, although this can be done if desired. The unit is protected against overload by a Heineman magnetic breaker with a type-2 delay curve.

The 0-220 volt position is used for the induction motor running-light test and the lower voltage position for the blocked-rotor test. For the blocked-rotor test about 50 volts is required, and a four-to-one step-down transformer could be used. However, the 0-110 volt position makes the unit more versatile for all-around use. There is ample control for the low voltage. The low-voltage position is also used to apply less than 80 volts to an unexcited salient-pole alternator running near synchronous speed. As the poles line up and fall out of phase with the resulting rotating field of the stator, the input line current fluctuates. This permits the direct and quadrature axis reactances to be measured. Incidentally, when alternators are used for this purpose, the input voltage fluctuates due to poor alternator regulation. This effect is so small with Variacs that students often think something is wrong with the test.

Ganged Variacs can also be used to build adjustable reactors and capacitors by connecting suitable single-phase units in delta across the Variac output.

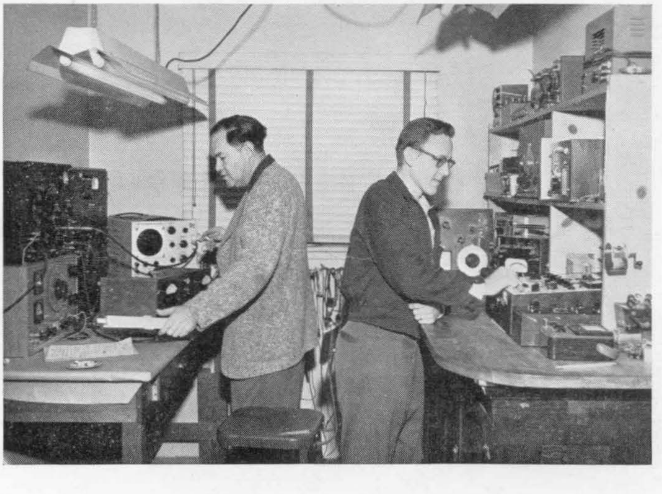
I wish to acknowledge the encouragement given me by Professor Harold Wolf, Chairman of the Electrical Engineering Department, and to Mr. Otto Sauer, who actually constructed the units.

WESTERN INSTRUMENT COMPANY OFFERS REPAIR SERVICE TO WEST COAST CUSTOMERS

West Coast users of General Radio instruments can now have their equipment repaired and recalibrated in California, thus avoiding the expense and delay that now occur when material is returned to our factory.

Western Instrument Company, 826 North Victory Boulevard, Burbank, California, has been appointed West Coast service agency for General Radio products. This firm has a well-equipped laboratory and machine shop to give prompt and competent repair service on all General Radio instruments. Their repairs and calibrations are made to the same specifications and standards as used at our factory, and we are glad to recommend their service to our friends in the West Coast states and adjacent areas.

Western Instrument Company is owned and operated by Albert K. Edgerton, who was graduated from Pomona College with the degree of A.B. in Physics in 1934. For the next three years he was employed in electronics in the Los Angeles area, and in 1936 he established the Western Instrument Company.



View of the modern, well-equipped laboratory at Western Instrument Company.

From the first, this company has been concerned with consulting and measurement services in electrical and related fields. Development and design facilities for industrial and laboratory controls, as well as measuring equipment, have been a corollary activity. Mr. Edgerton has been engaged in small-quantity production lots of special electrical and measuring equipment. During World War II he was a staff member of the Radiation Laboratory at M.I.T. in Cambridge, Massachusetts, for eighteen months, later becoming Chief Test Engineer for the Research Construction Company, an engineering and production organization affiliated with the Radiation Laboratory. Since 1946 he has devoted his full time to the operation of the Western Instrument Company, which continued during the war as an electrical measurements laboratory facility for Southern California industry.

Mr. Edgerton has found an increasing interest in the need for maintenance and calibration facilities for electrical and electronic laboratory equipment on the West Coast, and in early 1951 he became affiliated with the General Radio Company to handle their service and repairs in the area.

Engineering and commercial matters are still to be referred to our Los Angeles Office at 1000 North Seward Street, staffed by Mr. Frederick Ireland and Mr. James G. Hussey, but problems concerning the repair and recalibration of General Radio equipment can be taken up directly with Mr. A. K. Edgerton at the Western Instrument Company, 826 North Victory Boulevard, Burbank, California.

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THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VOLUME XXVII No. 1 JUNE, 1952

STANDARDIZED TERMINALS AND CONNECTORS

Also

IN THIS ISSUE

Page

● **SINCE THE EARLY DAYS OF RADIO** the name of General Radio has been identified with high quality standard parts. The Type 274 Banana Plug, originally designed as an improvement over earlier European types, has become universally accepted, with its companion jacks and jack-top binding posts; and it is interesting to note that, even in European countries where other dimensions are established in the metric system, the General Radio binding-post spacing of ¾″ has been adopted as standard.

The virtues of versatility and standardized dimensions in terminal and connecting systems are important both to the individual experimenter and to the manufacturer. In the laboratory, substantial savings in time can be realized by the use of terminals that can be easily connected together in different manners and configurations. In production, substantial savings in stocking, quantity purchasing, and standardized assembly can be realized by using parts that are adaptable to many uses and that are designed to follow a simple, standardized system of dimensions.

The General Radio Types 274, 874, 838, and 938 Terminals and Connectors have been carefully worked out to meet these requirements.

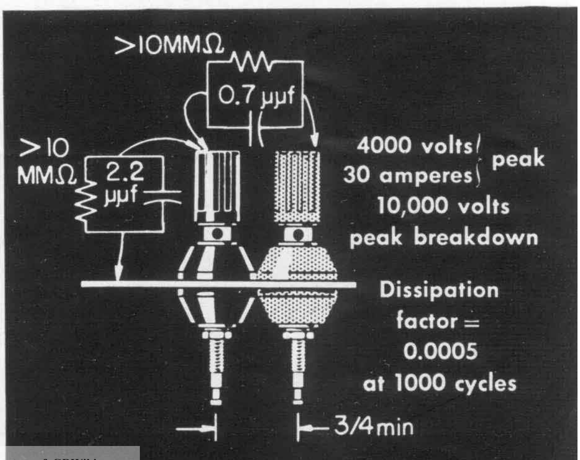


Figure 1. Electrical characteristics of a pair of Type 938 Binding Posts.

High quality materials are used throughout, excellent electrical characteristics have been achieved, harmonious appearance has been combined with functional correctness, and mechanical details have been so planned that versatility and simplicity are outstanding. The result of a continuing program of refinement and standardization has been the development of an integrated line of so-called electronic hardware that, it is believed, will meet all the connector needs of the electronic laboratory and the manufacturer of electronic laboratory equipment.

PART I — TERMINALS

Type 874 Coaxial Connector

The TYPE 874 Coaxial Connector has been previously described in detail,[1] and its adaptability demonstrated by its use in the extensive line of TYPE 874 Coaxial Elements.[2] Its main features are that any connector will plug into any other, no male and female versions being required, and that its tubular center conductor will accept any TYPE 274 Banana Plug or TYPE 838-B Alligator Clip. The cable connector, when mounted in a collet, becomes a panel connector. As such it becomes a general-purpose quick-connect-and-disconnect coaxial connector accepting any other TYPE 874 Connector or a TYPE 274-DB1 or TYPE 274-DB2 Insulated Single Plug. Its diameter is so chosen that a TYPE 938-P Grounded Jack-Top-Type Binding Post can be mounted adjacent to it at a spacing of ¾″. Since its height is the same as that of the binding post, a TYPE 274-MB Double Plug can then be plugged into the combination if the complete shielding of a coaxial cable is not required. Its bright-alloy-plated finish matches that of other terminals of all types.

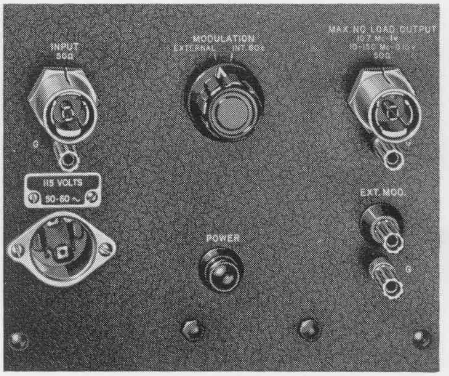


Figure 2. The Type 938-P Binding Post Assembly and the Type 874-P Panel Connector can be mounted as shown here on the Type 1023-A Amplitude Modulator to permit connection by either coaxial connector or double banana plug.

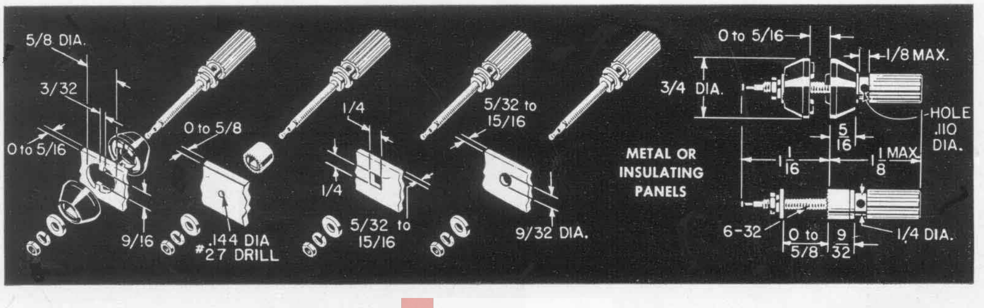
Type 938 Binding Post

The TYPE 938 Binding Post comes in three versions: the metal top TYPE 938-A, the black insulated top TYPE 938-C, and the red insulated top TYPE 938-D. A completely new design in all details,

[1] W. R. Thurston, "A Radically New Coaxial Connector for the Laboratory," *General Radio Experimenter*, XXIII, 5, October, 1948.

[2] W. R. Thurston, "Simple, Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, XXIV, 8, January, 1950.

Figure 3. Mechanical details of the Type 938 Binding Posts and Binding Post Assemblies. Locking keys in ⅝-inch mounting hole can be omitted if locking feature is not wanted.



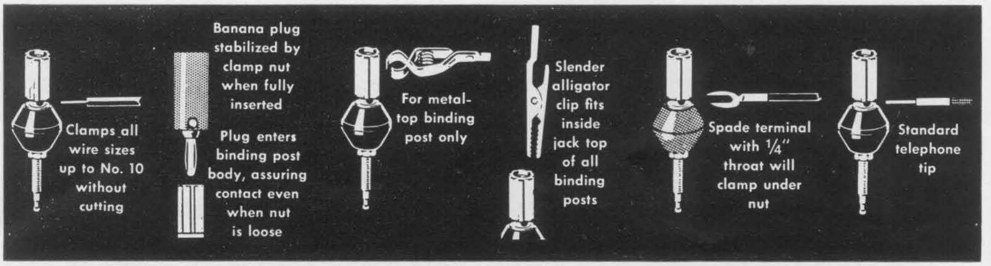


Figure 4. Six methods of connection that show the versatility of the Type 938 Binding Post.

these binding posts represent a substantial improvement over the older Type 138 Binding Posts which they replace.

The jack-top feature of the older binding posts is retained, but the hole into which the banana plug enters is in the body rather than in the top. If the top is not tightened down, there is therefore no danger of erratic contact caused by loose fit in the threads.

Back-of-panel connections to the binding post are soldered directly to a turret turned down on the mounting stud so that there is no danger of erratic contact from loosening up of nuts holding a soldering terminal.

The tops, fluted to resemble the Type KN knobs, are easily tightened and loosened with the fingers. At the end where the banana plug enters, they are chamfered to give a firm seat for the shoulder of the plug and to prevent rocking. At the end where a connecting wire enters the cross hole, they are contoured to produce a firm grip *without a shearing action.* This contour, combined with the proper choice of cross-hole size and location in the body, makes the binding post satisfactory for wire sizes from AWG No. 40 to No. 10, and for standard telephone tips. The body diameter is so chosen that a spade terminal with ¼″ throat will clamp securely between top and body. The top diameter is so chosen that a standard battery clip will fit the metal-top Type 938-A, and Type 838-B Alligator Clips will clip into the banana-plug holes on all three types, insulated and uninsulated. To prevent accidental loss, all tops are captive.

Insulation throughout is polystyrene to assure highest quality electrical behavior. Dielectric constant and dissipation factor are low, leakage resistance is high, and the effects of moisture are minimized. The insulated binding-post tops have polystyrene sleeves cemented over bright-alloy-plated threaded brass inserts. Type 938-BB Black Insulators and Type 938-BR Red Insulators furnish universal insulating mounting means with a single interchangeable piece. This piece, a polystyrene cone of pleasing proportions, is recessed to reduce capacitance and increase leakage path, and has shoulder contours at top and bottom that yield a high degree of versatility. At the top end, the hole is square to accommodate the square anti-rotational shoulder of the Type 938 Binding Posts; the dimensions of the square are so chosen that Type 274 and Type 938 Jacks fit snugly within it; and the square hole is slightly recessed within a round hole of the proper diameter to center the older Type 138 Binding Posts. At the bottom end, the locating shoulder is so recessed that, where two pieces are rotated 90° from each other, the shoulders nest within each other and the mounting surfaces can be brought together to touch. As a result, a pair of cones can be mounted on any thickness of panel from zero to 5/16″. On thin panels, the nesting of the locating flanges locks the two pieces so that they cannot rotate with respect to each other, and four openings are left in the nested locating shoulders that can be used to engage a tab in the panel hole to prevent rotation of the assembly. On thick panels the pieces can be keyed individually to the panel-hole tab.

The advantages of using individual insulating mounting cones for each binding post, as contrasted to the older TYPES 274-Y and 274-Z Double Insulators, are largely in versatility and simplification of stocking. Since each assembly is complete in itself, binding posts can be located anywhere on a panel at center-line separations equal to or greater than 3/4″. The problems of single binding posts, clusters of binding posts, or binding posts at non-standard separations can therefore be solved without special parts.[3] For grounded binding posts, however, the TYPE 938-F Spacer has been found a useful supplement to the insulating cones. This spacer, made of bright-alloy-plated brass, has a square center hole to fit the square anti-rotational shoulder of the TYPE 938 Binding Posts, and a flat knurl on the bottom to prevent rotation of the assembly when mounted on a panel. Two advantages accrue from the use of a binding post mounted on this spacer for a ground terminal. From an electrical standpoint, the short, direct connection to the panel furnishes a low-inductance ground; from a production standpoint, the assembly operation of connecting a wire to the binding post and to some ground point is eliminated.

For convenience in ordering, five complete binding-post assemblies are listed. These are:

TYPE 938-W: TYPE 938-A (metal top) + TYPE 938-BB (pair of black insulating cones)

TYPE 938-R: TYPE 938-A (metal top) + TYPE 938-BR (pair of red insulating cones)

[3]For applications where equipment is already designed to use the older TYPE 274-Y or TYPE 274-Z Panel Terminal Insulators, the TYPE 938-Z Replacement Binding Post Insulator can be directly substituted. This insulator, moulded of black polystyrene, has the same outside dimensions and mounts in the same holes as the older insulators, and it will accept either TYPE 938 or 138 Binding Posts or TYPE 938 Jacks. See price table on page 5.

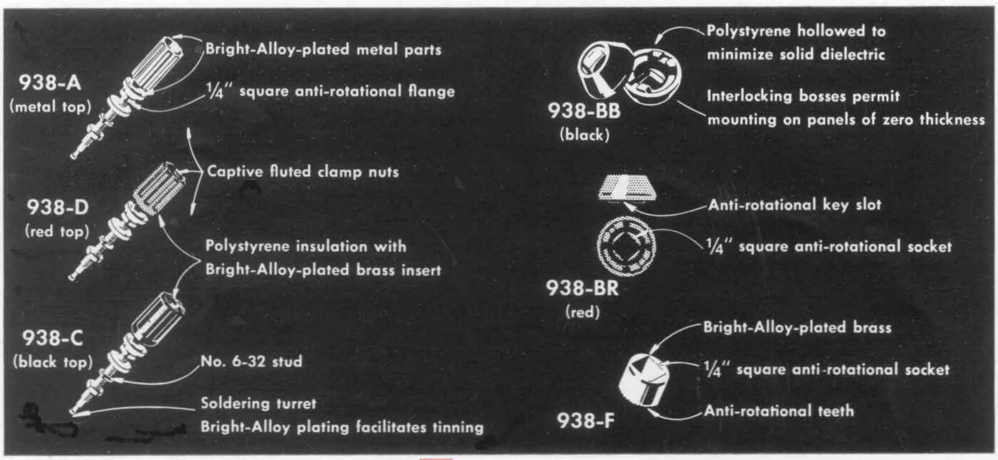


Figure 5. Basic parts of the Type 938 Binding Post.

TYPE 938-WB: TYPE 938-C (black insulating top) + TYPE 938-BB (pair of black insulating cones)

TYPE 938-WR: TYPE 938-D (red insulating top) + TYPE 938-BR (pair of red insulating cones)

TYPE 938-P: TYPE 938-A (metal top) + TYPE 938-F (metal spacer)

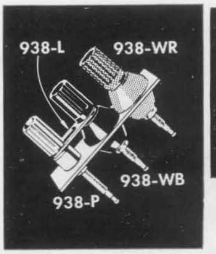


Figure 6. Typical binding post assemblies.

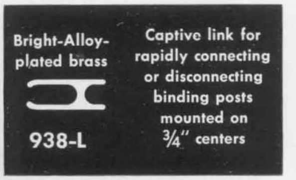


Figure 7. Shorting link is useful in connecting one post of a pair to a third, grounded, post as shown in Figure 6.

PART II
which discusses connectors will appear in the July issue.

BASIC PARTS

Type		*See Figure§*	*Code Word*	*Unit Prices†* 10*–99	100–999	1000–1999	2000–9999	10,000 up
938-A	Metal top B. P.	5	STANPARASP	$0.30	$0.26	$0.24	$0.23	$0.22
938-C	Black top B. P.	5	STANPARAWL	0.40	0.34	0.32	0.30	0.29
938-D	Red top B. P.	5	STANPARARM	0.40	0.34	0.32	0.30	0.29
938-BB	Black ins. (pair)	5	STANPARAUK	0.125	0.11	0.105	0.10	0.095
938-BR	Red ins. (pair)	5	STANPARATE	0.125	0.11	0.105	0.10	0.095
938-F	Spacer	5	STANPARBON	0.025	0.02	0.02	0.02	0.02
938-L	Shorting Link	7	STANPARBET	0.10	0.09	0.085	—	—

ASSEMBLIES

938-P	Metal top, 938-F Spacer	6	STANPARDOT	$0.325	$0.28	$0.26	$0.25	$0.24
938-W	Metal top, black ins.	*not shown*	STANPARANT	0.425	0.37	0.35	0.33	0.31
938-R	Metal top, red ins. .	*not shown*	STANPARGIG	0.425	0.37	0.35	0.33	0 31
938-WB	Black top and ins. . .	6	STANPARBAN	0.525	0.45	0.425	0.40	0.38
938-WR	Red top and ins.	6	STANPARCUB	0.525	0.45	0.425	0.40	0.38

*Minimum quantity sold. †Net prices. No further quantity discounts.
§For the convenience of the user, all binding posts and assemblies are supplied unassembled.

TYPE 938-Z REPLACEMENT BINDING POST INSULATOR

The TYPE 938-Z Insulators fit the TYPE 938 Binding Posts, as well as the obsolete TYPE 138 Binding Posts. Since, in addition to the above, the TYPE 938-Z Insulators mount in the same (½" diameter) holes, they serve as replacements for the TYPES 274-Y and 274-Z Insulators or to mount TYPE 938 Binding Posts in place of TYPE 138 Binding Posts.

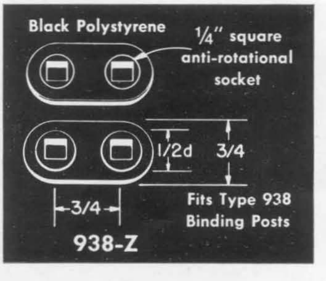


Figure 8. Flat insulators shown here are available for applications where present designs require them.

Type		*Code Word*	*Price† per pair* 5*–99	100–999	1000–1999	2000–9999	10,000 up
938-Z	Insulator	STANPARHOD	$0.175	$0.165	$0.155	$0.145	$0.14

*Minimum quantity sold. †Net prices. No further quantity discounts.

TWELVE TONS OF SALT AND AN IMPEDANCE BRIDGE DETECT LEAK IN PIPE LINE

A new raw-water intake line for the City of Wyandotte, Michigan, installed last year, consisted of 1700 feet of 42-inch concrete pipe laid in a trench 12 feet deep, below the bottom of the Detroit River. Before the trench was filled to cover the pipe, tests showed a leakage of only one gallon per minute, which was negligible compared to the leakage allowed by the specifications.

During the process of backfilling, a constant head of approximately 20 feet was maintained in the pipe. After about 800 feet of the work had been completed, a leak developed, so serious that two pumps, delivering 60,000 gallons per hour, were unable to fill the 12-inch riser pipe used as a test head.

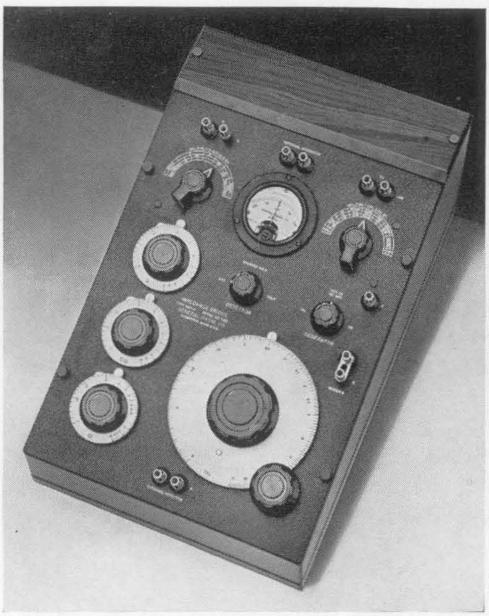
To repair the leak, it was first necessary to locate it. Pumping tests indicated that the leak was in the covered portion of the pipe.

The method chosen to locate the leak consisted of pumping into the pipe water containing known concentrations of various substances and using detection apparatus in boats on the river. Among the materials used were activated carbon, fluorescine dye, chlorine, ping-pong balls, and oranges. None of these gave positive results.

