The GENERAL RADIO
EXPERIMENTER

ELECTRICAL MEASUREMENTS
TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

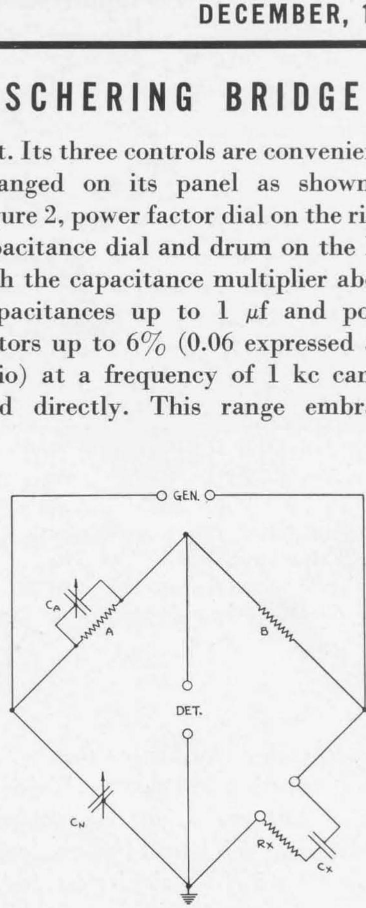
VOL. XI No. 7 DECEMBER, 1936

AN AUDIO-FREQUENCY SCHERING BRIDGE

● **THE PRESENT TREND** in a-c bridges, as in other measuring instruments, is toward direct-reading dials, which, in conjunction with decade multiplying switches, extend this direct-reading feature over a very wide range. It is equally desirable that the electrical quantities thus measured be those truly characteristic of the unknown impedance.

The two most important characteristics of any condenser are its capacitance and power factor. For any solid dielectric condenser these quantities remain practically constant over a wide frequency range. The Schering bridge circuit, Figure 1, in which the resistance balance of the bridge is obtained by connecting a variable air condenser across the ratio arm opposite the unknown capacitance, is well adapted for the direct measurement of power factor, for this air condenser can be calibrated to read directly in power factor at any one frequency.

The Type 716-A Capacitance Bridge makes use of the Schering bridge circuit. Its three controls are conveniently arranged on its panel as shown in Figure 2, power factor dial on the right, capacitance dial and drum on the left, with the capacitance multiplier above. Capacitances up to 1 μf and power factors up to 6% (0.06 expressed as a ratio) at a frequency of 1 kc can be read directly. This range embraces



$$D_X = R_X \omega C_X = A \omega C_A$$

Figure 1. Schematic diagram of a conventional Schering bridge

ALSO IN THIS ISSUE

A Redesign of Type 200-B Variac

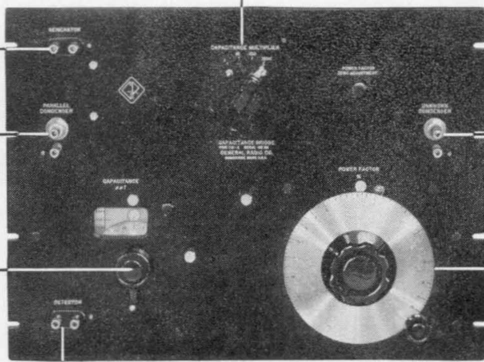


FIGURE 2. Panel view of the TYPE 716-A Capacitance Bridge showing principal controls

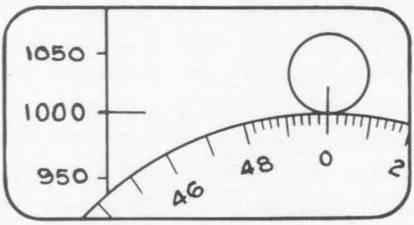
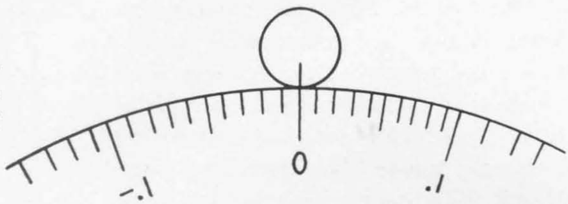


FIGURE 2a (left). This is a full-size drawing of the precision-condenser scale. The smallest division is 0.2 μμf and 0.04 μμf can be estimated

FIGURE 2b (right). The power-factor scale is also shown here full size. The open scale allows a power factor of 0.002% to be estimated



most of the capacitances met with in communication and electrical engineering; all but the largest sizes of paper condensers, mica condensers, cables, slabs of solid dielectric, liquids in large cells, and ground capacitances of generators and transformers.

This bridge can also be used for all the various substitution methods. The direct-reading controls greatly simplify not only the two balancings of the bridge but the calculations as well. The direct-reading range of the standard condenser, a TYPE 722-D Precision Condenser with only the large 1000-μμf scale, embraces most air condensers, small mica condensers, ceramic and all other kinds of insulators, slabs of all types of solid dielectrics and liquids such as insulating oils in oil cells.