Finally, through the cooperation of the Pennsylvania Salt Manufacturing Company, a brine solution was tried, and a conductivity measurement of the river water was used as an indicator. The detector consisted of a test cell that could be immersed in the water and a General Radio Type 650-A Impedance Bridge to measure the cell resistance. Calibration tests on the cell were made with various concentrations of salt in solution as well as measurements of the normal river water resistance as a function of the distance from shore.

Some twelve tons of salt were used in the test. Brine solution was pumped into the line, and the boat crew moved out from shore over the pipe line. The normal resistance of river water varied from 1,000 ohms at a point 25 feet from shore to 4,500 ohms 2,000 feet out. As the boat moved along, the galvanometer was kept at zero by changing the setting of the main resistance dial to balance the progressive change in water resistance.

The leak was located in a very short time and was evidenced by a sudden pronounced deflection of the galvanometer. Repeated tests each located the leak at the same spot, about 650 feet off shore. Excavation proved the leak to be at this spot and repairs were quickly made.



View of the Type 650-A Impedance Bridge.

The Type 650-A Impedance Bridge was selected for this job because it is completely self-contained, direct reading, and has more than adequate accuracy for the measurements.

The single resistance dial with logarithmic scale made it easy to monitor the change in normal resistance of the river water, so that pronounced deflection of the galvanometer could be obtained at the point of the leak.

The foregoing was abstracted from an article entitled "Leak Detection on Sub-Aqueous Raw-Water Intake Line," by George Hazey, Chief Operator, Filtration Plant, Wyandotte, Michigan, appearing in *Water and Sewage Works* for September, 1951.

PULSED SIGNALS IN NOISE

There are many occasions in the design, development, and manufacturing test of large electronic systems where a source of pulsed signals in noise is practically a necessity. Oftentimes a complete high-gain pulse-receiving amplifier is tied up to supply such signals where such complexity is hardly desirable.

For some applications at the Sperry Gyroscope Company, Great Neck, New York, this problem has been solved by use of the General Radio Type 1390-A Random Noise Generator in conjunction with simple auxiliary circuitry. The system is indicated in Figure 1 with appropriate waveforms in Figure 2.

The purpose of the detector is to transform the bi-polar random noise from the generator, Figure 2A, to unipolar, or video, noise, Figure 2B. The signal mixing tube is one in which the output is inversely proportional to the sum of its two inputs. Thus a mixer output of variable signal-to-noise ratio can be obtained by varying either the output of the 1390-A, Figure 2A, or the output of the pulse generator, Figure 2C, or both.

Although the simple addition of a video pulse and video noise, Figure 2D, is not mathematically identical to the noisy signal from a typical radar receiver which it attempts to simulate, this scheme is satisfactory for measurements where only relative data are required, such as production testing.

We are indebted to Robert Crane, Project Engineer, and Dudley Lesser, Test Methods Engineer, of the Sperry Gyroscope Company for permission to publish the foregoing note on the use of the Type 1390-A Random Noise Generator.

— Editor

Figure 1.

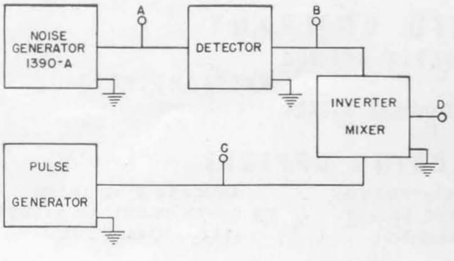
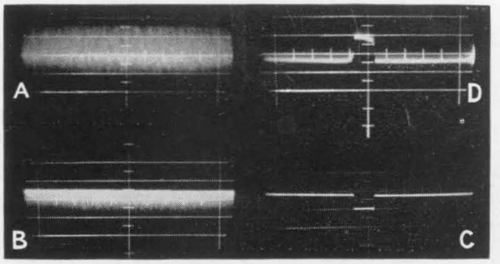


Figure 2.



MISCELLANY

SPEAKERS: Harold B. Richmond, Chairman of the Board, participated in the Electronics Panel at Research Day, sponsored by the Boston Chamber of Commerce April 18, 1952; Frank D. Lewis, Engineer, spoke at the Boston Section, I.R.E., March 27, 1952, on "A TV Station Monitor for Channels 2 to 83"; and on February 27, W. M. Ihde of our Chicago office addressed the Student Section, I.R.E., at Valparaiso Technical Institute, Indiana, on "Loudness — Its Meaning and Its Measurement."

VISITORS: We have welcomed recently at our Cambridge plant the following visitors from foreign countries: Paul Fabricant and Marius Berlin of Radiophon, Paris, exclusive distributors of General Radio products in France and the French Colonies; Dr. B. Hirschfeld, Director, and Dr. A. Morato, Chief Engineer, of Industria & Commercio de Radio Invictus, Sao Paulo, Brazil, accompanied by R. C. Auriema of Ad. Auriema, New York, our distributors for Latin America; Rev. Pierre Gouin, S. J., from Addis Ababa, Ethiopia, and Rev. Alfonso de la Mora, S. J., from Mexico City, both at present studying at Weston College.

A. S. T. M. 50th ANNIVERSARY

The American Society for Testing Materials is holding its 50th Anniversary Meeting and 10th exhibit of testing apparatus and laboratory supplies in New York at the Hotels Statler and New Yorker June 23 through 27. All who are interested in materials testing and associated equipment are cordially invited to attend the exhibit. The General Radio Company in Booth No. 19 will have on display equipment for the measurement of dielectric properties, of insulation resistance, of sound and noise, and of stresses on photo-elastic models. For those interested only in the exhibit, there is no entrance fee.

SUMMER CLOSING

VACATION — During the weeks starting July 28 and August 4 most of our employees will be vacationing. Manufacturing departments will be closed and other departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

STANDARDIZED TERMINALS AND CONNECTORS

PART II

● **IN PART I** of this article, the design and the features of the Type 938 series of binding posts were discussed. Another important type of terminal is the jack, designed to accept a banana plug, and typified by the Type 274-J Jack, which has been the industry standard for some 25 years. Not only are these jacks useful for making connections between various points with leads terminating in Type 274-DB Insulated Single Plugs and Type 274-MB Double Plugs, but they serve as excellent quick-connect-and-disconnect jacks for plug-in components. The length of the threaded portion will accommodate panel thicknesses up to 3/8″.

The new Type 938-J Jack supplements the inexpensive general-purpose Type 274-J Jack and incorporates design features that tie it more closely to the Type 938 Binding Posts. In particular it has a long, unthreaded section that makes it suitable for mounting in Type 938-BB and Type 938-BR Insulators or Type 938-F Spacers; the hole into which the banana plug enters is chamfered to stabilize the plug by furnishing a seat for its shoulder; and it provides a soldering turret at the opposite end so that back-of-panel connections can be made by soldering directly to the body to avoid possible erratic contact in a soldering lug. The Type 938-X Jack Assembly, comprising a Type 938-J Jack and a pair of Type 938-BB Black Insulators, is listed as a complete assembly for convenience in ordering.

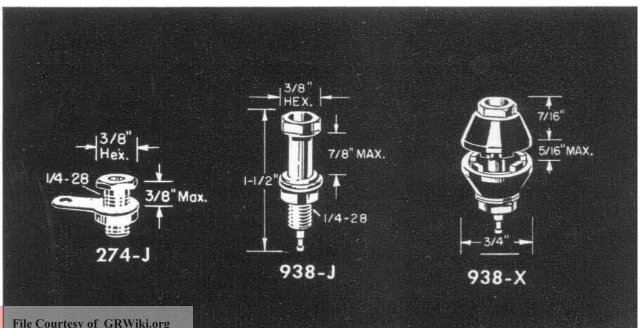


Figure 9. Dimensional sketches of the three standard General Radio jack terminals for banana plugs.

Type		*See Figure§*	*Code Word*	*Unit Price†*	
				10–99*	*100–999*
274-J	**Jack**	**9**	STANPARTOR	**$.075**	**$.0495**
938-J	**Jack**	**9**	STANPARACT	**.175**	**.15**
938-X	**Jack Assembly**	**9**	STANPARART	**.30**	**.26**

*Minimum quantity sold. †Net prices; no further quantity discounts.
§For the convenience of the user, all jacks and jack assemblies are supplied unassembled.

CONNECTORS

For making connections to coaxial terminals, jacks, and binding posts, General Radio manufactures a line of connecting devices, whose basic elements are four types of connectors: The Type 874-C Coaxial Connector, the Type 274 (Banana) Plug, the Type 838-B Alligator Clip, and the standard telephone tip.

Coaxial Connectors

The Type 874-C,[1] Type 874-C8,[1] and Type 874-C58[2] Cable Connectors are intended for use whenever complete shielding, both electrostatic and electromagnetic, is necessary or when inductance of the ground connection is important. These connectors are, respectively, designed for use with General Radio Type 874-A2 Polyethylene Cable, Army-Navy Type RG-8/U Cable, and Army-Navy Type RG-58/U Cable. The Type 874-A2 Cable is a double-shielded flexible cable having a stranded inner conductor, polyethylene insulation, and a non-contaminating vinyl jacket. It differs from the Type RG-8/U Cable in having a nominal characteristic impedance of 50 ohms and somewhat better mechanical flexibility. For high-frequency applications, where excellent shielding is essential, Type 874-R20 Patch Cords, comprising a three-foot section of Type 874-A2 Cable terminated at each end in a Type 874-C connector, are offered as complete assemblies. For low-frequency applications, where good mechanical flexibility is more important than the utmost in shielding, Type 874-R21 Patch Cords, which are made up with single-shielded cable, are recommended. Both patch cords plug easily into all Type 874 Coaxial Elements.

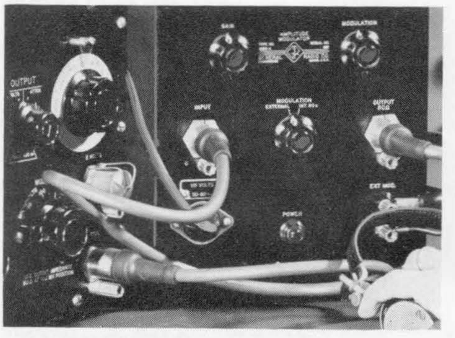


Figure 10. View showing connections to the Type 1001-A Standard-Signal Generator and the Type 1023-A Amplitude Modulator using Type 874 Coaxial Connector. Cable connectors plug easily and quickly into panel connectors to give complete shielding and low VSWR.

Type§		*Code Word*	*Price*
874-R20	**Patch Cord**	COAXHATTER	**$6.00**
874-R21	**Patch Cord**	COAXHUNTER	**5.50**

§See Figure 11.

[1] W. R. Thurston, "Simple, Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, XXIV, 8, January, 1950.
[2] "Coaxial Connectors for RG-58/U and Other Cables," *General Radio Experimenter*, XXVI, 11, April, 1952.

Figure 11. View of the Type 874-R20 Patch Cord (left) and the Type 874-R21 Patch Cord (right).

Banana-Plug Types

TYPE 274 Banana Plugs are offered in several forms. For use with plug-in components, they are available with threaded studs, tubular-rivet heads, and jack tops designed to accept other TYPE 274 Plugs. For use with connecting leads, they are available as TYPE 274-DB Insulated Single Plugs and as the well-known TYPE 274-MB Double Plug. The designs for these insulated plugs are completely new, and many important improvements over the older TYPE 274-D and TYPE 274-M have been incorporated.

All insulation is polystyrene to assure excellent electrical characteristics; red and black color coding is available for the single plugs; the insulating bodies are so shaped that, when the plugs are inserted into the jack tops of insulated-top TYPE 938 Binding Posts or other insulated TYPE 274 Plugs, all metal surfaces are covered except those immediately surrounding the cross holes into which the connecting wires are inserted. The setscrews are tapped into the cross holes coaxially with the banana plugs rather than at right angles and are located at the bottom of the jack-top holes. Set with a screwdriver inserted into the jack-top holes, they are not exposed when leads are connected. The metal parts at the entrances of the jack-top holes are recessed within the insulation to prevent a user's fingers from accidentally coming in contact with live metal when the plugs are being handled. Maximum insulation, consistent with a design in which leads are connected in a direction normal to the center line of the banana plugs, has therefore been achieved. In other respects the design features of the TYPE 938 Binding Posts have been reproduced.

The jack-top holes are so shaped that, when plugs are inserted, the junction is stabilized mechanically by a chamfer into which the plug shoulder enters; the cross holes will accept telephone tips and wires in sizes up to AWG No. 10 without shearing; connections can be easily made to the metal parts within the jack-top holes by TYPE 838-B Alligator Clips.

The TYPE 274-ND Shielded Double Plug supplements the TYPE 274-DB and TYPE 274-MB Insulated Plugs for applications where coaxial cables must be used to assure good electrostatic shielding but where there is no need for the excellent electromagnetic shielding and low ground-connection inductance of a complete coaxial system. This connector comprises a pair of TYPE 274-P plugs mounted on an insulating piece surrounded by an oval die-cast metal shell.

When the connector is plugged into a pair of TYPE 938 Binding Posts, the shell extends down over the binding posts and insulators to a level that just clears the metal panel, thereby providing almost complete electrostatic shielding. Previously this connector has been furnished with a hole through one end of the oval adjacent to one of the TYPE 274-P Plugs through which the cable passes. For use with unbalanced systems that follow the convention of having the lower of a pair of binding posts on a vertical panel at ground potential, the connector has been so connected that the cable is brought out at the bottom. Its design has now been modified so that the cable can be brought out at either top or bottom, the unused hole being covered with a snap button. At the same time a spring connection has been added to the internal assembly so that the new TYPE 274-NF Shielded Cable can be plugged in directly from the top.

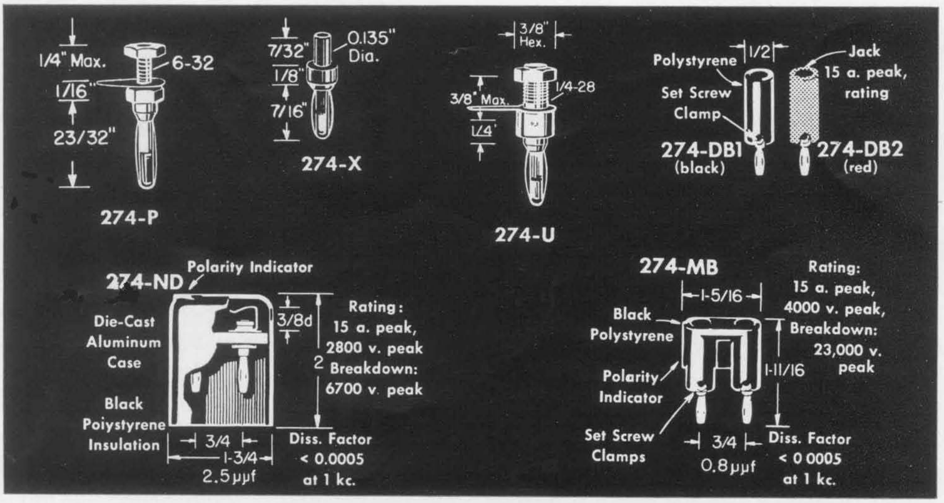


Figure 12. Dimensional sketches of General Radio banana-plug connectors.

Type§		Code Word	Unit Price† 10*–99	Unit Price† 100–999
274-P	Plug	STANPARCAT	$0.125	$0.105
274-X	Plug	STANPARTIN	.085	.067
274-U	Plug	STANPARGOT	.15	.13

Type§		Code Word	Unit Price† 1*–9	Unit Price† 10–99	Unit Price† 100–199	Unit Price† 200–999
274-MB	Double Plug	STANPARBUG	$0.65	$0.55	$0.52	$0.49
274-DB1	Insulated Single Plug (black)	STAPLUGANT	.50	.40	.38	.36
274-DB2	Insulated Single Plug (red)	STAPLUGARC	.50	.40	.38	.36

*Minimum quantity sold. †Net prices; no further quantity discounts.

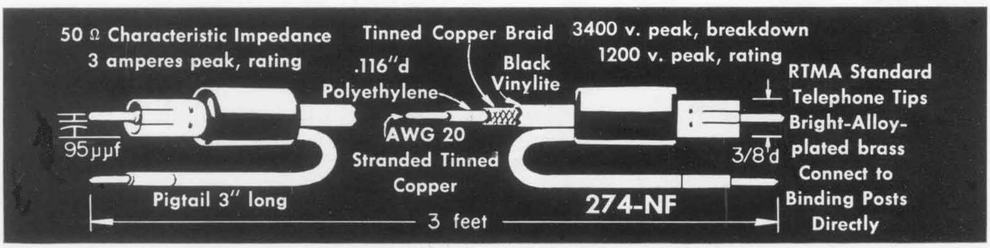
274-ND	Shielded Double Plug	STAPLUGDOG	$1.50 each

§See Figure 12. For the convenience of the user, Types 274-P and 274-U are shipped unassembled.

Patch Cords

This new Type 274-NF Cable has been introduced to make it possible to assemble, quickly and easily, a coaxial cable terminating in any of the Type 274, 874, or 838 Connectors. It consists of a three-foot length of flexible, 50-ohm cable terminated at each end in a standard telephone tip and slotted sleeve combination that resembles the so-called phonograph connector. This coaxial fitting plugs directly into the Type 274-ND Shielded Double Plug for connection to Type 938 Binding Posts or into a Type 874-Q6 Adaptor for connection to a Type 874 Coaxial Connector. A 3″ pigtail terminated in a standard telephone tip and connected to the outer conductor is also provided at each end for attaching the non-coaxial Type 274 and Type 838 Connectors. A truly universal set of coaxial cables can there-

Figure 13. Dimensional sketches, with specifications, of the Type 274-NF Shielded Lead Assembly.



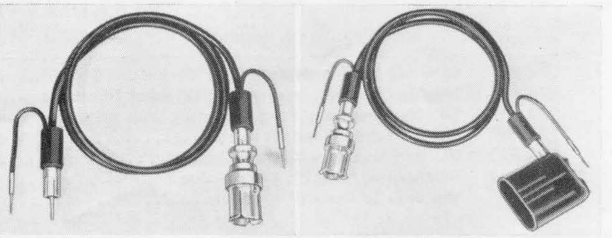
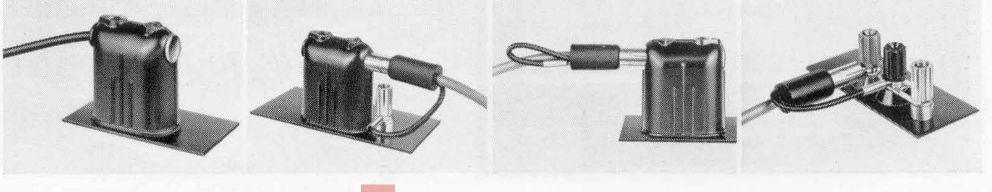


Figure 14. Two patch cords using the Type 274-NF Shielded Lead Assembly: (left) the Type 874-R31 Patch Cord, pin-and-sleeve to 50-ohm coaxial, and (right) the Type 874-R32 Patch Cord, shielded double banana plug to 50-ohm coaxial. Coaxial connector is Type 874-Q6 Adaptor.

fore be easily obtained. Complete assemblies listed are the TYPE 274-NC Patch Cord, which now consists of a TYPE 274-NF Shielded Cable and two TYPE 274-MB Double Plugs (see Figure 16); the TYPE 274-NE Patch Cord, which now consists of a TYPE 274-NF Shielded Cable and two TYPE 274-ND Shielded Double Plugs (see Figure 16); the old TYPE 874-R31 Patch Cord, which now consists of a TYPE 274-NF Shielded Cable and one TYPE 874-Q6 Adaptor; the TYPE 874-R32 Patch Cord, which now consists of a TYPE 274-NF Shielded Cable, one TYPE 274-ND Shielded Double Plug, and one TYPE 874-Q6 Adaptor; and a new TYPE 274-NH Patch Cord consisting of a TYPE 274-NF Shielded Cable, a TYPE 274-ND Shielded Double Plug, and two TYPE 838-B Alligator Clips. In addition to these combinations, any other desired combination can be secured by individual purchases of the basic TYPE 274-NF Shielded Cable and the appropriate terminating connectors. The pigtail connection, which is not needed for the coaxial connection to the TYPE 274-ND Shielded Double Plug proper, serves a useful function as an auxiliary ground connection for an output system that may be operated balanced or unbalanced. A frequently used binding-post arrangement consists of three binding posts in a vertical row, the two top binding posts providing a connection to the balanced output and the bottom binding post a convenient ground point to which the middle binding post can be connected by a TYPE 938-L Shorting Link when unbalanced operation is desired. Connection to this binding-post arrangement cannot be used with a TYPE 274-ND Shielded Double Plug when the middle and bottom binding posts are connected with the TYPE 938-L Shorting Link because of interference between the connector shell and the link. When the TYPE 274-NF Shielded Cable is used, however, the TYPE 938-L Shorting Link can be dispensed with, the TYPE 274-ND Shielded Double Connection to the bottom binding post made with the cable pigtail.

Figure 15. Views illustrating the various methods of connection possible with the Type 274-NF Shielded Lead Assembly and the Type 274-ND Shielded Double Plug. Left to right:
(1) The Shielded Double Plug terminating a shielded cable and plugged into a pair of Type 938 Binding Posts.
(2) The Type 274-NE Patch Cord plugged into a pair of Type 938 Binding Posts with the telephone-tip pigtail connected to a grounded post.
(3) The Type 274-NE Patch Cord plugged into a pair of binding posts, with the unused telephone-tip pigtail tucked into the cable sheath.
(4) The Type 274-NF Patch Cord with its pin terminals connected directly to a pair of binding posts and with a Shorting Link (Type 938-L) connecting to a grounded post.



COMPLETE LEAD ASSEMBLIES

Type		*See Figure*	*Code Word*	*Price*
274-NC	Shielded Lead Assembly with Unshielded Terminals	16	STANPARZOO	$3.80
274-NE	Shielded Lead Assembly with Shielded Terminals	16	STAPLUGEYE	5.50
274-NH	Shielded Lead and Plug Assembly with Alligator Clips	16	STANPARMAP	4.25
274-NF	Basic Shielded Lead Assembly	13	STANPARGAG	2.50
874-R31	Pin and Sleeve to 50-ohm Coaxial	14	COAXFLEXOR	4.50
874-R32	Shielded Banana Plug to 50-ohm Coaxial	14	COAXFITTER	5.75
874-Q6	Pin Jack to Coaxial Adaptor	14	COAXCLOSER	2.00

For use where mechanical clearances are too small for the new models, we can still supply the permanently assembled older types, now designated as TYPE 274-NCO and TYPE 274-NEO. They are priced the same as the new models.

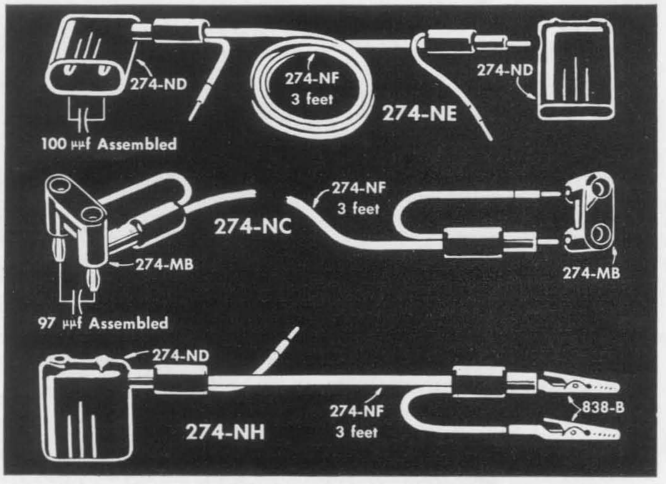


Figure 16. View of three patch cords made up from the basic Type 274-NF Shielded Lead Assembly.

TEST LEADS

The new TYPE 838 Parts provide a system of test leads and connectors comparable in versatility to the patch cords made up with the TYPE 274-NF Shielded Cable. Comprising test leads, test prods, and alligator clips, they differ from the hardware items usually found in the laboratory in the quality of the materials used and in their adaptability to different applications and connection configurations. The common element is the RTMA standard telephone tip, in which each end of the test leads is terminated. Connections can be made with this tip to every one of the terminating connectors described in this article except the TYPE 274-ND Shielded Double Plug and the TYPE 874-Q6 Adaptor. The TYPE 838-AR and TYPE 838-AB Test Leads, made of AWG No. 18 flexible wire, have high-grade rubber insulation

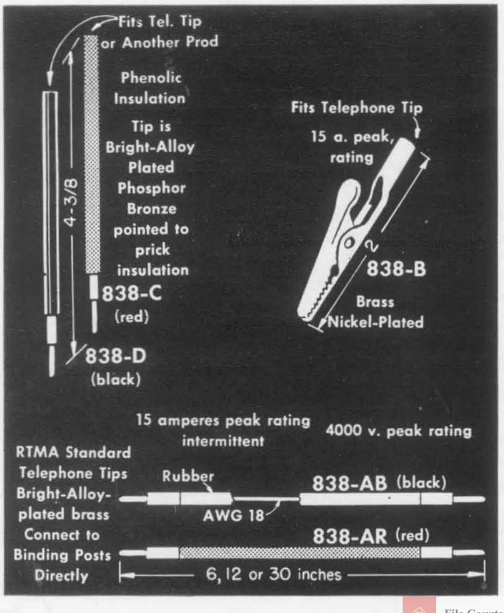


Figure 17. View of the Type 838 Test Leads, Prods, and Clips.

color-coded red or black, and are furnished in lengths of 6″, 12″, and 30″. The Type 838-C and Type 838-D Test Prods have bright-alloy-plated phosphor-bronze telephone tips, pointed for piercing insulation, and phenolic insulation at the top accepts any standard telephone tip. Not only can test leads be plugged into this socket, but any number of test prods can be stacked up to produce a test prod of extra length for making connections to points that are difficult of access. When multiple test prods of this type are assembled, no gaps in insulation occur, so that there is no exposed metal with which the hands of a user can come in contact. The Type 838-B Alligator Clips, made of nickel-plated brass, have ferrules shaped to act as a socket for standard telephone tips or Type 274 Banana Plugs. They can therefore be used as a clip extension for any connector described in this article except the Type 874-Q6 Adaptor.

Type§		*Code Word*	*Unit Price*†			
			5–9*	*10–19*	*20–99*	*100 up*
838-AB6	**6″ Black Test Lead**	STANPARLAP	**$0.40**	**$0.38**	**$0.36**	**$0.34**
838-AB12	**12″ Black Test Lead**	STANPARLEG	**.40**	**.38**	**.36**	**.34**
838-AB30	**30″ Black Test Lead**	STANPARLID	**.45**	**.43**	**.41**	**.38**
838-AR6	**6″ Red Test Lead**	STANPARLOG	**.40**	**.38**	**.36**	**.34**
838-AR12	**12″ Red Test Lead**	STANPARLOT	**.40**	**.43**	**.36**	**.34**
838-AR30	**30″ Red Test Lead**	STANPARLUG	**.45**	**.43**	**.41**	**.38**

Type§		*Code Word*	*Unit Price*†				
			1–9	*10–99*	*100–199*	*200–999*	*1000 up*
838-C	**Red Test Prod**	STANPARPIN	**$1.00**	**$0.95**	**$0.90**	—	—
838-D	**Black Test Prod**	STANPARPEG	**1.00**	**.95**	**.90**	—	—
838-B	**Alligator Clip**	STANPARNIP	—	**.20***	**.19**	**$0.18**	**$0.17**

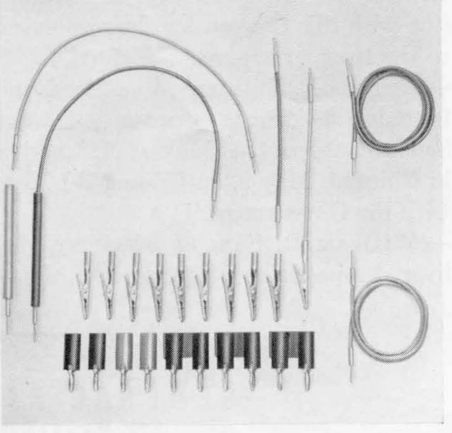
*Minimum quantity sold. †Net; no further quantity discounts. §See Figure 17.

TEST LEAD KIT

A handy kit of test leads and connectors is now available at a considerable saving over the price of the parts purchased separately. This kit consists of:

1 Type 838-C Red Test Prod
1 Type 838-D Black Test Prod
1 each Type 838-AR Red Test Leads, 6″, 12″, and 30″
1 each Type 838-AB Black Test Leads, 6″, 12″, and 30″
10 Type 838-B Alligator Clips, of phosphor bronze
3 Type 274-MB Double Plugs
4 Type 274-DB Insulated Single Plugs

Type		*Code Word*	*Price*
838-K	**Test Lead Kit**	KIOSK	**$7.75**



This completely integrated line of terminals, connectors, and leads has met the diversified requirements of General Radio instruments in a most satisfactory manner. Old instruments have been changed to utilize the new parts and new instruments incorporate them as standard. Your laboratory or manufacturing problems should be similar to ours. Why not try them?

— H. C. Littlejohn

MISCELLANY

SPEAKERS: Donald B. Sinclair, General Radio Chief Engineer and President of the Institute of Radio Engineers, spoke at the Spring Technical Conference on Television at Cincinnati, April 19, and at the Airborne Electronics Conference in Dayton, May 13. He was the keynote speaker at the Southwestern IRE Conference in Houston, May 16, and gave the luncheon address at the Conference on Electronics and Machines, sponsored by the Chicago Professional Group on Industrial Electronics, where his subject was "What's Happened to Measurements?" He also spoke at the New England Radio Engineering Meeting and at local section meetings in Evansville, Indiana; Cedar Rapids, Iowa; Kansas City, Missouri, and New York.

In late April, Dr. Sinclair attended the Institution of Electrical Engineers, Radio Section, Convention on "British Contributions to Television" held in London. At the dinner held in conjunction with this Convention, he responded to the toast to overseas delegates.

— Arthur E. Thiessen, Vice-President for Sales, spoke at the Convention of the Scientific Apparatus Makers of America in Chicago, May 9, on "Doing Business with the Government."

— William R. Saylor, Engineer, delivered a paper on "Stroboscopic Measurements in Textiles" at the Northern Textile Conference of the American Institute of Electrical Engineers at Philadelphia, April 24.

Summer Closing

VACATION—During the weeks starting July 28 and August 4, most of our employees will be vacationing. Manufacturing departments will be closed and other departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

Western Electronic Show and Convention

The Western Convention, Institute of Radio Engineers, and the Western Electronic Show will be held at the Municipal Auditorium, Long Beach, California, August 27-29, 1952. *Experimenter* readers attending the show are cordially invited to visit the General Radio booth and to look over the display of equipment for measuring impedance, voltage, power, and frequency at ultra-high frequencies. The new Sound-Level Meter and Sound-Survey Meter recently described in the *Experimenter* will also be displayed.

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THE General Radio EXPERIMENTER

VOLUME XXVII No. 3 AUGUST, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A GUARD CIRCUIT FOR THE CAPACITANCE BRIDGE

Also IN THIS ISSUE

● **TO INCREASE** the usefulness and flexibility of the very popular Type 716-C Capacitance Bridge, the Type 716-P4 Guard Circuit is now offered as an accessory. Although the vast majority of capacitance measurements, whether one is dealing with components or material testing, can be made with a two-terminal connection, there are a number of situations where a three-terminal measurement is required. One of the most common is encountered in the measurement of the dielectric properties of insulating materials. In many instances it is possible to make entirely satisfactory dielectric measurements on two-terminal specimens, but there exist conditions under which it becomes essential to use a guarded or three-terminal measurement in order to realize the best possible accuracy of measurement. While it is possible to compute with reasonable accuracy the fringing effects that occur in two-terminal measurements, it is frequently necessary to eliminate the surface effect from the measurement. For example, the measurement of dissipation factor of a two-terminal specimen under conditions of high humidity can sometimes run into serious difficulty because of leakage over the edge of the material being measured.

The guard circuit, which provides the solution to the above problem,

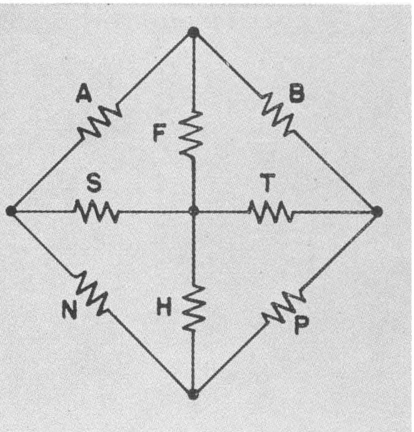


Figure 1. General bridge network with guard circuit.

also provides the solution to an important related problem. When components and materials are to be measured over wide ranges of humidity and temperature, as is required by modern testing specifications, the measurement should be made with the specimen in some sort of conditioning chamber. The problem raised by the connection between the specimen and the bridge is a very serious one when accurate measurements are desired and when only two-terminal equipment is available. The guard circuit is provided with a double-shielded cable which can be used between the bridge and the specimen mounted in the conditioning chamber. The high lead is guarded, and the undesired capacitances are placed in the guard circuit where they are effectively eliminated from the measuring circuit proper. This technique permits the same accuracy of measurement to be obtained when the component is at some distance from the bridge as would be obtained if it were connected directly to the terminals.

BASIC PRINCIPLES

With the addition of a fifth point[1] to a conventional four-arm bridge network, it becomes possible to measure the direct impedance between two points of a three-terminal network. Such a network is shown in Figure 1, with impedances between the fifth point and each of the four corners of the bridge. It can be shown that the network is in balance if *either* of the following conditions are met:

$$\frac{A}{N} = \frac{B}{P} = \frac{F}{H} \tag{1}$$

$$\frac{A}{B} = \frac{N}{P} = \frac{S}{T} \tag{2}$$

[1] "A Guard Circuit for Capacitance Bridge Measurements," R. F. Field, *General Radio Experimenter*, March, 1940.

Obviously these conditions include the ordinary equation of balance of the four-arm network A-B-N-P.

TERMINOLOGY

The terminology to be used in connection with a network such as Figure 1 is not clearly established nor standardized. The word "guard" is used rather consistently in the literature to designate the third point in a three-electrode measuring system, the connotation being that the third terminal or electrode "guards" the two measuring electrodes or terminals. With respect to the measuring network itself, however, the usage is not so consistent. The circuit arrangement used in the Type 716-P4 Guard Circuit is frequently referred to in the literature as a "Wagner Ground." On the other hand, the circuit connected across the voltage source is often referred to as a guard circuit, and the circuit across the detector called a coupling circuit. This terminology can cause difficulty, however, if the generator and detector are interchanged, as they occasionally may be, particularly in a low-voltage bridge.

The following terminology is arbitrarily adopted in connection with the Type 716-P4 Guard Circuit:

(*a*) The third terminal of a three-terminal network or electrode system is referred to as the "guard" or "guard point."

(*b*) The fifth terminal of the measuring network is also called "guard" or "guard point."

(*c*) The two arms connected across the similar arms of the bridge are called the guard circuit, irrespective of the method of connecting generator and detector.

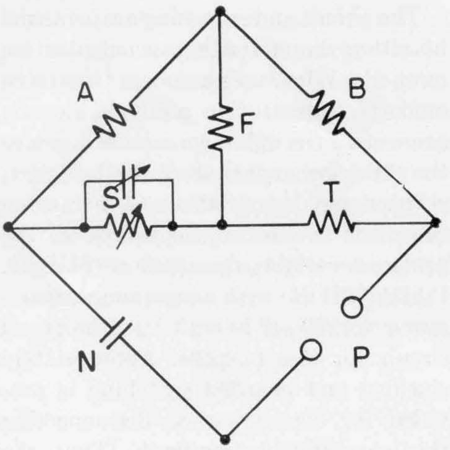


Figure 2. Basic schematic of bridge with guard circuit.

(*d*) The two arms connected across the unlike arms of the bridge are called the coupling circuit.

(*e*) The entire auxiliary circuit is named the TYPE 716-P4 Guard Circuit.

CIRCUIT DESIGN CONSIDERATIONS

The usual design of guard circuit for capacitance bridges makes the guard arm impedances *S* and *T* approximately equal to the impedances *A* and *B* of the arms of the bridge. When this is done, the guard arms must be capable of being balanced to about the same degree of precision as the bridge arms themselves, and the precise balance must be made irrespective of the magnitude of the undesired impedances in the three-terminal network being measured. A different design approach is used in the General Radio guard circuit in that the guard arms are of relatively high impedance compared to the ratio arms of the TYPE 716-C Capacitance Bridge. The basic philosophy is that of introducing no more admittance than is necessary to balance the admittance between the high terminal and guard. When this condition is met, the guard circuit balance is less critical.

In the TYPE 716-P4 Guard Circuit the capacitance balance provided consists of a 1000 $\mu\mu$f variable capacitor, with the only fixed capacitance being the zero capacitance of the variable unit plus the circuit wiring stray capacitance.

For the resistive balance, a fixed resistor is used in arm *T* and a variable resistor in arm *S*. These elements, shown schematically in Figure 2, make it possible to balance any combination of capacitance and loss introduced across arm *T* by the terminal impedance of the unknown.

DESCRIPTION

An elementary schematic diagram of the TYPE 716-P4 Guard Circuit is shown in Figure 3, as connected to a TYPE 716-C Capacitance Bridge, also shown in elementary form.

The guard circuit proper consists of a set of resistive arms (corresponding to *S* and *T* in the general network of

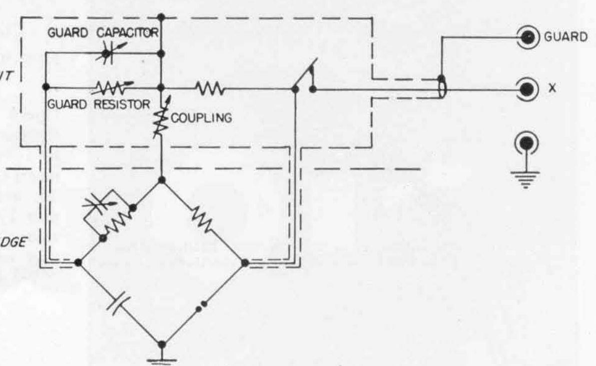


Figure 3. Elementary schematic circuit diagram of the Type 716-P4 Guard Circuit connected to the Type 716-C Capacitance Bridge.

Figure 1) one of which is a fixed resistor, the other variable, consisting of a pair of rheostats for coarse and fine adjustment. The variable capacitor and variable resistor together permit complete adjustment of the guard circuit.

The coupling circuit consists simply of an adjustable resistor connected between the guard point and the junction of the resistive arms of the bridge. This allows a *partial* coupling balance, balancing the capacitive component of the guard-to-ground terminal impedance. The availability of means for partial balance of the coupling circuit facilitates the balancing of the guard circuit.

The circuit and switching are arranged by either direct reading or substitution methods. When measurements are to be made by substitution methods, i.e., by connecting the unknown capacitor across the precision capacitor of the bridge, it is necessary to connect a balancing capacitor in the adjacent arm of the bridge. A variable air capacitor (SUBST. CAPACITOR) with a maximum capacitance of 1100 $\mu\mu$f is built into the guard circuit for this purpose. Appropriately shielded and guarded switching is provided for connecting or disconnecting this capacitor as required. Thus the only external connection required is that to the unknown itself, whether direct-reading or substitution methods are employed.

Four pairs of ratio arms are provided in the bridge, for direct-reading operation at 100 cycles, 1 kc, 10 kc, and 100 kc. Correspondingly, four sets of resistive guard arms are provided in the guard circuit, selected by a panel switch. Four adjustable resistors are provided, with the switching so arranged that they are used in pairs for each switch setting, one "coarse" and one "fine" adjustment.

Shielding

Although the circuits just described are exceedingly simple, it is necessary that components, switches, and leads of the guard circuit be carefully shielded in order to realize the full accuracy of the Type 716-C Capacitance Bridge. In the Type 716-P4 Guard Circuit, all components which could contribute unde-

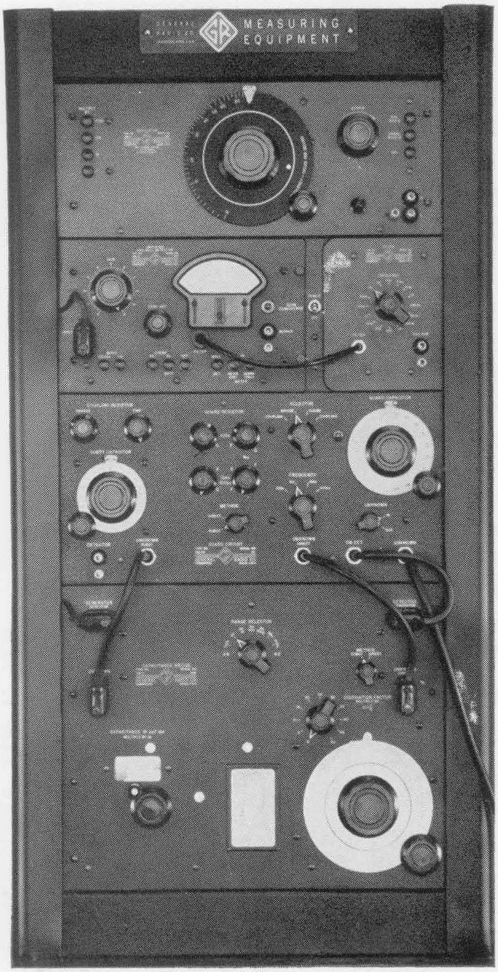


Figure 4. View of the Type 1610-A Capacitance Measuring Assembly consisting of guard circuit and bridge mounted in a relay-rack with associated equipment: Type 1302-A Oscillator, Type 1231-BRFA Amplifier and Null Detector, Type 716-P4R Guard Circuit, and Type 716-C Capacitance Bridge. Assembly includes relay rack and all necessary cables. Oscillator and amplifier operate from a 115-volt, 60 cycle power line.

sired capacitance to ground are mounted in an insulated shielded compartment, which is connected to the guard point, thus placing the stray capacitances into the guard circuit, where they are harmless. Special double-shielded leads are used to connect the guard circuit to the bridge and to the unknown. The entire assembly is enclosed in a grounded metal cabinet, which serves to fix the internal guard-to-ground capacitance at a definite value and also to shield the system against 60-cycle pickup.

The circuit connections are so arranged, as shown in Figure 3, that two-terminal measurements can be made directly with the bridge. It is merely necessary to disconnect the two cables at the UNKNOWN DIRECT and UNKNOWN SUBST. terminals of the bridge. No other circuit rearrangement is necessary.

—Ivan G. Easton

SPECIFICATIONS FOR THE 716-P4 GUARD CIRCUIT

Capacitance Range: Designed primarily for use with the x1 multiplier ranges of the Type 716-C Capacitance Bridge, i.e., a range of 0-1000 $\mu\mu f$.

Frequency Range: Corresponds to that of Type 716-C Capacitance Bridge.

Guard Balance Capacitor: Any value of capacitance between the guard point and the high measuring terminal up to 1000 $\mu\mu$f can be balanced out.

Mounting: Available in two models: Type 716-P4M in walnut cabinet matching cabinet of Type 716-CM; Type 716-P4R for relay-rack mounting. Leads are arranged for placing the guard circuit directly above the bridge.

Accessories Supplied: One Type 874-Q2 Coaxial Adaptor.*

Net Weight: Type 716-P4R, 17 lbs.; Type 716-P4M, 23 lbs.

Dimensions: 19 x 8¾ x 9⅝ inches.

*U. S. Patents 2,125,816 and 2,548,457.

Type		*Code Word*	*Price*
716-P4M	**Guard Circuit (in Walnut Cabinet)**	BOSOMGUARD	**$315.00**
716-P4R	**Guard Circuit (for Relay-Rack Mounting)**	BONUSGUARD	**295.00**

TYPE 1610-A CAPACITANCE MEASURING ASSEMBLY

The new guard circuit described above, in conjunction with equipment regularly available, makes a well-integrated assembly for the measurement of capacitance and dissipation factor over a wide range of frequency.

For convenience in ordering, setup, and use, the bridge, guard-circuit, oscillator, and detector are assembled in a bench type cabinet rack, complete with all interconnections. The assembly is designated as Type 1610-A Capacitance Measuring Assembly.

With this equipment, two-terminal or three-terminal measurements of capacitance and dissipation factor can be made either by direct or substitution methods, over the frequency range from 60 cycles to 100 kc.

Type		*Code Word*	*Price*
1610-A	**Capacitance Measuring Assembly**	SEDAN	**$1850.00**

A GOOD CAUSE

The letter reproduced below merits the consideration of all electronic engineers and manufacturers. Few will deny that electronic equipment is tending to become increasingly complex — in design, in construction, in operation, and in maintenance.

At the recent Joint AIEE-IRE-RTMA Symposium on Progress in Quality Electronic Components, the statement was made that 60 per cent of all electronic equipment in operation by the fleet is not operating satisfactorily. When we consider that a destroyer uses

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS
WASHINGTON 25, D. C.

IN REPLY REFER TO
S67(801)
EN8/A2-6
Ser 801/819-45
6 June 1952

Attention Technical Director for Research and Engineering

Gentlemen:

Subj: Electronics; project simplification

The increasing complexity and resultant increased maintenance and reduced reliability of electronics equipment is a matter of great concern to the Bureau of Ships. Every effort is being made by the Bureau of Ships to simplify the design of electronics equipment. To successfully accomplish our objective, the full cooperation of the engineering staffs of all Bureau of Ships contractors is needed.

The Bureau of Ships solicits and will welcome proposals from contractors which will result in the production of less complex and more easily maintained equipment. Such proposals for simplification of designs are desired any time during the performance of existing contracts and will be evaluated on a not-to-delay production basis. It is understood that under no circumstances shall changes be invoked in existing contracts unless authorized by formal change under the contracts.

In order to insure proper evaluation by the Bureau of proposals for simplification of design, it is requested that the proposal completely set forth any existing specification requirements which cannot be fully met. Such proposals should also recommend specification changes which will be necessary to accomplish the proposed simplification.

Proposals for simplification of designs on existing contracts should be forwarded to Bureau of Ships, Electronics Design and Development Division, Code 810, Washington 25, D. C.

Sincerely yours,

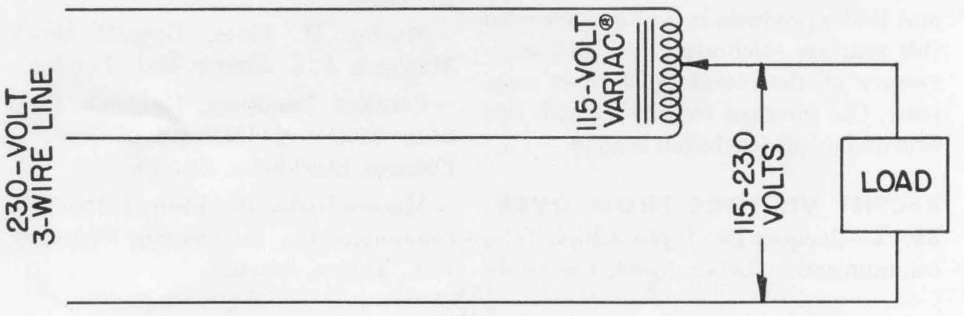
/s/ H. E. Bernstein
Acting Assistant Chief of Bureau
for Electronics

3200 vacuum tubes and that the process of navigation in a B-50 involves some 2500, such a statement no longer seems startling.

With these thousands of tubes in the operation of each fighting unit, the possibilities for failure are high and the maintenance requirements are severe.

Simplification of design is a prime necessity if the world is not to become bogged down in a morass of inoperative devices. Design simplification offers a challenge to the engineer that he must accept. The simplest way is often the most difficult, requiring considerable horse sense and, usually, a higher degree of creative endeavor than mere textbook engineering.

A USEFUL VARIAC CIRCUIT



The circuit shown in the accompanying illustration will be found useful where a limited range of control is needed on a 230-volt, 3-wire circuit.

The range of control is from 115 to 230 volts, and the effective rating of the 115-volt Variac is doubled. Since the common wire in a 3-wire system is usually grounded, the load should *not* be grounded when this connection is used.

NATIONAL ELECTRONICS CONFERENCE

Plan to visit the General Radio exhibit at the 1952 National Electronics Conference to be held in Chicago September 29 through October 1. In booths 62 and 63, General Radio will show an extensive line of UHF-VHF measuring equipment, the new General Radio Sound-Measuring System, and a number of impedance bridges for laboratory and production testing.

The UHF-VHF equipment on display will include instruments for the measurement of voltage, power, frequency, standing-wave ratio, admittance, impedance and receiver characteristics.

The sound-measuring equipment includes the sound-level meter, sound-survey meter, auxiliary microphones, octave-band and continuous-spectrum analyzers, and an acoustic calibrator.

Among the bridges exhibited will be a resistance-limit bridge, useful for both laboratory measurement and production testing, and an a-c comparison bridge for checking capacitors and inductors against a standard sample at 1000 and 5000 cycles.

MISCELLANY

ELECTED — Harold B. Richmond, Chairman of the Board, General Radio Company, to Life Membership of the Corporation of the Massachusetts Institute of Technology.

NATIONAL ELECTRONICS CONFERENCE, Chicago, Sept. 29 - Oct. 1. Visit Booths 62 and 63 to see displays of General Radio Equipment.

CONGRATULATIONS to Seyffer and Co., A.G., exclusive distributors of General Radio products in Switzerland, who this year are celebrating the 30th anniversary of the founding of their company. Our pleasant association with this firm and its officers began in 1939.

RECENT VISITORS FROM OVERSEAS—Jacques Bendayan, Chief, Telecommunication Laboratories, Cables de Lyon de le Compagnie Génerale de Electricité, Lyon, France. Mr. Bendayan was accompanied by Marius Berlin, of Radiophon, Paris, exclusive distributors of General Radio products in France and the French colonies.

—Professor Abdul Rahman Hamoui, of the Engineering School, Syrian University, Aleppo, Syria.

—Dr. A. Malodi, Director of Broadcasting, Republic of Indonesia, Djakarta, Indonesia.

—Stanley H. Lives, General Works Manager, A. C. Cossor, Ltd., London.

—Per-Olof Lundbom, Research Engineer, Research Institute of National Defense, Stockholm, Sweden.

—Masaru Ibuka, President, Tokyo Telecommunication Engineering Company, Ltd., Tokyo, Japan.

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

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VOLUME XXVII No. 4 SEPTEMBER, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE VACUUM-TUBE BRIDGE AND ITS ACCESSORIES

Also

IN THIS ISSUE

● **THE TYPE 561-D VACUUM-TUBE BRIDGE,** first described twenty years ago,[1] is used for measuring directly the vacuum-tube coefficients of amplification factor, transconductance, and plate resistance. Not a tube tester, the bridge is a laboratory-type instrument of high accuracy that permits a study of tube performance at widely varying operating conditions.

The method devised by Tuttle[2] substitutes accurately known and controlled individual voltage sources of low internal impedance for the resistive ratio arms of the usual bridge. Several advantages accrue from this departure from previous practice: the impedance of the measuring circuits has a minimum effect on the results, the voltage sources can be connected at convenient circuit points to permit grounding the tube cathode and the "low" side of the heater, control grid, screen, and plate supplies. The flexibility of the method permits the measurement of the tube coefficients referred to *any* pair of electrodes

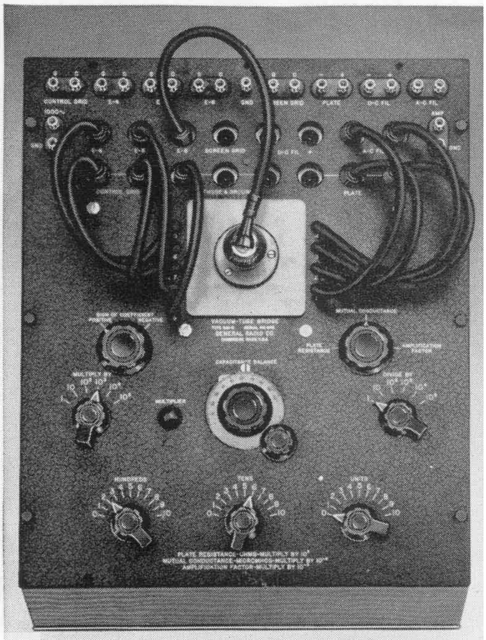


Figure 1. Panel view of the vacuum-tube bridge with adaptor and tube plugged into test position.

[1]W. N. Tuttle, "A Bridge for Vacuum-Tube Measurements," *General Radio Experimenter*, Vol. 6, No. 12, May, 1932.

[2]W. N. Tuttle, "Dynamic Measurement of Electron-Tube Coefficients," *Proc. IRE*, Vol. 21, No. 6, June, 1933.

and to coefficients of either polarity — positive or negative. The introduction of a third voltage source, in quadrature, has provided a simple means for balancing out the capacitive component introduced by interelectrode and socket capacitances without affecting the coefficient results even at high plate resistance or high transconductance conditions. The circuit, shown schematically in Figure 2, is more fully described in many textbooks and in the I.R.E. Standards on Electron Tubes.[3]

[3] "Standards on Electron Tubes: Methods of Testing, 1950," *Proc. IRE*, Vol. 38, Nos. 8 and 9, August and September, 1950.

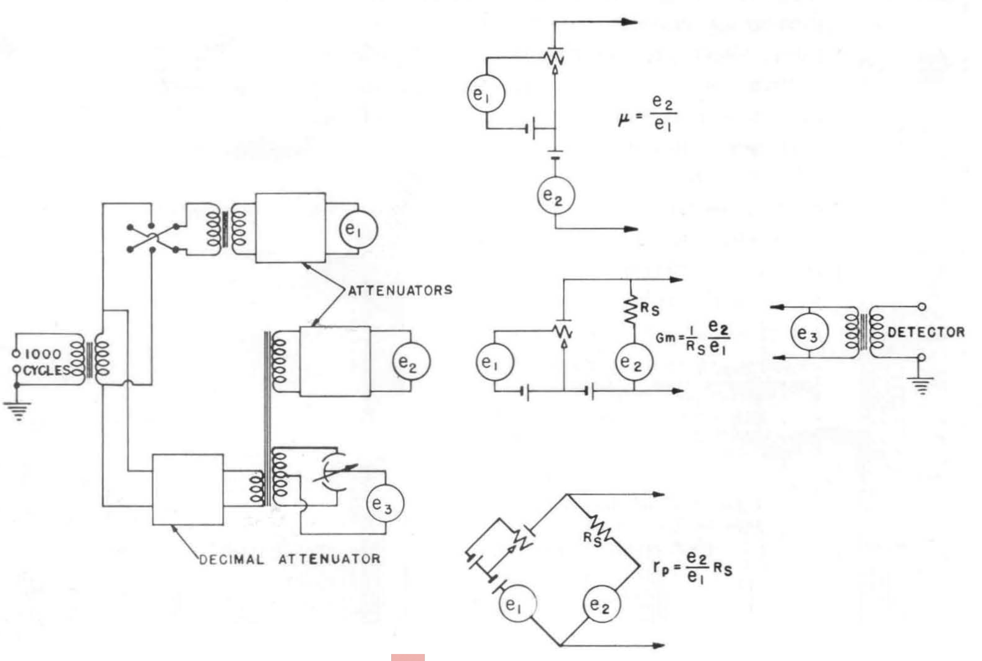
NEW ADAPTORS FOR THE VACUUM-TUBE BRIDGE

Sub-Miniature Types Now Available

Although the fundamental circuit has remained unchanged since the first TYPE 561-A Vacuum-Tube Bridge was designed, the mechanism for connecting the tube into the circuit has required considerable modification. The original bridge had 4-, 5-, 6-, and 7-pin sockets on the panel with provision for connecting other types through binding posts.[2] An 8-pin socket was added later, but, as the list of tube bases grew, it became evident that the panel socket system would eventually be inadequate. In later models, therefore, the socket system has been made truly universal by supplying for each type of tube base a separate adaptor, which plugs into a single plug-in panel socket, with shielded cables connecting each terminal of the panel socket to the correct point in the measuring circuit.[4] These cables are now doubly shielded to improve performance when tubes with high plate resistance or high transconductance are being measured.

[4] W. N. Tuttle, "A Redesign of the Vacuum-Tube Bridge," *General Radio Experimenter*, Vol. 16, No. 6, November. 1941.

Figure 2. Elementary schematic diagram of the circuits used in the vacuum-tube bridge.



The separate-adaptor method has proved completely satisfactory. When a new type of tube base becomes generally accepted, a new adaptor is added to the list. A convenient storage case, which can be wall-mounted if desired, is supplied for storing the adaptors and the accessory grid-connection cables.

The adaptors now regularly supplied include the Universal adaptor, the 4-pin, 5-pin, 6-pin, small 7-pin, large 7-pin, octal, locking-in, miniature button 7-pin, miniature button 9-pin (noval), acorn (5- and 7-pin with the plate and grid-cap connections at the opposite ends — a challenge to the adaptor designer), 7-wire sub-miniature (for flat-press sub-miniature tubes of any number of leads up to seven), and 8-wire "button-base" sub-minar (which in addition to the 8-wire sub-miniatures can be used for some of the randomly-oriented wire-lead sub-miniatures).

Figure 4 shows the two sub-miniature adaptors (flat-press and sub-minar), which are designed to plug into the octal-base adaptor. For those sub-miniature tubes with the short wire leads, there are provided the separate 5-pin, 6-pin, and 7-pin flat-press and 8-pin sub-minar sockets shown in Figure 5, which can be wired directly to the 9-pin Universal adaptor. Tubes with which these sub-miniature adaptors or sockets can be used are listed in Tables I and II.

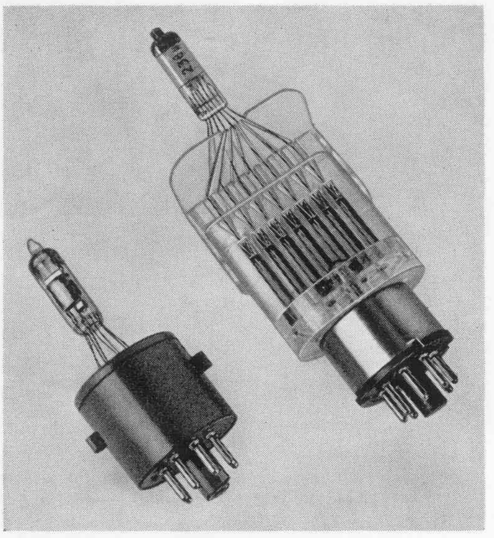
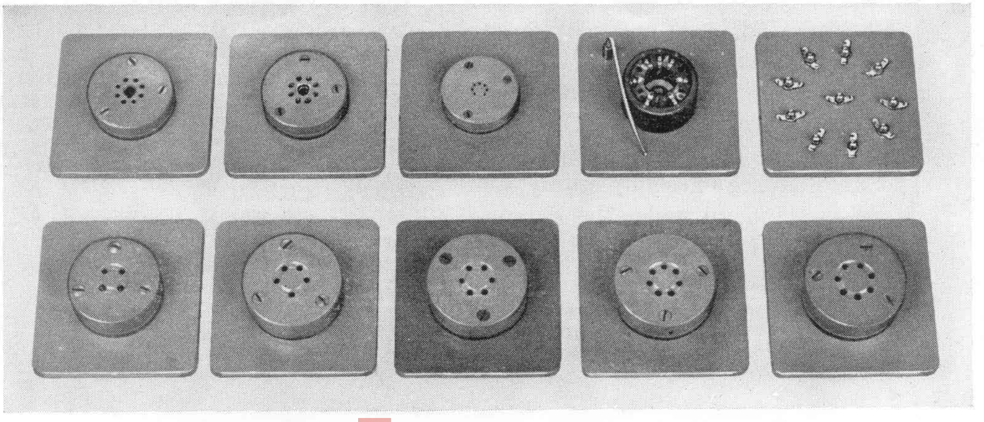


Figure 4. Adaptors for sub-miniature tubes. Flat-press types with up to 7 leads are tested in the Type 561-415-2 Adaptor with a comb-like structure for selecting and guiding the leads into the spring contacts. Eight-wire sub-minar tubes are tested in the round Type SOA-3 Adaptor, which has provision for locking the leads into the socket. Both types plug into the standard octal adaptor.

The 7-wire sub-miniature adaptor design is bound to please anyone who has striven to feed the flimsy tube wires in-

Figure 3. Group of adaptors furnished with the bridge. The noval adaptor (not shown) is similar in appearance.



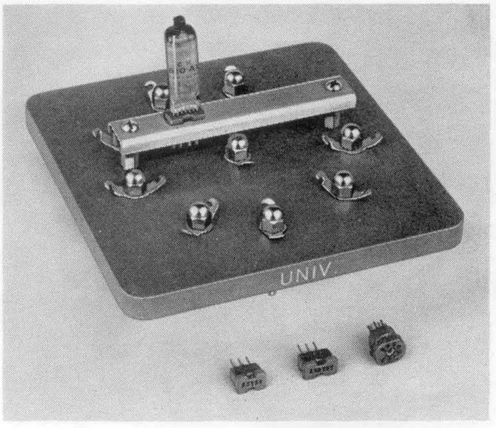


Figure 5 For sub-miniature types with short leads, sockets are supplied which can be mounted on the Universal adaptor. This photograph shows one way of mounting the Type SOT-50 7-pin socket (for flat-press tubes) on a Universal adaptor. In the foreground are shown, left to right, Type SOT-46 for 5-pin tubes, Type SOT-49 for 6-pin tubes, and Type SOT-48 for 8-wire sub-minar tubes.

dividually into a test socket. Part of the adaptor is a molded, tapered, comb-like arrangement which greatly facilitates the separation of the tube leads and guides them into the adaptor contact springs. See Figure 4.

Since there are many TYPE 561 Bridges in the field that do not have this full complement of adaptors and sockets, they have been made available as individual accessories and are listed in the price table below. New adaptors will be added as their need becomes evident.

All of the adaptors and sockets are made of low-loss material to insure a negligible error in the measurement of the plate resistance of special purpose tubes, such as the electrometer tubes. The adaptors are unusually sturdy, designed to stand up under the rigorous demands of production testing.

— A. G. BOUSQUET

The lists of tube types given in Tables I and II below are not necessarily all inclusive. An attempt has been made merely to list all tubes which have been announced prior to the publication of this article. Our intention is to keep the TYPE 561-D Vacuum-Tube Bridge and its complement of adaptors always up to date.

Table I

Eight-wire sub-minar tubes. These tubes can be plugged into the TYPE SOA-3 Adaptor. If the wire leads have been cut short, the TYPE SOT-48 Socket with the Universal adaptor should be used.

1AC5	5635	5897	5970
1AD5	5636	5898	5977
1C8	5637	5899	5987
1D3	5639	5900	6021
1E8	5640	5901	6026
1Q6	5643	5902	6110
1S6	5644	5903	6111
1T6	5718	5904	6112
1V5	5719	5905	6153
1W5	5797	5906	6154
2B5	5798	5907	6169
6AK4	5840	5908	6184
6BA5	5851	5916	6193
6BF7	5873	5967	6195
6BG7	5885	5968	6205
6BK7	5896	5969	6206

Table II

Flat-press sub-miniature tubes with all leads in a single plane. These tubes, with anywhere from 3 to 7 wire leads, can be measured in the TYPE 561-415-2 Tube Adaptor. If the wire leads are cut short, the SOT-46, SOT-49, or SOT-50 Socket with the Universal adaptor should be used.

1AD4	CK-525AX	CK-547DX	5829
1AE5	CK-526AX	CK-548DX	5854
1AG4	CK-527AX	CK-549DX	5875
1AG5	CK-528AX	CK-551AXA	5884
1V6	CK-529AX	CK-553AXA	5886
2E31	CK-531DX	CK-574AX	5889
2E35	CK-532DX	CK-623CX	5971
2E41	CK-533AX	5672	5972
2G21	CK-534AX	5676	5975
CK-502AX	CK-535AX	5677	5995
CK-503AX	CK-536AX	5678	6029
CK-505AX	CK-537AX	5697	6050
CK-506AX	CK-538DX	5702	6088
CK-510AX	CK-539DX	5703	6148
CK-512AX	CK-541DX	5704	6149
CK-518AX	CK-542DX	5744	6150
CK-522AX	CK-544DX	5784	6151
CK-524AX	CK-546DX	5785	6152

SPECIFICATIONS
FOR THE TYPE 561-D VACUUM-TUBE BRIDGE

Range: Amplification factor (μ); 0.001 to 10,000.

Dynamic internal plate resistance (r_p); 50 ohms to 20 megohms.

Transconductance (g_m); 0.02 to 50,000 micromhos.

Under proper conditions, the above ranges can be exceeded. The various parameters can also be measured with respect to various elements, such as screen grids, etc. Negative as well as positive values can be measured.

Accuracy: Within $\pm 2\%$ for resistances (r_p switch position) from 1000 to 1,000,000 ohms. At lower and higher values the error increases slightly.

The expression $\mu = r_p g_m$ will check to $\pm 2\%$ when the quantities are all measured by the bridge, and when r_p is between 1000 and 1,000,000 ohms.

Tube Mounting: Adaptors are provided as follows: 4-pin, 5-pin, 6-pin, small 7-pin, large 7-pin, octal, locking-in, miniature button 7-pin, miniature button 9-pin (noval), acorn (5- and 7-pin), flat-press sub-miniature up to 7 wires, and 8-wire sub-minar. For short-lead sub-miniature tubes, sockets are supplied which can be mounted on one of the adaptors. Thus all standard commercial receiving tubes can be measured. In addition, a Universal adaptor, with nine soldering lugs, is provided so that unmounted tubes, or tubes with non-standard bases, can be measured conveniently. The panel jack plate and the adaptors are made of low-loss material, usually yellow phenolic, reducing to a minimum the shunting effect of dielectric losses on the dynamic resistance being measured.

Current and Voltage Ratings: The tube circuits have large enough current-carrying capacity and sufficient insulation so that low-power transmitting tubes may be tested in addition to receiving tubes. Maximum allowable plate current is 150 ma and maximum plate voltage is 1500 volts.

Electrode Voltage Supply: Batteries or suitable power supplies are necessary for providing the various voltages required by the tube under test.

Bridge Source: A source of 1000 cycles is required. The Type 1214-A Oscillator, Type 813-A Audio Oscillator or the Type 723-A Vacuum-Tube Fork is suitable for this purpose.

Null Indicator: The Type 1231-B Amplifier and Null Detector with Type 1231-P2 Filter and a pair of sensitive head telephones are recommended.

Accessories Supplied: Adaptors as listed above, all necessary plug-in leads, and shielded patch cords for connecting generator and detector.

Mounting: The instrument is mounted in a walnut cabinet. A wooden storage case is provided for the adaptors and leads. Storage space is provided for a spare Universal adaptor, on which any type of socket can be permanently mounted.

Dimensions: (Length) 18⅜ x (width) 15¾ x (height) 12 inches.

Net Weight: 60 pounds.

Type		*Code Word*	*Price*
561-D	**Vacuum-Tube Bridge**	BEIGE	**$650.00**

Table III

Socket and Adaptor Accessories currently supplied in the accessory case of the Type 561-D Vacuum-Tube Bridge. Adaptors can be purchased separately at the following prices:

	Price
Type 561-413- 2 Adaptor for 4-prong tubes	$ 7.00
Type 561-413- 3 Adaptor for 5-prong tubes	7.00
Type 561-413- 4 Adaptor for 6-prong tubes	7.00
Type 561-413- 5 Adaptor for small 7-prong tubes	7.00
Type 561-413- 6 Adaptor for large 7-prong tubes	7.00
Type 561-413- 7 Adaptor for octal tubes	7.00
Type 561-413- 8 Adaptor for loctal tubes	7.00
Type 561-413- 9 Universal Adaptor	7.00
Type 561-413-10 Adaptor for 7-pin miniature tubes	7.00
Type 561-413-11 Adaptor for acorn type tubes	16.00
Type 561-413-12 Adaptor for 9-pin miniature (noval) tubes	9.00
Type SOA-3 Socket Adaptor for 8-lead button-base sub-miniature (sub-minar) tubes	3.00
Type 561-415-2 Socket Adaptor for flat-press sub-miniature tubes with up to seven leads in one plane	15.00
Type SOT-46 5-pin flat-press sub-miniature socket	package 1.50
Type SOT-49 6-pin flat-press sub-miniature socket	
Type SOT-50 7-pin flat-press sub-miniature socket	
Type SOT-48 8-pin button-base sub-miniature (sub-minar) socket	
Type 561-140 Adaptor Case	25.00

DELIVERY SCHEDULES

The heavy demands for the rearmament program of the United States and our allies have given us at General Radio a real job to do. As most of our readers know, it takes time to produce precision equipment. The process of manufacturing it is not the kind that can be speeded up quickly to meet increased demand — rather, the production growth is a slow and careful process if quality, accuracy, and satisfactory long-life performance are not to be impaired.

The problem is further complicated by the extensive line of equipment that we manufacture. General Radio makes over 400 different products, ranging in complexity from banana plugs to frequency standards and, in price, from a few cents to several thousand dollars. With few exceptions (Variacs, for one example), instruments are produced not on a continuous production line, but in lots which are carefully scheduled so as to have, in normal times, all four-hundred-plus products always available from stock. A production cycle for a typical instrument, including the time required for delivery to us of outside purchased components, is now from six to ten months.

When new orders outrun manufacture, production lots are sometimes entirely sold before they can be completed. At all times we try to forecast, product by product, based upon experience, what the probable demand will be, so that no item will ever be oversold, or at least for only a short time. That is, production is scheduled "on spec" in anticipation of orders. Some factors influencing demand are, however, unpredictable. Procurement of a single instrument, in considerable quantity, by one of the military services, if immediate delivery is desired, is one example. Another is the specification of an instrument for making required tests on military equipment made in large quantities by other manufacturers. When this happens, there is little we can do but wait for the next production lot, since all production time is scheduled for many months ahead. Everything possible is done, however, to expedite the next lot.

Add to these the technical difficulties that can arise during manufacture, especially on new products, and the failure of outside purchased material to arrive on schedule or, when it does arrive, to meet specifications, and the result is that our delivery schedules suffer.

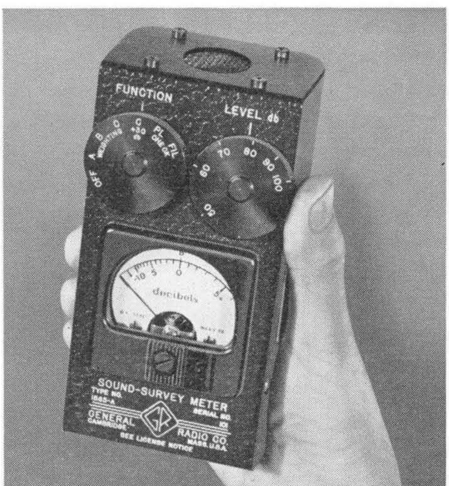
Sometimes our delivery promises are not as good as we would like to see them, but we think you, our customers, would rather wait a little longer than in normal times and be sure of getting the quality of product you are accustomed to expect from General Radio.

QUIET SHIP

The United States Lines' new record-breaking ocean liner, *SS United States*, is said to be remarkably quiet. To prove this, a General Radio pocket-size Sound-Survey Meter went along on the trial runs, to compare sound levels in the various spaces of the ship. Trial runs are short and time is limited, but Gibbs and Cox, Inc., the naval architects who designed the ship, found that with the

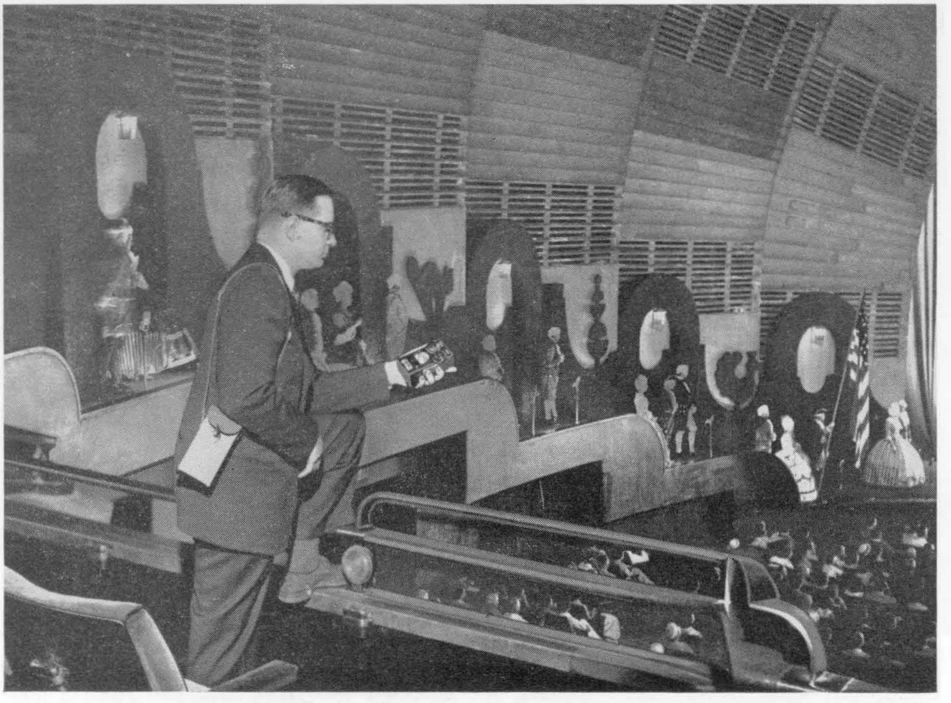
The *SS United States*, new holder of the Atlantic blue ribbon, has attained speeds of 35.59 knots on her eastbound voyage, 34.51 knots on her westbound voyage, and an average speed of over 35 knots in her initial voyages.

Sound-Survey Meter the necessary sound-level measurements could be made as rapidly as one could walk through the ship, and the results confirmed their impression that the ship was unusually quiet.



Pictured at the left is the Type 1555-A Sound-Survey Meter which proved so convenient for the measurements made on the *SS United States* mentioned above. Since its announcement in the April *Experimenter* this meter has been enthusiastically received. Interesting applications are being found for it and of course many of them are in the field of sound reproduction and reinforcement. One of these is well illustrated on the next page.

The Sound-Survey Meter delivers a lot of information on noise levels for such a small instrument and is well-adapted to measurements of this type (ideal for such purposes, users say).



Mr. Warren Jenkins, Sound Engineer at Radio City Music Hall, checks performance of sound reinforcement system at this theater with the General Radio TYPE 1555-A Sound-Survey Meter.

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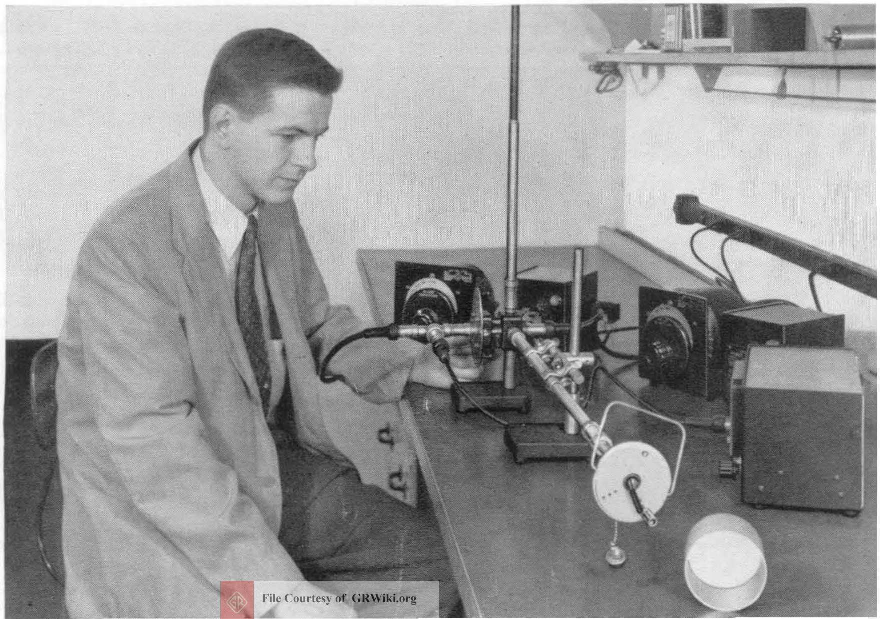
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

NEW COAXIAL ACCESSORIES — ADAPTORS, LINE STRETCHER, COMPONENT MOUNT, BALUN, TERMINATIONS, AND INSERTION UNIT

●**EARLY IN THE DEVELOPMENT OF RADAR,** the importance of smooth coaxial connections became evident, and coaxial measuring equipment was found necessary to achieve them. The virtues of completely shielded structures with uniformly distributed parameters and simple geometric configurations were quickly recognized, and a tremendous effort was put forward to bring coaxial measurement techniques up to a level adequate for accurate measurement. Out of this work came widespread use of the slotted line, the directional coupler, the "line stretcher," the wave-guide-below-cutoff attenuator, the matching section, the balun, the "magic T," and all the other items of

Figure 1. View of the Type 874-M Component Mount as set up for measuring a resistor at 500 megacycles with the Type 874-LK Constant-Impedance Adjustable Line and the Type 1602-A Admittance Meter.



microwave "plumbing." However, most of these devices were developed for relatively narrow frequency ranges. Accuracy was important. Flexibility and versatility in use were secondary.

At the end of the war it became clear that commercial use of the entire portion of the spectrum sampled by radar was inevitable. Therefore, the manufacturer of measuring equipment was faced with the problem of synthesizing the devices and methods that had been devised for specific frequencies into a universal system that would cover a wide frequency range extending downward to the lower frequencies where lumped-parameter devices are satisfactory and upward to the high frequencies where wave guide and cavity devices become desirable.

Out of a study of this problem grew the General Radio TYPE 874 line of coaxial elements. The element of flexibility is achieved by making various component parts plug into one another readily, and the element of versatility is obtained by making a sufficient variety of component parts.

The common element in this integrated line of parts is the TYPE 874 Coaxial Connector.[1] It was considered essential from the beginning that a connector be used that would plug into another identical connector. Experience had shown that combinations of elements not originally anticipated would be found useful and that male and female connectors would complicate this added usefulness.

The various connectors that had been developed during the war were reviewed, and it was found that nothing was available that would meet this need. The TYPE N Connector had been established as standard, and a continuing program of development had brought its mechanical design and electrical performance to a high degree of perfection as a general system connector. As a connector for an integrated line, however, it failed to meet the requirement that any connector plug into any other connector since it was basically a male-female design. It was, therefore, decided that a new connector, designed specifically for measurements, was needed.

Ideal specifications for this new connector were agreed upon as follows:

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

Figure 2a. Type 874-QNP and -QNJ Adaptors to Type N Connector.

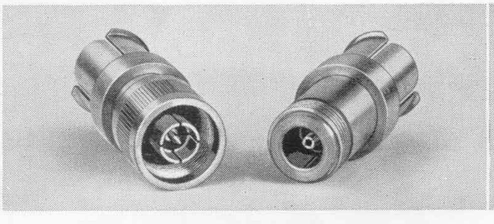


Figure 2b. Type 874-QCJ and -QCP Adaptors to Type C Connector.

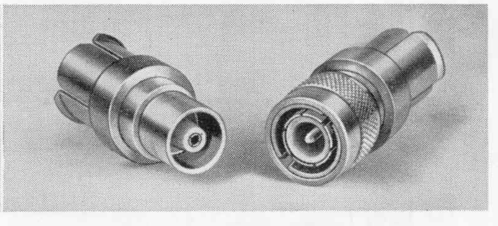


Figure 2c. Type 874-QBJ and -QBP Adaptors to Type BNC Connector.

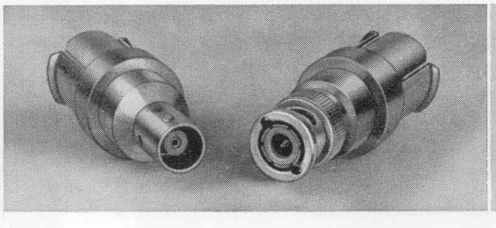
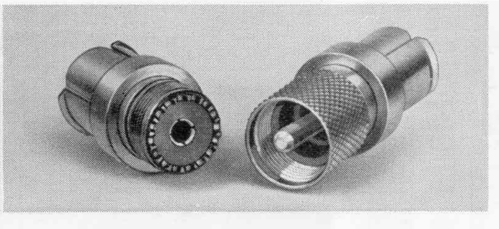


Figure 2d. Type 874-QUJ and -QUP Adaptors to Type UHF Connector.



1. Each connector should plug into any other connector.

2. Electrical characteristics should be at least as good as those of the Type N Connector.

3. The connector should be adaptable to mounting on panels, solid-outer-conductor coaxial lines, or flexible cables without basic change.

4. The connector should accept not only other connectors of the same type but also Type 274 Banana Plugs.

5. The connector should be designed as a quick-connect-and-disconnect instrument connector rather than as a system connector with provision for locking junctions together,[2] pressurizing, etc.

6. The characteristic impedance should be 50 ohms to simplify calculations and to approximate the characteristic impedance of Type RG Cables in widespread use.

These objectives were ultimately achieved and the success of the Type 874 Connector in meeting general laboratory requirements has been amply demonstrated. In General Radio equipment, its advantages have been so apparent that it has been adopted throughout as a universal connector, not only for v-h-f and u-h-f devices, but also for lower-frequency equipment where the shielding and small ground inductance of a coaxial connector are essential.

A virtually complete line of high-frequency coaxial measuring equipment has been designed around the Type 874 Connector. Most of these pieces have been previously announced and are now widely used throughout industry and in educational institutions. They include a slotted line, admittance meter, bolometer bridge, and a variety of accessory equipment.

[2] An external spring-type lock is available.

To make the features of this line of coaxial equipment as universally available as possible, the General Radio Company now offers (1) a line of adaptors which will permit interconnection of Type 874 equipment with other commonly used coaxial systems, (2) a constant-impedance line stretcher, (3) a component mount to facilitate the measurement of resistors, capacitors, inductors, and other circuit elements, (4) a balun for converting balanced to unbalanced impedances, (5) short and open circuit terminations to aid in setting up measuring equipment, and (6) an insertion unit for mounting arbitrary coaxial networks.

ADAPTORS

The new Type 874 Coaxial Adaptors are designed to connect measuring equipment using Type 874 Coaxial Connectors to other pieces utilizing any of the common high-frequency coaxial connectors — Type N, Type C, Type

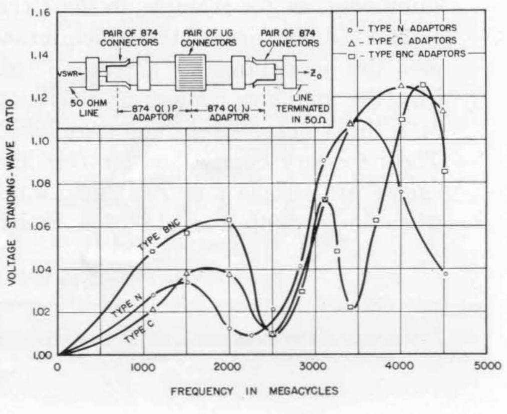


Figure 3. VSWR as a function of frequency for typical adaptors. Measurements were made on pairs of adaptor units, as shown in the sketch, and, hence, the standing-wave ratios shown are the totals produced by two pairs of Type 874 Connectors plus a pair of UG-type (i.e., N, C, or BNC) connectors.

BNC, and Type UHF.[3] These adaptors are shown in Figure 2. Their excellent electrical characteristics[4] are illustrated in the plots of VSWR versus frequency, shown in Figure 3. The use of these adaptors makes it possible to utilize the advantages of the Type 874 line when measurements are made on equipment fitted with military-type connectors. The availability of both male and female adaptors makes possible the conversion to Type 874 Connectors with a minimum of interconnecting elements.

[3] Drawings 874-QHP and 874-QHJ are available for manufacturing adaptors to Type HN Connectors.

[4] UHF connectors do not have a constant impedance and introduce an appreciable reflection in the line at the higher frequencies.

TYPE 874 ADAPTORS

Type No.	*Elements Used in Adaptor*	*Code Word*	*Price*
874-QNP	Type 874 Connector and Type N Plug Connector...	COAXNUTTER	$4.50
874-QNJ	Type 874 Connector and Type N Jack Connector...	COAXNAGGER	3.75
874-QBP	Type 874 Connector and Type BNC Plug Connector.	COAXBUNNER	6.00
874-QBJ	Type 874 Connector and Type BNC Jack Connector.	COAXBOGGER	5.75
874-QCP	Type 874 Connector and Type C Plug Connector...	COAXCUFFER	6.50
874-QCJ	Type 874 Connector and Type C Jack Connector...	COAXCOGGER	4.75
874-QUP	Type 874 Connector and Type UHF Plug Connector .	COAXYUPPER	4.25
874-QUJ	Type 874 Connector and Type UHF Jack Connector.	COAXYUNDER	4.00

TYPE 874-LK CONSTANT-IMPEDANCE ADJUSTABLE LINE

Measurements on 50-ohm coaxial systems can be greatly facilitated if the lengths of transmission lines in the system can be adjusted without introducing appreciable discontinuities.

It is usually not possible to measure impedance directly at the location of an unknown, because some length of line exists between the point at which the measurement is made and the point at which it is desired. This line length may be a piece of coaxial cable necessary to connect the measuring instrument to an inaccessible unknown, as, for instance, an antenna; it may be in the measuring equipment, as, for example, in the Type 1602-A Admittance Meter, which measures the admittance at a point 5 cm. from the unknown connector; or it may be in the structure of the unknown itself. The necessary corrections for this line length are simple and straightforward when made with the aid of a Smith chart, but become tedious when a long series of measurements is to be made.

The need for these corrections can be eliminated if the electrical distance between the measuring point and the desired point can be made equal to an integral number of half-wavelengths. This can be easily accomplished by the use of a line of adjustable length (line stretcher) inserted between the unknown and the measuring device, provided the line has a uniform characteristic impedance. Conventional adjustable lines, however, do not have a constant characteristic impedance as the length is varied and are, therefore, not satisfactory for this purpose. This disadvantage is eliminated in the Type 874-LK Constant-Impedance Adjustable Line shown in Figure 4.

This air-dielectric coaxial line has a maximum length of 80 cm. and a minimum length of 58 cm. with an adjust-

Figure 4. View of the Type 874-LK Constant-Impedance Adjustable Line.

ment range of 22 cm. The line is fitted with Type 874 Coaxial Connectors at each end and a locking mechanism for maintaining the adjustment.

The ratio of the diameters of the inner and outer conductors, and hence the characteristic impedance, is held constant at all points along the line. This is accomplished by having the inner and outer conductors slide at different points as shown in Figure 5. No significant electrical discontinuities are introduced by the steps because the stray capacitance resulting from the abrupt changes in diameters are compensated by slightly offsetting the steps in the inner and outer conductors. Because the characteristic impedance is constant, this line is aperiodic and thus can be used over a wide frequency range. The VSWR of a typical line as a function of frequency is shown in Figure 6.

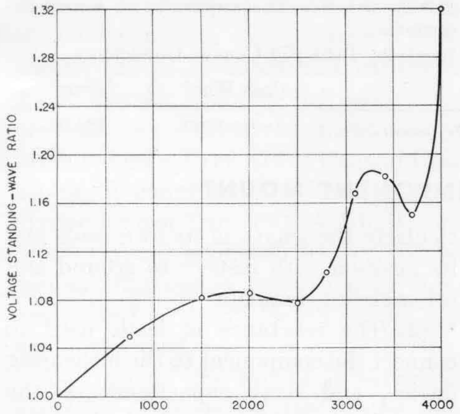


Figure 6. Voltage-standing-wave ratio as a function of frequency for a typical Type 874-LK Constant-Impedance Adjustable Line. These values include the VSWR of two pairs of Type 874 Connectors, and the magnitude plotted at each frequency is the maximum of several measurements made with different settings of the line.

In impedance measurement, the error introduced by the adjustable line is a function of the frequency and the unknown impedance. The maximum error

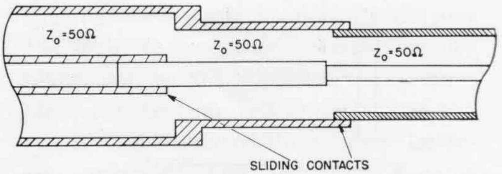


Figure 5. Simplified cross section of the adjustable line, showing how the sliding contacts are arranged to hold the characteristic impedance constant as the length is varied.

is proportional to the VSWR of the adjustable line itself when terminated in 50 Ω.

A line of this type has many uses. In addition to using it as a half-wave line to eliminate line corrections, one can adjust the measuring-point-to-desired-point distance to be an odd number of quarter wavelengths and thereby convert an admittance reading device into an impedance reading device and vice versa. This line can, for instance, be used in this way to increase the accuracy and range of measuring instruments, particularly the Type 1602-A Admittance Meter, as a converter of low impedance (high admittance) to low admittance, which can be measured with greater accuracy than high admittance; it can also be used to make the admittance meter direct reading in impedance. In a matched system, on the other hand, no admittance variation occurs, but the line can be used to obtain a constant-magnitude, variable-phase output voltage. It has been used to provide differently phased voltages for elements of an antenna array.

One of the common uses for the adjustable line is in a matching section for converting a load impedance to the characteristic impedance of a line system. Proper matching is often necessary. It minimizes standing-wave ratio and the accompanying line loss; or enables one to draw maximum power from a source.

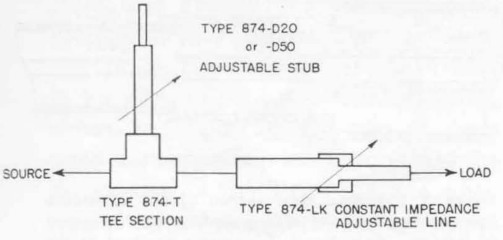


Figure 7. Functional diagram of an impedance-matching transformer made up of coaxial elements.

In matching for unity standing-wave ratio, a point on the line is found at which the real part of the effective admittance is equal to the characteristic admittance, and a shunt susceptance, usually in the form of an adjustable-length short-circuited line, is inserted to cancel out the imaginary part. Thus the line will appear matched on the generator side of the shunt susceptance. The matched condition can be determined by measurement with the admittance meter or the slotted line.[5] A matching section utilizing this principle is shown in diagrammatic form in Figure 7. It consists of a Type 874-LK Adjustable Line, a Type 874-T Tee, and a Type 874-D20 or D50 Adjustable Stub.

When it is desired to draw maximum power from a generator, the generator must face the conjugate of its internal impedance. Experimentally this condition can be achieved by adjusting the transformer elements until the power dissipated in the load is a maximum.

[5]R. A. Soderman and W. M. Hague, "U-H-F Measurements with the Type 874-LB Slotted Line," *General Radio Experimenter*, November, 1950.

SPECIFICATIONS

Impedance: 50.0 ohms.

Length: Maximum, 80 cm.; minimum, 58 cm.; adjustment range, 22 cm.

VSWR: Less than 1.10 at 2000 Mc; approximately linear with frequency at lower frequencies.

Terminals: Type 874 Coaxial Connectors.

Type		*Code Word*	*Price*
874-LK	**Constant-Impedance Adjustable Line............**	COAXKEEPER	**$36.00**

THE TYPE 874-M COMPONENT MOUNT

The measurement of the admittance or impedance of components at high frequencies is complicated by many factors, the most important of which generally are:

(1) The component's arrangement in the circuit in which it is to be used, particularly the length of its own leads and its position with respect to ground and other circuit elements.

(2) The reactance of leads used to connect the component to the measuring device, and stray capacitance of the measuring terminals to which the leads are connected.

The complications resulting from (1) can be minimized by approximating as closely as possible the contemplated environment; those from (2) by using a coaxial connecting system whose effect

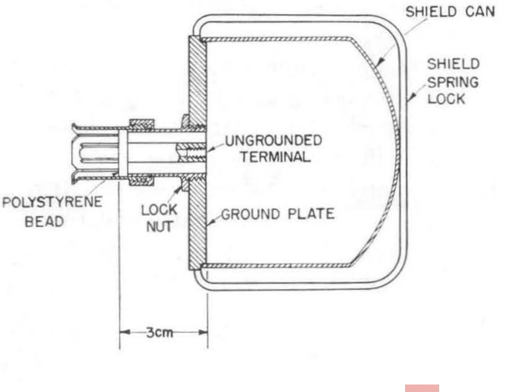


Figure 8. Cross section of the component mount.

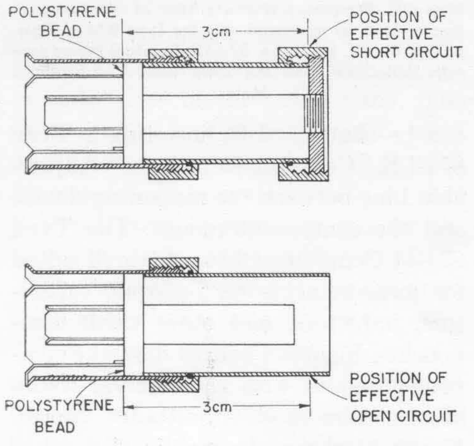


Figure 9. Cross-section diagrams of the Type 874-WN3 Short-Circuit Termination and the Type 874-WO3 Open-Circuit Termination.

can be readily computed or compensated.

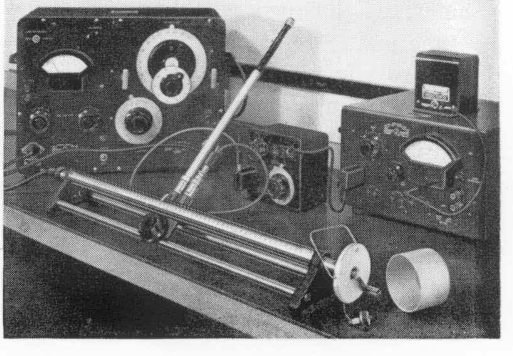
The Type 874-M Component Mount has been designed with these objectives in mind. It provides a shielded enclosure of convenient size within which a component can be mounted in a variety of ways, thereby enabling the user to approximate a circuit environment closely. Mounted on a Type 874-B Coaxial Connector, it connects to a Type 874-LB Slotted Line or Type 1602-A Admittance Meter through a smooth 50-ohm coaxial system that makes correction or compensation for "lead" length simple and straightforward.

A sketch of the mount is shown in Figure 8. The end of the center conductor of a section of 50-ohm air line is used as the ungrounded terminal and the outer conductor is extended in the form of a disc for a ground plane. The unknown is connected between the center conductor and the ground plate. It is connected by screws or binding posts, which are provided. Several mounting holes are arranged on the ground plate to provide a variety of spacings — ½ inch, ¾ inch, 1 inch, and 1¼ inch. If necessary, a larger ground plate can be installed or the ground plate can be removed entirely and the center unit mounted directly on the device under test. The shield cover isolates the unknown from external electrostatic or electromagnetic interference.

To correct for the effect of the coaxial line connecting the measuring point and the component to be measured, one must know the line length accurately. The line length can be determined most readily by an impedance measurement with the line terminated in a short or open circuit at the terminals to which the component is to be connected. A low-inductance disc, supplied with the unit, can be screwed into the center terminal in place of the unknown to short-circuit the system at the ground plane.

Alternatively, to avoid the need for disconnecting the component to be measured from its mounting, the entire component mount can be unplugged and a Type 874-WN3 Short-Circuit Termination or a Type 874-WO3 Open-Circuit Termination can be substituted. These terminations, supplied as accessories, place a short or open circuit at a distance of 3 cm. from the bead in the coaxial connector, a distance equal to that between the bead and the ground plane in

Figure 10. View of the component mount plugged into a General Radio slotted line for the measurement of a resistor.



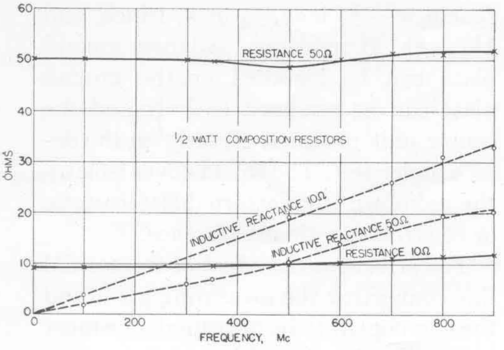


Figure 11. Frequency characteristics of two composition resistors as measured with the Type 874-M Component Mount, the Type 874-LK Constant-Impedance Adjustable Line, and the Type 1602-A Admittance Meter.

the component mount. These units are shown in Figure 9.

The effect of the coaxial line can be calculated from transmission-line equations or read from a Smith chart; or it can be eliminated by inserting a TYPE 874-LK Constant-Impedance Adjustable Line between the measuring device and the component mount. The TYPE 874-M Component Mount is well suited for measurements on resistors, capacitors, inductors, and other small components. Figures 1 and 10 show the component mount with the General Radio Slotted Line and Admittance Meter. Figure 11 shows the results of a set of measurements made with the TYPE 874-M Component Mount and the TYPE 1602-A Admittance Meter.

SPECIFICATIONS

Frequency Range: d-c to 5000 Mc.

Accessories Supplied: One TYPE 874-WN3 Short-Circuit Termination, one TYPE 874-WO3 Open-Circuit Termination.

Other Accessories Recommended: One TYPE 874-LK Constant-Impedance Adjustable Line.

Dimensions: Diameter of ground plate, 3 inches. Height of shield can, 2⅝ inches.

Terminal: TYPE 874 Coaxial Connector.

Type		*Code Word*	*Price*
874-M	**Component Mount**	COAXYMOUNT	**$25.00**

THE TYPE 874-UB BALUN

The TYPE 874-UB Balun brings to the measurement of balanced impedances the simple, accurate techniques already highly developed for coaxial systems. The need for measurements of this kind is growing rapidly with the use of balanced systems in television and communications, and satisfactory equipment has not previously been available.

For accurate impedance measurements, it has generally been found impractical to use conventional transformers to effect the conversion from balanced to unbalanced impedance because of losses and limited frequency range. The TYPE 874-UB Balun has, therefore, been designed to use an artificial half-

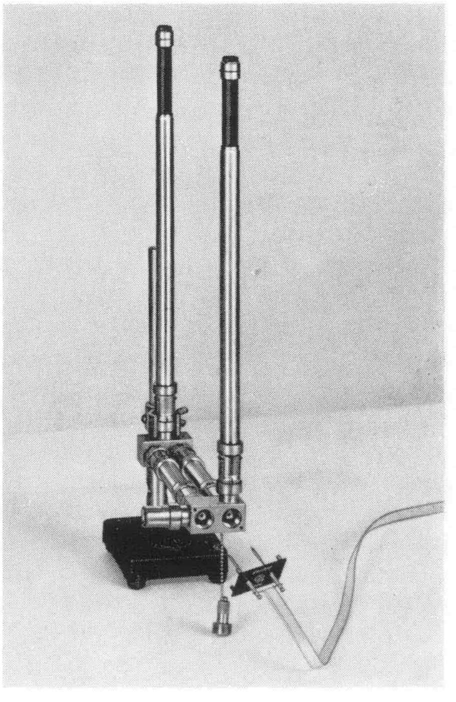


Figure 12. View of the Type 874-UB Balun with two Type 874-D20 Adjustable Stubs and two Type 874-L10 Air Lines as tuning elements. The 300-ohm connector is shown in the foreground. The balun is shown mounted on a Type 874-Z Stand.

wave line, which, when tuned to the operating frequency, makes the desired conversion accurately and without appreciable loss in the balun itself. The balun, shown in Figure 12, can be used over a frequency range from 50 to 1000 megacycles. It is made tunable so that the best possible accuracy can be obtained at any frequency within its range.

The basic theory underlying the operation of the balun is as follows:

The voltage appearing at one end of a section of transmission line, an integral number of half-wavelengths long, is equal in magnitude and 180 degrees out of phase with the voltage at the other end, independent of impedance. In addition, the impedance appearing at one end is equal to that at the other end. If a half-wavelength line is connected as shown in Figure 13, it provides a balanced output from an unbalanced input, and vice versa. The unbalanced voltage is equal to the voltage from either balanced terminal to ground, that is, one half the voltage between the balanced terminals. The impedance seen at the unbalanced terminals will be one quarter the impedance at the balanced terminals.

The use of an actual half-wavelength section of line restricts the frequency range greatly unless many different lengths of line are used. A much wider frequency range can be obtained by using a semi-artificial or loaded half-wave line as shown in Figure 14. The principle of operation of the artificial half-wave line has been described previously.[6]

The Type 874-UB Balun consists of two connector blocks with terminals for connecting various lengths of line and shunt tuning elements to cover a wide frequency range. The balun is adjusted for proper operation at a particular frequency by means of the shunt tuning elements. The necessary measurements to indicate correctness of tuning adjustments are conveniently made with the Type 1602-A Admittance Meter. A Type 874-WN3 Short-Circuit Termination and a Type 874-WO3 Open-Circuit Termination are supplied with the balun to facilitate tuning adjustments. At the higher frequencies, Type 874-D20 Stubs are used as tuning elements, and at the lower frequencies Type 874-VC Variable Capacitors are used. Figure 15 shows the frequency ranges obtainable with various combinations of elements.

The unbalanced end of the balun is a Type 874 Coaxial Connector, and thus the balun can be used with any General Radio measuring equipment and, by

[6] D. B. Sinclair, "Measuring Balanced Impedances with the R-F Bridge," *General Radio Experimenter*, Volume XVII, No. 4, September, 1942.

Figure 13. Diagram showing how a half-wave line operates as a balanced-to-unbalanced transformer.

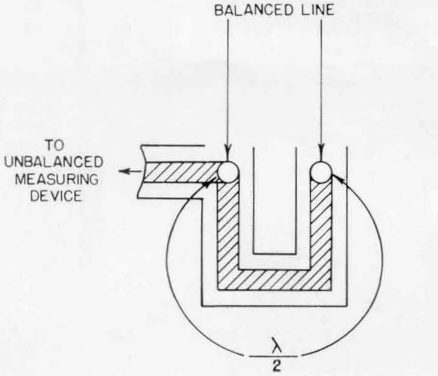
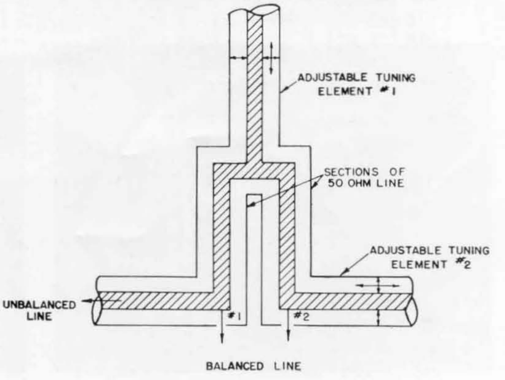


Figure 14. Diagram of a loaded, or semi-artificial half-wave line, which can be tuned over a wide frequency range.



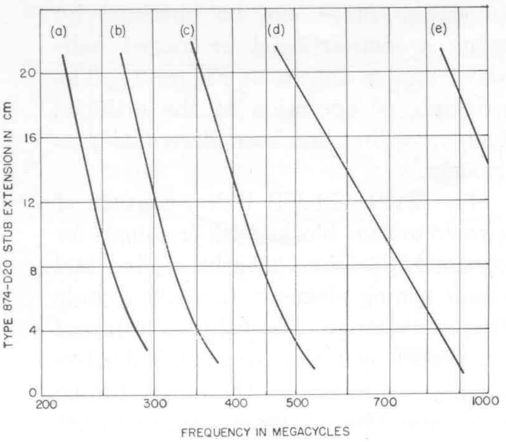


Figure 15. Tuning ranges of the balun for various combinations of tuning elements as listed in the specifications (next page). Note that the complete UHF-TV range is covered by a single combination.

means of the previously described adaptors, with equipment of almost any other manufacture.

When the balun is used with the Type 1602-A Admittance Meter and the Type 874-LK Adjustable Line, the adjustable line can be set so that the effective distance between the unbalanced terminals of the balun and the measuring point in the admittance meter is an odd number of quarter wavelengths. Under these conditions the admittance meter readings multiplied by ten give the actual balanced impedance in ohms. Figures 16 and 17 show the balun in operation.

In order to minimize errors, the balanced line under measurement should have its characteristic impedance remain constant right up to the terminals of the balun. The line impedance may be appreciably affected by the proximity of the grounded balun block; and, hence, for the most accurate results, a terminal unit designed for the line to be tested should be used for connection to the balun. The Type 874-UB-P1, a terminal unit designed for 300-ohm twin lead, is supplied with the balun. This is shown in Figure 12. This terminal unit is equivalent to a short length of 300-ohm line and compensates for the presence of the balun block. When it is used for measurements on 300-ohm twin lead, it insures a constant 300-ohm characteristic impedance directly to the balun terminals. If desired, balanced lines having other characteristic impedances can be measured using the 300-ohm terminals if corrections are made for the equivalent length of 300-ohm line in the terminal unit. Data for this correction are supplied in the operating instructions that accompany the instrument.

Figures 18 and 19 show typical measurements made with the Type 874-UB Balun.

Figure 16. The Type 874-UB Balun in use with a slotted line to measure 300-ohm twin lead.

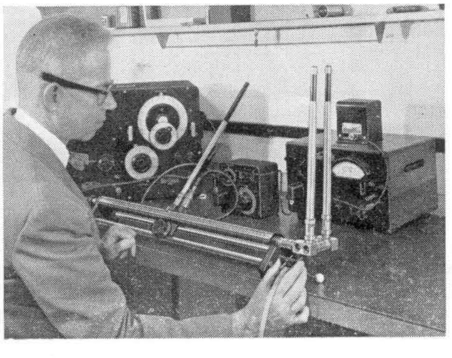
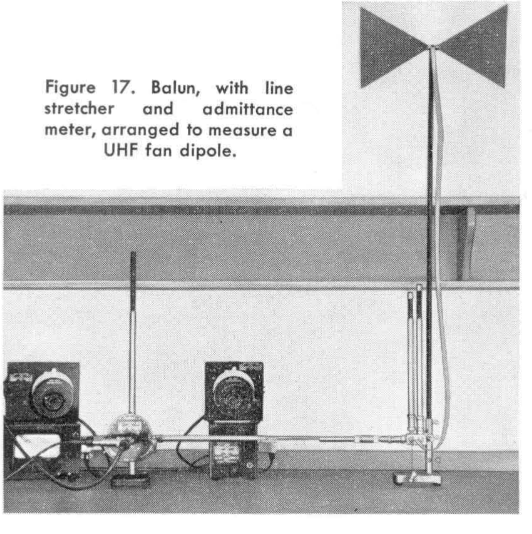


Figure 17. Balun, with line stretcher and admittance meter, arranged to measure a UHF fan dipole.



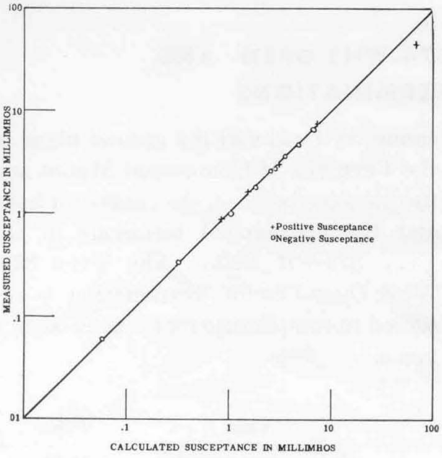


Figure 18. Measured vs. calculated values of susceptance for various short-circuited lengths of 300-ohm balanced line at 400 megacycles. Measurements were made with the Type 874-UB Balun and the Type 1602-A U-H-F Admittance Meter.

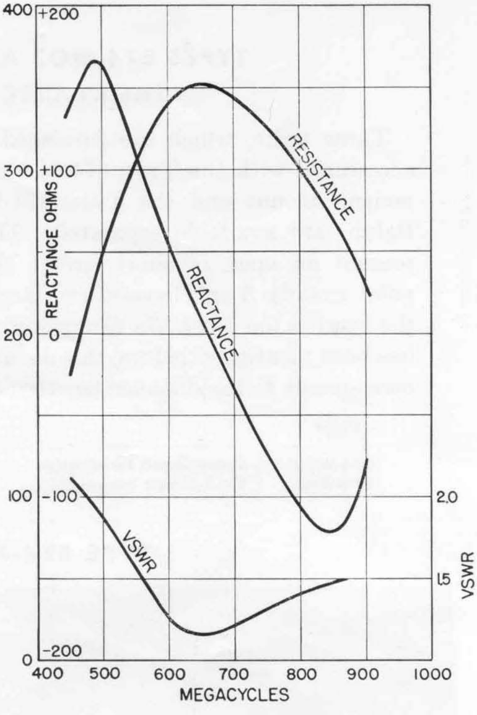


Figure 19. Measured values of resistance, reactance, and VSWR of the fan dipole shown in Figure 17.

SPECIFICATIONS

Frequency Range: 50 to 1000 Mc with proper accessories (see Figure 15).

Accessories Supplied: One TYPE 874-UB-P1 300-ohm Terminal, one TYPE 874-WN3 Short Circuit Termination, one TYPE 874-W03 Open-Circuit Termination.

Other Accessories Recommended: One TYPE 874-LK Constant-Impedance Adjustable Line (when used with the TYPE 1602-A Admittance Meter), and one TYPE 874-Z Stand.

Accessories Required for Various Frequency Ranges:

Figure 15 Curve	*Accessory Equipment*	*Frequency Range*
(d), (e)	2-Type 874-D20 Adjustable Stubs	470-1000 Mc
(c)	2-Type 874-D20 Adjustable Stubs and 2-Type 874-L10 Air Lines	350-525 Mc
(b)	2-Type 874-D20 Adjustable Stubs and 2-Type 874-L20 Air Lines	275-380 Mc
(a)	2-Type 874-D20 Adjustable Stubs and 2-Type 874-L30 Air Lines	225-280 Mc
	2-Type 874-D50 Adjustable Stubs and 2-Type 874-L30 Air Lines	170-280 Mc
	2-Type 874-VC Variable Capacitors + Lengths of Line[7]	50-300 Mc

[7]Actual lengths required for operation in this frequency range will be available in the near future. Write for information.

Type		*Code Word*	*Price*
874-UB	**Balun**	COAXYBALUN	**$70.00**
874-D20	**Adjustable Stub (20 cm.)**	COAXTUBBER	**10.50**
874-D50	**Adjustable Stub (50 cm.)**	COAXBIGGER	**12.00**
874-L10	**50-Ω Air Line (10 cm.)**	COAXDECKER	**6.50**
874-L20	**50-Ω Air Line (20 cm.)**	COAXVENTER	**6.50**
874-L30	**50-Ω Air Line (30 cm.)**	COAXTRIPLY	**7.50**

TYPES 874-WO3 AND 874-WN3 OPEN- AND SHORT-CIRCUIT TERMINATIONS

These units, which are furnished as accessories with the Type 874-M Component Mount and the Type 874-UB Balun, are available separately. They present an open or short circuit at a point exactly 3 cm. beyond the face of the bead in the Type 874 Connector. As has been mentioned before, this distance corresponds to the distance between the connector bead and the ground plane in the Type 874-M Component Mount and the distance between the connector bead and the unbalanced terminals in the Type 874-UB Balun. The Type 874-WO3 Open-Circuit Termination is designed to compensate for fringing capacitance.

Type		*Code Word*	*Price*
874-WO3	**Open-Circuit Termination**	COAXYTRIPO	**$2.50**
874-WN3	**Short-Circuit Termination**	COAXYTRINU	**3.75**

TYPE 874-X INSERTION UNIT

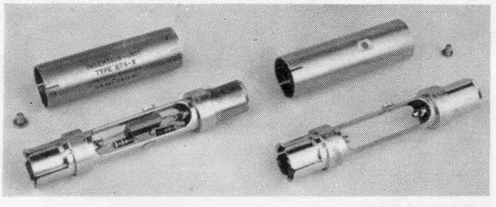


Figure 20. Two views of the Type 874-X Insertion Unit. The left-hand view shows how circuit elements can be conveniently mounted in the structure.

This unit is a hollow cylinder fitted with Type 874 Connectors at each end. Its cover sleeve slides back to allow access to a region inside of about 2 inches in length and 9/16 inch in diameter. In this region between the Type 874 Connectors, almost any arbitrary arrangement of small components, such as resistors, capacitors, or inductors, can be mounted. The insertion unit, shown in Figure 20, has been used as a shielded housing for impedance matching networks, attenuator pads, VHF transformers, filters, and a variety of other networks.

Type		*Code Word*	*Price*
874-X	**Insertion Unit**	COAXHOPPER	**$10.00**

All Type 874 Connectors are covered by U. S. Patents Nos. 2,125,816 and 2,545,847.

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THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW SERIES OF STANDARD INDUCTORS

Also IN THIS ISSUE

● **HIGHLY ACCURATE STANDARDS** of resistance, capacitance, and inductance, representing the basic parameters of an electrical network, are necessarily among the major tools used in any measurement and standardizing laboratory. For many years General Radio Company has endeavored to produce such high quality standards and to improve them from time to time as dictated by enhanced knowledge and advancement in the arts of measurement and manufacturing technique. At this time a new standard inductor, known as the Type 1482, which is superior in several aspects to the long-used Type 106 Standard Inductor, is announced.

For precise work, one naturally desires an inductance standard which is insensitive to its electrical environment and ambient humidity, and which has a known temperature coefficient of minimum value. In these respects, the new Type 1482 Standard Inductors are definitely superior to the old Type 106 units.

These new inductors are symmetrically wound toroids and have thus a much higher degree of astaticism than existed in the adjacent

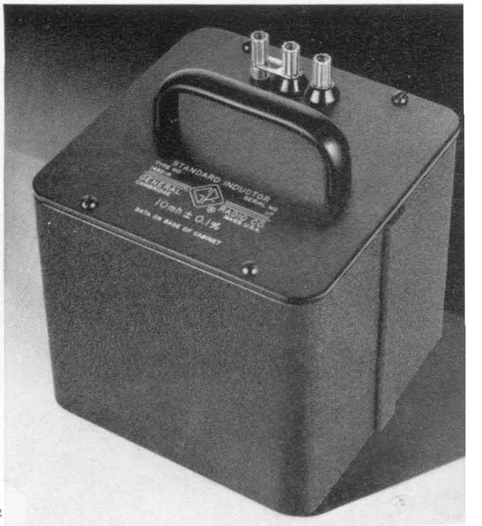


Figure 1. Panel view of the Type 1482 Standard Inductor.

pair of D-shaped coils used in the older type. They have essentially no pick-up from a moderately uniform electromagnetic field and, when energized, they produce no such field in their vicinity. Accordingly, they may be used close to each other or to other circuit components.

With no external magnetic field, these toroidal units can be housed in a metallic case and thus given an electrostatic shield with no complicated frequency correction of inductance due to eddy current reaction. Any attempted electrostatic shielding of the Type 106 Standard Inductors would have required abnormally large cases.

The Type 1482 Inductors are wound on a low thermal expansion ceramic core having an elliptical cross section to avoid sharp bends in the winding. After adjustment, they are packed in granulated cork into a cylindrical cardboard carton, together with a small amount of silica gel to insure dehydration. Having a simple geometrical construction and being uniformly supported at all points with no restraining clamps, it is expected that long-time observations will prove these "floating" inductors will have a high degree of stability. This belief is fortified by the results obtained in the accelerated aging techniques to which all of these inductors are subjected prior to final calibration. Furthermore, their temperature coefficient of inductance is definitely positive and of the order of 30 parts per million per degree C. This checks closely a theoretical value of twice the linear expansion coefficient of copper. For precise work, appropriate temperature corrections can thus be applied. This was not possible with the old Type 106 Inductors, whose thermal coefficients were indefinite both in sign and magnitude and could only be specified as less than $\pm$ 40 parts per million per degree C.

Continuing with the assembly, the cylindrical carton is supported on three wooden dowels and completely cast with a potting compound into the cubical aluminum case. These inductors are thus hermetically sealed and devoid of ambient humidity variations encountered in the older units.

The two extremities of the winding are brought out to a pair of insulated terminals. As calibrated and as ordinarily used, the LOW terminal is externally strapped to a third terminal which is grounded to the case. While so doing lowers the natural frequency of the unit slightly, it affords at the terminals a definite impedance, $R + j\omega L$, which is independent of the environs of the inductor. If desired, the ground link may be removed to afford a three-terminal ungrounded inductor.

A uniform progressive banked winding is applied around the ceramic core (single winding), avoiding overlapping at the extremities which would result in excessive distributed capacitance. Holes

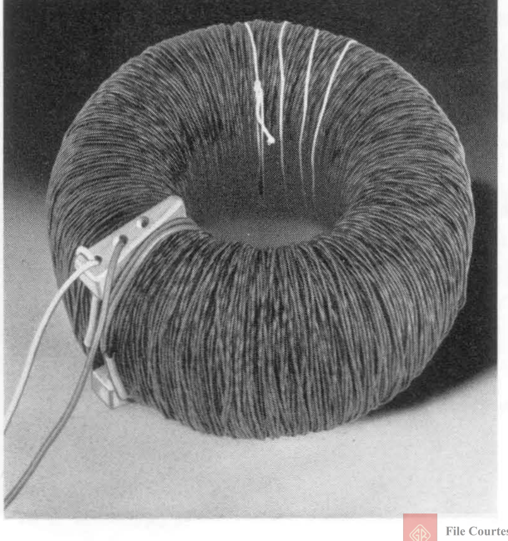


Figure 2. View of the toroidal inductor before installation in cabinet.

fabricated in the core at the extremities of the winding allow the final turn to embrace either ⅓, ⅔ or all of the flux, thus permitting a finer degree of adjustment. While a toroidal winding is not, inherently, highly efficient with respect to copper loss, the maximum practical amount of copper has been used in all units to produce the highest possible low-frequency Q values. Inductors of 100 mh and less are wound of appropriate Litzendraht wire, and those of 1 mh and less are of "duplex" construction consisting of two paralleled semi-circumferential windings.

These inductors are offered in the convenient 1-2-5 unit values, which permits a precise direct comparison between them on a unity-ratio bridge. For example, the 2-unit may be compared with two 1-units in series, the 5-unit versus two 2-units plus a 1-unit in series, the 10-unit versus two 5-units in series, etc. Complete cross-checking is thus possible in a standardizing laboratory equipped with two sets of these inductors. As catalogued at the present time, inductance values extend from 100μh to 1 h inclusive. These are adjusted with a nominal limit of $\pm$ 0.1 per cent of absolute inductance except the 100-μh and 200-μh units for which the nominal limit is $\pm$ 0.25 per cent.

Additional inductors of 10h, 5h and 2h have been made and can be supplied on special order. The nominal limit for these units is $\pm$0.1 per cent.

A certificate attached to the bottom of the case gives useful data for the precise use of each individual inductor. The series inductance at 100 cycles per second and at the indicated stabilized temperature is given as obtained by direct comparison, precise to better than 0.005 per cent, with a like standard which has been certified by the National Bureau of Standards with an indicated accuracy (see table). Since this comparison measurement is at least sixfold more precise than the Bureau certification, the absolute inductance of each inductor at 100 cps is known within the limits set by the Bureau for its particular magnitude.

It is well known that effective series inductance increases with frequency owing to the existence of distributed capacitance. While insignificant at low frequencies with the smaller-valued inductors, this increase may become appreciable with the larger-valued units. For convenience, the increments to be added to the 100 cycles per second value when operating at 200 cycles per second, 500 cycles per second, and 1 kc are tabulated when they are of significant magnitude. These increments are individually computed from the equation

$$\Delta L = L_2 - L_1 = \left(\frac{f_2^2 - f_1^2}{f_r^2 - f_2^2}\right) L_1 \qquad (1)$$

which is precise up to at least 10 per cent of the natural frequency f_r. Individual values of f_r and d-c resistance at the stabilized temperature are measured and tabulated. Using the latter, together with the resistive coefficient of copper, 0.00393, more precise thermal corrections can usually be made than by the use of thermometers.

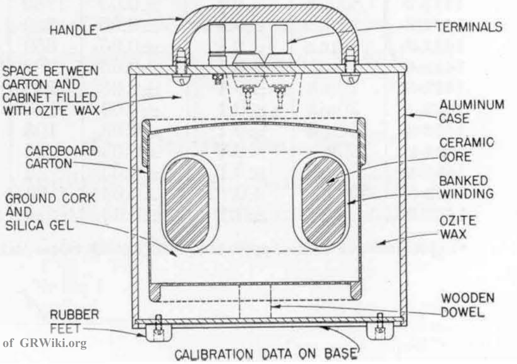


Figure 3. Cross-section drawing of the Type 1482 Standard Inductor showing details of construction and mounting.

Due to the effective thermal insulation afforded by the granulated cork, the input power should be limited to 3 watts, which produces a 20°C. temperature rise in the windings, and for precise work a limitation of 200 milliwatts, Δ T less than 1.5°C., may be taken. Corresponding current limitations may then be set in terms of resistance. These are recorded on the certificate. An auxiliary limitation of 500 volts at the terminals will rarely be encountered within a 20°C. rise in the windings.

At low frequencies, where the inductor is ordinarily used, the dissipation factor depends essentially on copper loss and is given by

$$D = \left(\frac{R_{d\text{-}c}}{2\pi L}\right)\left(\frac{1}{f}\right) = \frac{K}{f} \qquad (2)$$

For convenience, the numerical value of the coefficient K is recorded on the calibration certificate, f being in cycles per second.

The TYPE 106 Inductors are now obsolete and are superseded by the new TYPE 1482 series. The TYPE 1481 series of fixed toroidal inductors, announced two years ago*, will be continued. These are much smaller in size than the TYPE 1482 units and, having a ferromagnetic dust core, possess higher 100-cycle Q values at the expense of a voltage coefficient of inductance and a reduced accuracy of calibration.

— HORATIO W. LAMSON

*General Radio Experimenter, December, 1950.

SPECIFICATIONS

Inductance Range: 100μh to 1 h, inclusive. Inductors of 2h, 5h, and 10h are available on special order.

Accuracy: Nominal limits of adjustment, see table. Limits of measured certificate value, see table.

D-C Resistance: See table for approximate values.

Low Frequency Dissipation Factor: See table for K values used in Equation (2).

Resonant Frequency: See table.

Maximum Input Power:
For 20°C. rise, 3 watts.
For precise work, 1.5°C. rise, 200 milliwatts.
See table for corresponding current limitations.

Mounting: Aluminum cabinet with carrying handle and rubber feet, black crackle finish. Certificate data attached to base of cabinet.

Terminals: Two insulated jack-top terminals, plus ground terminal and strap.

Dimensions: 6½" x 6½" x 8" height overall.

Weight: 11½ pounds.

Type	*Nominal Inductance*	*Nominal Limits* %	*Limits of Certificate Value* %	**Resonant Frequency* kc	**D-C Resistance* ohms	**K Values* Eq. (2)	**Maximum Milliamperes rms for* 200mw	3w	*Code Word*	*Price*
1482-B	100μh	±0.25	±0.10	3500	0.26	400	870	3400	INDUCTOTAG	**$48.00**
1482-C	200μh	±0.25	±0.05	2300	0.37	300	740	2800	INDUCTOTED	**48.00**
1482-D	500μh	±0.1	±0.05	1250	0.54	170	600	2400	INDUCTOTIM	**55.00**
1482-E	1mh	±0.1	±0.05	820	1.03	165	390	1500	INDUCTOTOP	**55.00**
1482-F	2mh	±0.1	±0.05	650	2.00	150	310	1250	INDUCTOTUB	**55.00**
1482-G	5mh	±0.1	±0.05	380	4.4	140	210	800	INDUCTOVAT	**55.00**
1482-H	10mh	±0.1	±0.03	250	8.0	127	160	600	INDUCTOVEX	**60.00**
1482-J	20mh	±0.1	±0.03	170	18	145	105	400	INDUCTOWAD	**60.00**
1482-K	50mh	±0.1	±0.03	105	46	145	66	250	INDUCTOWET	**60.00**
1482-L	100mh	±0.1	±0.03	65	90	145	47	180	INDUCTOWIG	**60.00**
1482-M	200mh	±0.1	±0.03	42	120	96	40	160	INDUCTOWOW	**60.00**
1482-N	500mh	±0.1	±0.03	26	350	110	24	100	INDUCTOYAK	**60.00**
1482-P	1h	±0.1	±0.03	16	590	94	18	70	INDUCTOYES	**60.00**

*Representative values, approximate. Actual values indicated on certificate.

A CALIBRATION-CHECK SERVICE FOR SOUND METERS

Our Sales and Engineering Offices in Cambridge, New York City, Chicago, and Los Angeles now offer a new, free service to owners of General Radio Sound-Level Meters and Sound-Survey Meters[1] in those areas. When circumstances of a measurement problem call for assurance, or reassurance, that results be highly accurate, or when a possible calibration error is indicated or suspected, it is desirable to check the over-all calibration of the instrument in question. An accurate yet simple check can be made using the Type 1552-A Sound-Level Calibrator[2] plus a suitable oscillator and voltmeter. However, the majority of General Radio sound-meter users have no need for frequent checks, and purchase of calibrating equipment is in these instances difficult to justify, particularly for the owner of a Type 1555-A Sound-Survey Meter,[3] for whom the calibrating equipment would cost[4] more than the instrument to be calibrated. The new calibration-check service, available at our branch offices, is expected to meet the needs of the majority of sound-meter owners.

To use the service, just take the sound meter to a Sales and Engineering Office, addresses of which appear on the last page of the *Experimenter*. The calibration check requires only a few minutes, and no charge is made for it. Someone qualified to make the check is generally available, but it is suggested this be verified by telephone beforehand. We request that instruments be delivered personally or via messenger, and that no instruments be shipped to us for this service, since our field office shipping facilities are very limited. If the calibration check indicates that the instrument requires repair, the repair work should be handled in the usual manner by our factory or by an authorized repair facility.

— W. R. Thurston

[1]For a description of these instruments, see the March and April, 1952, issues of the *Experimenter*.

[2]E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

[3]Type 1555-A Sound-Survey Meter, $125; carrying case, $10.

[4]Type 1552-A Calibrator, $45; 400-cycle oscillator, $60 to $85; simple, rectifier-type voltmeter, $25 (available from meter manufacturers or supply houses).

THE BASIS FOR FIELD CHECKING SOUND-METER CALIBRATION

1. SOUND-LEVEL METER

A sound-level meter includes a microphone, an amplifier, an attenuator, and an indicating meter. The stability of these four elements determines the over-all calibration stability of the instrument, so it is important that they hold their initial, factory-calibrated characteristics over long periods of time in field use. Since the attenuators and rectifier-type indicating meters used give very little difficulty at their present stage of development, this discussion deals mainly with the amplifier and the microphone.

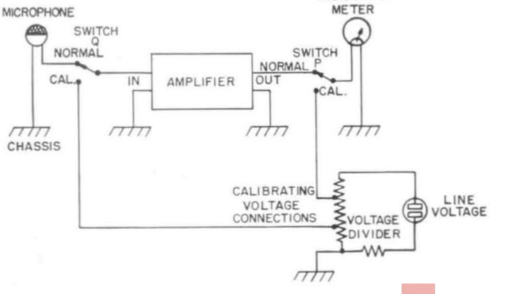
Checking the Amplifier

Amplifier gain can change slightly as a result of normal drift in tube characteristics and changes in *A* and *B* battery voltages. There is also the possibility of a sudden, abnormal change in some component that could affect gain and cause incorrect readings. To prevent errors of this type, all General Radio Sound-Level Meters, old and new, have built-in calibration circuits for checking amplifier gain, plus an adjustment for correcting slight, normal variations from the proper value.

The calibration circuit consists of a resistance-type voltage divider and two switches, as shown in Figure 1. For checking the calibration, the voltage divider is connected to a convenient power line having a nominal voltage corresponding to the value on the instrument nameplate (115 or 230 volts), and this divider provides two calibrating voltages, the ratio of which is factory set to equal the proper value of amplifier gain. Operation of switch *P* applies the larger calibrating voltage directly to the indicating meter. Operation of switch *Q* applies the smaller calibrating voltage to the amplifier input, so that this voltage is multiplied by the gain of the amplifier and then applied to the indicating meter. Clearly, if the second meter reading equals the first, the amplifier gain equals the voltage-divider attenuation and is therefore at its correct value.[1] It should be noted that the absolute value of the equal readings obtained, which depends on line voltage, is not important, and that the long-term accuracy of this check depends only on the stability of resistors.

[1]For power frequencies other than 60 cycles, the second reading should be less than the first by specific amounts at specific frequencies, owing to the frequency characteristic of the amplifier.

Figure 1. Schematic diagram of the calibration circuits in the sound-level meter.



Checking the Microphone

The microphone can be checked by applying to it a known sound-pressure level. This is conveniently done with the sound-level calibrator,[2] a small, enclosed, highly stable speaker, which fits over the sound-level-meter microphone. This device provides an over-all check on the calibration, from microphone to meter. Since the amplifier can be checked independently, and since the attenuator and indicating meter seldom cause any difficulty, an over-all check is, in effect, a check of the microphone.

When 2 volts at 400 cycles, obtained from an oscillator and measured by a voltmeter, are applied to the terminals of the Type 1552-A Sound-Level Calibrator, the sound-pressure level is 85 decibels for the Type 9898 Crystal Microphone supplied with Type 759 and Type 1551-A Sound-Level Meters. The level produced has other values for other types of microphones, because of differences in cavity shapes and sizes and acoustic leakage between the calibrator housing and the microphone. A reading that differs from the proper value by a small amount, say less than 2 decibels, probably indicates a mere shift in microphone sensitivity and can properly be compensated by resetting the amplifier gain adjustment. If the difference is large, however, it may be the result of more serious microphone trouble, in which case a factory check and possible repair are suggested in accordance with our regular repair procedure.

[2]E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

This calibration check is a single-frequency measurement and does not explicitly indicate what the performance will be at other frequencies. The single-frequency test, however, will show whether or not the microphone has been damaged, and, in the absence of damage, it is reasonable to assume that the frequency characteristic has not materially changed.

2. SOUND-SURVEY METER

The sound-survey meter includes the same four basic elements as does the sound-level meter, but it is relatively inexpensive and highly miniaturized. Giving the greatest possible portability and convenience of use, the sound-survey meter is intended for the many less exacting applications requiring sound-level measurements and does not include amplifier calibrating circuits. The over-all calibration is readily checked by the use of the sound-level calibrator.

— W. R. Thurston

MORE USEFUL VARIAC CIRCUITS

The note entitled "A Useful Variac Circuit," appearing in our August issue, has evoked letters from readers who have used similar but still more useful circuits. Mr. G. M. Brown, Electronics Engineer for the New York Central System, offers the circuit of Figure 1, which includes a manual switch to give control over a 245-volt range. A similar circuit was submitted by Mr. G. D. Stark of Allis-Chalmers Manufacturing Company.

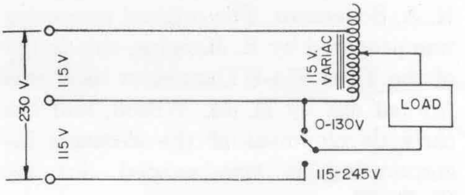
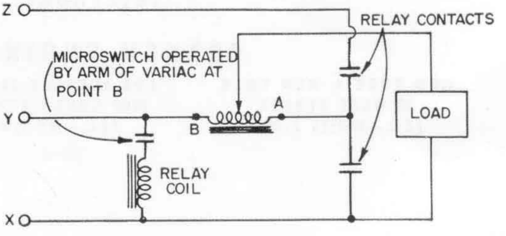


Figure 1.

Mr. J. H. Odenheimer, Plant Engineer, Switchgear Department, General Electric Company, Philadelphia, states that he has used the circuit published in the *Experimenter* and also the modification shown in Figure 2, which gives full control at double the rating. He describes this circuit as follows:

"This modification involves a limit switch (or micro switch) accurately mounted on the Variac in such a way that the switch is operated by the Variac arm just as it reaches the extreme end of its travel in the increasing (clockwise) voltage direction. This limit switch actuates a latching-type transfer relay which transfers end *A* of the Variac winding from the *X* side of power to the *Z* side. In this position, counterclockwise rotation of the Variac continues to increase the output voltage up to 230 V. Voltage is reduced in a similar manner by going through two rotations of the Variac. The interrupting duty on the contacts of the transfer relay is not severe since the transfer is made with only magnetizing current flowing through the Variac winding."

Figure 2.



The arrangement of Figure 3 was submitted by Mr. E. M. Shores of General Laboratory Associates, Ltd. Here, the switching from one range to the other is performed by push buttons and a relay.

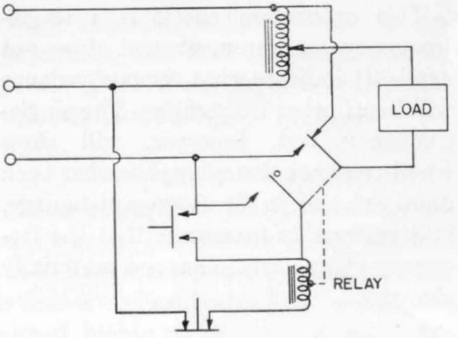


Figure 3.

MISCELLANY

CREDITS — The new additions to the 874 series of coaxial elements announced in last month's issue were developed by R. A. Soderman. The original connector was proposed by E. Karplus, the design of the TYPE 874-B Connector itself was worked out by H. M. Wilson, and the early development of the elements incorporating it was carried out by W. R. Thurston.

THIRD CONFERENCE ON HIGH-FREQUENCY MEASUREMENTS — Under the joint sponsorship of AIEE, IRE, and the National Bureau of Standards, the Third Conference on High-Frequency Measurements will be held in Washington on January 14-16, 1953. This conference will follow the pattern of similar meetings held in 1949 and 1951 and will be devoted exclusively to the techniques and problems of high-frequency measurements, with particular emphasis on new developments.

RECENT VISITORS to the General Radio plant and laboratories include: Mr. Carl Schrader of the firm Radiometer, Copenhagen, Denmark; Mr. John C. Lagercrantz, exclusive representative for General Radio products in Sweden; Mr. Morisaburo Katakami, Engineer, Yokogawa Electric Works, Ltd., and Mr. Hanzo Omi, Chief Engineer, Fuji Communications, App Mfg. Co., Ltd., Tokyo, Japan; Mr. Georg Kurlbaum, General Manager, Metrawatt, A. G., Nuremberg, Germany; and Mr. Magan Pancholy, Senior Scientific Officer, National Physical Laboratory of India, New Delhi.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW COMPARISON BRIDGE FOR THE RAPID TESTING OF COMPONENTS

Also

IN THIS ISSUE

● **THE TREND** toward complexity and more exacting specifications in electronic equipment has been accompanied by a tremendous increase in the quantities produced, and, as a result, more and more precise components — resistors, capacitors, and inductors — are being used. In general, it is necessary to measure these components before assembly, and this measurement, particularly for 1 per cent or 0.25 per cent components, is usually made on a "laboratory-type" bridge. As the number of components to be measured increases, the need grows for an accurate and simple, general-purpose bridge for production testing, and, to fill this need, the Type 1604-A Comparison Bridge, shown in Figure 1, has been developed.

In making the most precise bridge measurements, a substitution method is used. In one form of the general method, the bridge is "standardized" with a known standard impedance that has nearly the same value as the unknown to be measured. In this case, the bridge is used primarily to

Figure 1. Panel view of the Type 1604-A Comparison Bridge.

measure the small difference between the standard and the unknown, and the effect of the bridge errors approaches zero as the difference between the standard and unknown approaches zero. The Type 1604-A Comparison Bridge is standardized in our calibrating laboratory at a 1000-ohm impedance level, and the true bridge zero is hand calibrated. At this point the bridge errors are effectively zero. By restricting the impedance difference range to ±5 per cent or ±20 per cent, bridge errors stay small and we obtain "laboratory accuracy" on a "production-type" bridge. This bridge is sufficiently accurate so that this standardization at 1000 ohms will hold good from a few ohms to a few megohms. However, the standardization can be checked at any time by simply interchanging the standard and unknown and noting that the bridge reading reverses.

The Type 1604-A Comparison Bridge is completely self-contained, consisting of a cathode-ray tube visual detector, bridge, and an oscillator which operates at 1 kc or 5 kc. It can be used to measure both impedance difference, $\triangle Z$, and dissipation-factor difference, $\triangle D$ (or storage-factor difference, $\triangle Q$), for resistors, capacitors, and inductors. By providing a $\triangle D$ or $\triangle Q$ balance as well as a $\triangle Z$ balance, a thorough check of components can be made. For example, if capacitors are being checked, not only will those that are outside capacitance limits be rejected, but also those with abnormal dissipation factors.

Ease of operation has been stressed, so that measurements can be made rapidly. Two dials, conveniently located, are rotated to balance the bridge, or, for more rapid operation, the dials can be used to calibrate the cathode-ray tube, which then indicates the unbalance instantly. At balance, the dials indicate directly the D or Q difference and the impedance difference between the standard and unknown, expressed as a percentage of the standard impedance. Ordinarily, the bridge is used to check components from current production or purchase lots against a similar component independently measured and used as a standard. However, if a laboratory standard is used, rather than a sample component, the instrument becomes a precision laboratory comparison bridge.

This bridge can be used for the direct comparison of components over a very wide impedance range, from approximately 2Ω to 20 Meg Ω. The basic accuracy of the bridge is ±0.1 per cent, decreasing somewhat at the extremes of its impedance range. Two impedance-difference ranges are provided: one, 0 to ±5 per cent for accurate comparison of components close to each other in value; the other, 0 to ±20 per cent, of somewhat lesser accuracy, for checking to the common tolerances of ±10 per cent and ±20 per cent. The impedance-difference dial is shown in Figure 2.

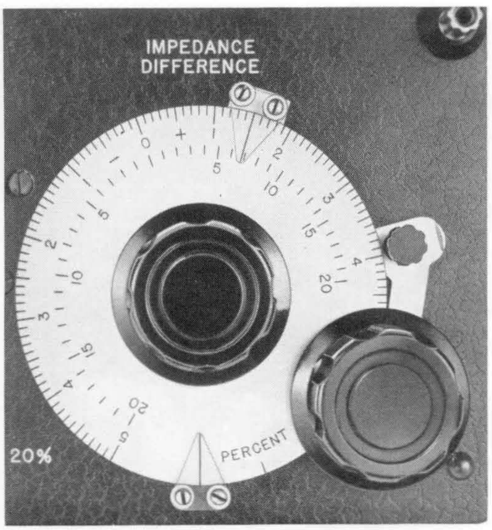


Figure 2. Close-up of the impedance-difference dial.

CIRCUIT

A simplified schematic diagram of the bridge is shown in Figure 3. A precision linear potentiometer in the ratio arms is used to provide a ±20 per cent impedance-difference range. This potentiometer is shunted to provide a ±5 per cent range for more precise comparisons. A differential capacitor across the ratio arms provides the dissipation-factor balance. The point at which the bridge is grounded can be switched, so that measurements can be made with the unknown either grounded or ungrounded.

The detector is a three-stage, high-gain, non-linear amplifier. The highly non-linear amplifier permits the bridge to be balanced without continual resetting of the gain control. Balance is indicated on a cathode-ray tube. The detector time constant has been made less than 100 microseconds, so that, for practical purposes, the error voltage appears instantly.

The oscillator is a conventional R-C phase-shift oscillator which is coupled to the bridge through a shielded bridge transformer and a cathode follower. The cathode follower eliminates any reaction of the bridge back on the oscillator, while the special transformer shielding prevents any unbalanced voltages from the oscillator from affecting the bridge balance. A differential capacitor is used to balance the capacitance from the transformer shield to the ends of the shielded winding.

RANGE OF MEASUREMENT

The upper and lower limits of impedance measurement with this type of bridge are determined by three main factors: residual impedances, pickup from stray fields, and sensitivity.

At high impedances these limiting conditions are:

1. Parallel capacitance and resistance across the measuring terminals of the bridge.
2. Electrostatic pickup because of the high impedance level.
3. Decreased sensitivity because of the load of the detector on the bridge.

In the Type 1604-A Comparison Bridge, the input impedance of the detector is high, and sufficient sensitivity is provided so that detector loading does not limit performance. Thorough shielding within the bridge effectively eliminates errors from electrostatic pickup. However, in strong electrostatic fields, pickup external to the bridge is possible. Generally, this external pickup will be at 60~ and can easily be eliminated by inserting a filter, such as the Type 1231-P5 Adjustable Filter, at the filter jack on the panel. Parallel resistance across the measuring terminals is extremely high and is completely negligible. Shunt capacitance, however, does limit the high impedance range. When the unknown is grounded, the shunt capacitance, C_s, includes the capacitance of some shielding within the bridge and is approximately 40 $\mu\mu$f. With the unknown ungrounded, however, the shield capacitance is placed across the bridge ratio arms and C_s is less than 1$\mu\mu$f. Since the bridge measures the parallel com-

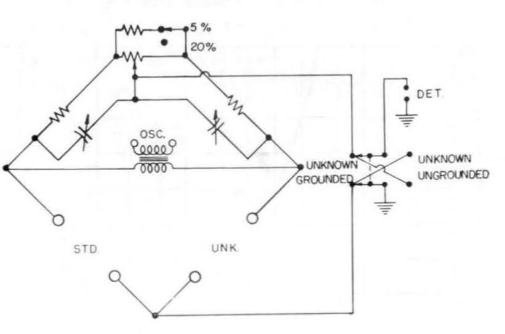


Figure 3. Elementary circuit of the bridge.

bination of the impedance to be measured and the stray capacitance across the measuring terminals, this extremely low value of shunt capacitance is necessary for high impedance measurements. An analysis of the bridge balance equations shows that the error at high impedance is:

For capacitance $1 + \frac{C_s}{C_x}$ (See Figure 4.)

For inductance $1 - \omega^2 L_x C_s$ (See Fig. 5.)

For resistance $1 + \omega^2 R_n^{\,2} C_s^{\,2}$ (See Fig. 6.)

For a maximum error of 0.1 per cent on the 5 per cent range, these expressions must equal $1 \pm .02$ since

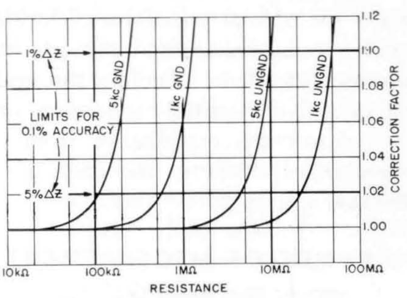
$(1 \pm .02) \times 5$ per cent $= (5.0 \pm 0.1)$ per cent. This corresponds to a high impedance limit of 50 $\mu\mu$f, 500h, 20 Meg Ω at 1 kc.

At low impedances the range is limited by

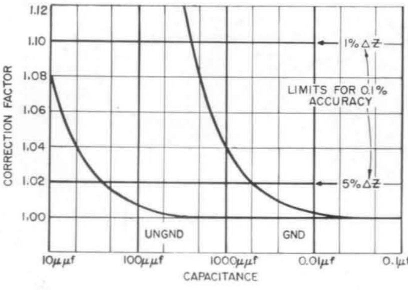
1. Series inductance and resistance in the standard and unknown bridge arms.
2. Electromagnetic pickup because of the high currents at low impedance.
3. Decreased sensitivity because of the load of the bridge on the oscillator.

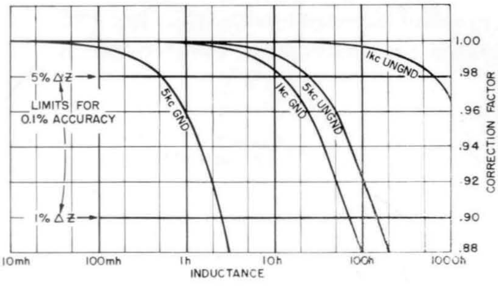
To maintain constant sensitivity, the voltage across the bridge must be held constant as the impedance level decreases. This requires supplying more power to the bridge. Since this power is limited, the low impedance range is limited. Sufficient sensitivity to balance the bridge to within 0.1 per cent can be maintained to an impedance level of about 2 ohms. At this low impedance level, large currents (about ½ ampere) flow through the bridge arms. The resultant electromagnetic pickup between bridge elements causes an error in the bridge balance. This error has been kept small by careful placement of leads. Series inductance and resistance has been kept small by using heavy bus-bar wiring in the bridge arms. The effect of this series impedance is further reduced by keeping the bridge wiring as symmetrical as practicable. The low impedance limit of the bridge is shown in Figures 7, 8, and 9. For a maximum error of 0.1 per cent on the 5 per cent range, the bridge may be used to 2 Ω, 0.5 mh, 30 μf at 1 kc.

The impedance difference and dissipation-factor-difference ranges are limited by the effect of cross-coupling terms in the bridge balance equations. As the impedance difference increases, it causes an error in the measured dissipation-factor difference. Similarly, as the dissipation-factor difference increases, it causes an error in the measured impedance difference. Because of these cross-



(Below) Figure 4, (below right) Figure 5, (right) Figure 6.





coupling terms, we have limited the dissipation-factor-difference range to ± 0.02 where the maximum error in the impedance-difference measurement becomes 0.1 per cent. Instead of limiting the impedance-difference range to about 2 per cent, we have accepted a slightly larger error in the dissipation-factor-difference measurement.

USES

Because the bridge is calibrated in per-cent deviation, the job of sorting components to a given tolerance is greatly simplified. The high accuracy of the measurement, plus the fact that $\triangle D$ or $\triangle Q$ as well as $\triangle Z$ is measured, insures an accurate production check of components.

The Type 1604-A Comparison Bridge can be used in either of two ways. First, an unknown can be compared against a suitable standard by rotation of the balance dials of the bridge until the cathode-ray tube indicator shows a balance. The difference between the standard and unknown is then read from these dials directly. Second, the cathode-ray tube can be calibrated at the desired sorting tolerance and used to give an instantaneous "go, no-go" indication. The first method provides better accuracy, while the second permits really high-speed sorting.

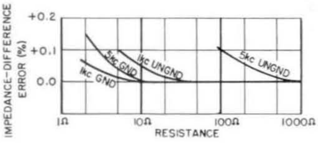
For production testing, the standard need not be a precision laboratory standard, but can be a component, similar to those being checked, which has been independently measured. A standard precisely at the desired value is not necessary, since an offset zero is provided within the bridge. Thus if ± 2 per cent resistors are being sorted and the available standard is off ± 1.3 per cent, the bridge zero can be offset exactly 1.3 per cent and the resistors checked as if a perfect standard were available.

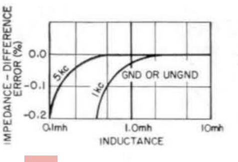
To select or to check matched pairs of components, no standard is necessary. The pair are simply connected to the standard and unknown terminals, the difference between the components being indicated directly by the bridge.

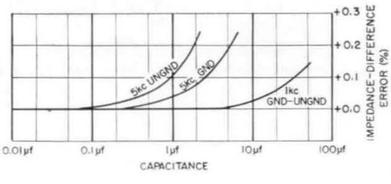
The Type 1604-A Comparison Bridge is ideal for measuring center-tapped windings to be sure that the tap is correctly centered. Similarly, two windings on the same core can be compared for unity turns ratio. In these cases the measurement is made with identical currents through the two windings.

An example of a production problem at the General Radio Company shows the type of application for which the Type 1604-A Comparison Bridge has realized large economies in test time. A large air-core inductor, accurate to 0.25 per cent, is used in the frequency-discriminator section of one of our frequency monitors. Variations in wire from spool to spool, winding tension, and other variables make it impossible to hold the inductance to a 0.25 per cent tolerance by simply counting turns as the coil is wound. As a result, these coils are wound with a few per cent more inductance than necessary and then "peeled down." The coils were formerly measured on a Type 667 Inductance Bridge to within 0.1 per cent, turns removed, and the measurement repeated. This process would then be repeated as many times as necessary to bring the coil within limits. The operation was

(Left) Figure 7, (center) Figure 8, (right) Figure 9.







time-consuming with a precision laboratory bridge. The job has now been speeded up considerably by a direct comparison with a standard coil. The coil to be adjusted is placed on a turntable which makes contact to one end of the winding. This contact is brought through a slip ring to the grounded unknown terminal on the Type 1604-A Comparison Bridge. The other end of the winding is connected directly to the bridge. The bridge instantly indicates that the coil is outside limits. Turns are now removed while the coil is still connected to the bridge. As each turn is removed, the cathode-ray tube instantly indicates the approach to balance. When the balance condition is reached, the wire from the coil is cut and soldered to its terminal. In this way the coils are easily and quickly made identical within 0.1 per cent.

The comparison bridge has also proved very helpful in the measurement of very small capacitors. In this application the bridge is not used to compare two small capacitors, but actually measures one capacitor directly. We had several lots of 1, 2, and 3 $\mu\mu$f condensers to be checked. These were quickly checked by placing 100 $\mu\mu$f capacitors at the standard and unknown terminals of the bridge and setting the offset zero so that the bridge indicates zero. By placing the small capacitors to be measured in parallel with the 100 $\mu\mu$f capacitor at the unknown terminals, the small capacitor can be measured by re-balancing the bridge. The ± 5 per cent $\triangle Z$ scale now reads ± 5 per cent of 100 $\mu\mu$f or ± 5 $\mu\mu$f full scale. Each division of the scale (see Figure 2) represents 0.1 $\mu\mu$f. By suitable choice of the shunting capacitor, the full-scale reading can be made any value. At ± 1 $\mu\mu$f or less, full scale, stray capacitances become very important and must be considered if accurate measurements are to be made.

The comparison bridge is ideal for checking ganged potentiometers that must track each other within a given tolerance. A point-by-point measurement of a pair of non-linear potentiometers on a laboratory bridge can be very time-consuming and costly. By calibrating the cathode-ray tube at the desired tolerance and connecting the potentiometers to be checked to the standard and unknown terminals of the bridge, the potentiometers can be checked in a second or two by simply rotating them through their range while watching the cathode-ray tube. Failure to track within the specified limits at any point is instantly indicated.

Similarly, ganged condensers for oscillators or filters can be checked in a small fraction of the time required by a point-by-point measurement. Furthermore, the condensers are not checked at a few discrete points but continuously over their whole range.

These are but a few of the possible applications for which the Type 1604-A Comparison Bridge can be used, but they serve to illustrate its versatility. It combines ease of operation with sufficient accuracy for component testing in nearly all production jobs.

— M. C. Holtje

SPECIFICATIONS

Deviation Range: For impedance, $\pm 5\%$ and $\pm 20\%$, selected by a panel switch. For dissipation factor, $\pm .015$ at 1 kc, $\pm .075$ at 5 kc.

Impedance Range and Accuracy: Impedances between 2 Ω and 20 MΩ can be compared. For the 5% deviation range the basic accuracy is $\pm 0.1\%$, but at extreme values of impedance the accuracy is somewhat poorer. The range for resistors, capacitors, and inductors for which the $\pm 0.1\%$ accuracy applies is given in the table:

	R	*C*
1 kc	2 Ω – 20 MΩ	30 μf – 50 μμf
5 kc	4 Ω – 2 MΩ	2 μf – 50 μμf

L

500 μh – 250 h
200 μh – 10 h

These ranges apply when comparing components whose dissipation factor differences do not exceed .02. On the 20% deviation range the accuracy is 0.5% over the same impedance ranges.

Dissipation Factor Accuracy: The accuracy of measurement of differences of dissipation factor at 1 kc is ±(.0005+2% of the impedance difference), and at 5 kc, ±(.0025+2% of the impedance difference).

Frequency: Frequencies of 1 kc and 5 kc are provided, selected by panel switch. The frequency is within ±3% of the nominal value.

Grounding: Two ground positions are provided, one of which grounds the junction of the standard and unknown impedances. With this connection the total impedances between the high terminals and ground are compared. In the other connection the junction of the ratio arms of the bridge is grounded, leaving both terminals of the standard and unknown ungrounded. With this connection the direct impedance between terminals of a component is measured, and terminal impedances to ground, within certain limits, will not affect the bridge balance.

Voltage Applied to Unknown: Approximately one volt, for impedances above 500Ω. For lower values of impedance the voltage is decreased, corresponding to a source impedance of the order of 100 Ω.

Zero Adjustment: An adjustable index mark is provided with locking means so that the zero can be offset to correspond to the deviation of the standard component from the desired nominal value.

Accessories Supplied: Line-Connector cord.

Accessories Required: For general purpose, use adjustable calibrated standards such as the Type 1432 Decade Resistors, Type 219 Decade Capacitors, and Type 1490 Decade Inductors. Fixed standards such as the Type 509 Standard Capacitors, Type 1481 Inductors, and Type 500 Resistors may also be used whenever appropriate values are available.

For production tests, the standard is often a component of the type to be tested, that has been measured independently or otherwise selected.

Mounting: Welded aluminum cabinet.

Dimensions: (Width) 12 inches, (height) 14¼ inches, (depth) 10 inches.

Net Weight: 22½ pounds.

Type		*Code Word*	*Price*
1604-A	**Comparison Bridge**	FATTY	**$335.00**

Licensed under patents of the Radio Corporation of America.

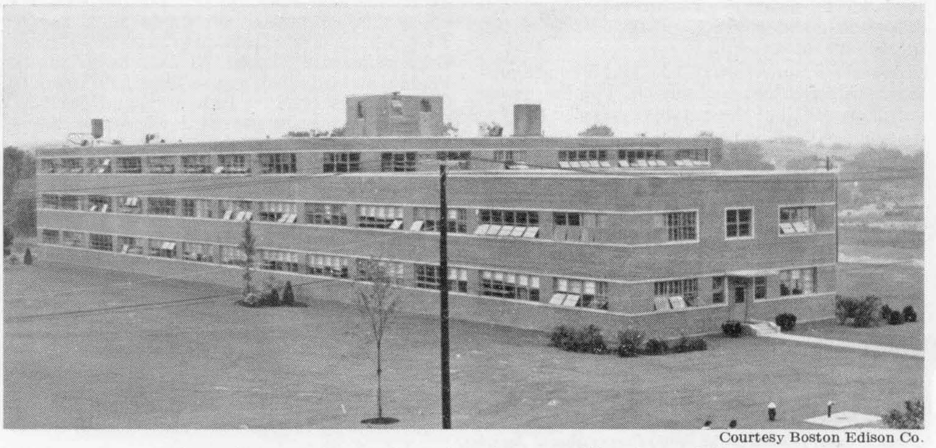
NEW BRANCH PLANT

Recognizing that the demands of another emergency could not be met by the then-available facilities, the General Radio Company, in 1948, began to explore the possibilities for expansion. Any further major expansion was, for many reasons, all but impossible at the present location in Cambridge. After a careful search, accompanied by an analysis of the residence locations of its employees, availability of suitable local manpower pools, accessibility, including nearness to highway and railway facilities, a building site was chosen in a country district in West Concord, Massachusetts, some eighteen miles west of Cambridge. About eighty acres of land were purchased to allow for adequate open space around any buildings that might eventually be constructed.

The Korean trouble brought the need sooner than could have been expected. In the late spring of 1950 the rearmament program began in earnest, and General Radio was called upon to make its contribution of precision test equipment and components at a rate far beyond the capacity of its plant. In fact, the ascending curve of new defense orders matched closely the curve caused by the rearmament program beginning in 1940.

Plans for construction on the new site were drawn up immediately, but before construction could be started a certification of the necessity of this new facility was required. This was issued by the National Production Authority upon the request of the Department of Defense, and building was started in July, 1951. The first production operations began in April, 1952.

This modern, fireproof plant has seventy-two thousand square feet of floor space and is devoted to manufacturing, with auxiliary shipping, receiving, and stockroom facilities.



Courtesy Boston Edison Co.

View of the new General Radio branch plant at West Concord, Mass.

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