Capacitances greater than 1000 μμf and up to 1 μf may be compared by direct substitution. The standard condenser in the bridge, together with its multiplier, may act merely as a balancing arm, or may also take up the difference between the unknown and the external standard. The bridge is thus eminently suited to the inter-comparison of sets of standards and to production testing, in which the differences between the standard and the production units in both capacitance and power factor may be seen to fall inside or outside predetermined limits.

The resistance balance of the bridge may also be made by means of an external resistor, a TYPE 602 Decade Resistance Box, connected in parallel with one of the capacitance arms. Placed across the standard condenser (see Figure 3) the bridge becomes direct reading in parallel resistance and capacitance. This covers all ordinary measurements of the resistance of electrolytes. Greater accuracy may be obtained by using a substitution method.

When an external precision condenser is used, as was always the case with the older TYPE 216 Capacity Bridge, the resistance balance may be made with a series resistance. Tenth-ohm steps in this resistance give a finer adjustment than it is possible to read on the power factor dial, except at frequencies below 200 cycles. In this manner the power factor balance may be made to 0.0001% (0.000001 expressed as a ratio).

The various features of the TYPE 716-A Capacitance Bridge, which make possible the wide range of uses just catalogued, are shown pictorially in Figure 2 and Figure 4. The most prominent of these are the open scales of the TYPE 722-D Precision Condenser used as the standard of capacitance and of the TYPE 539-TA Air Condenser used for measuring power factor. FIGURE 2a shows that 1 $\mu\mu$f, for which the precision condenser is direct reading, covers a space of 0.2 inches or 5 divisions. The limit of backlash and linearity of the worm are about 0.1 $\mu\mu$f, which is ½ division, and 0.04 $\mu\mu$f has some significance. FIGURE 2b shows that around the zero of the power factor scale the smallest division is 0.01% (0.0001), so that 0.002% (0.00002) may be estimated. The negative portion of the scale is introduced so that in substitution measurements, in which the unknown condenser is connected across the internal standard, the power factor balance can be obtained without introducing extra loss in the balancing condenser connected across the UNKNOWN CONDENSER terminals. The scale of the power-factor dial is approximately logarithmic from 0.1% up and extends to 6%.

The capacitance range of the bridge is extended to 1 μf by using four different ratio arms. The switching needed to control these ratio arms is shown schematically in Figure 5. Associated with each ratio arm in the B arm is a mica condenser of such size that the resistance-capacitance product is approximately constant. The exact equalizing of these products is carried out in

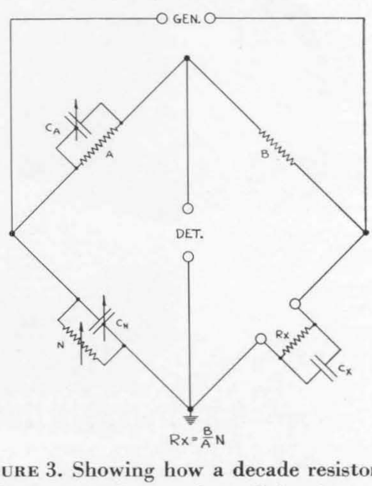


FIGURE 3. Showing how a decade resistor can be connected to read parallel resistance

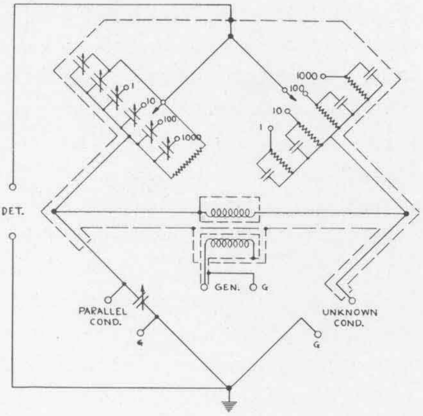


FIGURE 5. Complete circuit diagram of the TYPE 716-A Capacitance Bridge

the A arm by means of four variable air condensers. A fifth air condenser, whose control on the panel is marked POWER FACTOR ZERO ADJUSTMENT, is provided to compensate for the temperature coefficient of the terminal capacitance of the input transformer.

The success of a direct-reading bridge depends on so arranging the various component parts that no extra capacitances are placed across the capacitance arms. To attain this end both ratio arms with their adjusting condensers, the power factor condenser, and the input transformer are mounted on insulated sub-panels and completely enclosed by dust covers. This shield is connected to the junction of the ratio arms so that all terminal capacitances of these parts are placed across these arms and balanced out by the initial adjustment of the power factor condensers. The shielding is extended to the high UNKNOWN CONDENSER terminal and through the panel with the result that the capacitance across these terminals is not greater than 1 $\mu\mu$f. The input transformer is doubly shielded and the direct admittance of the generator winding to the insulated shield is kept very small. Its effect on the reading of the power factor dial is small and comparable to the change in power factor of the standard condenser with setting.

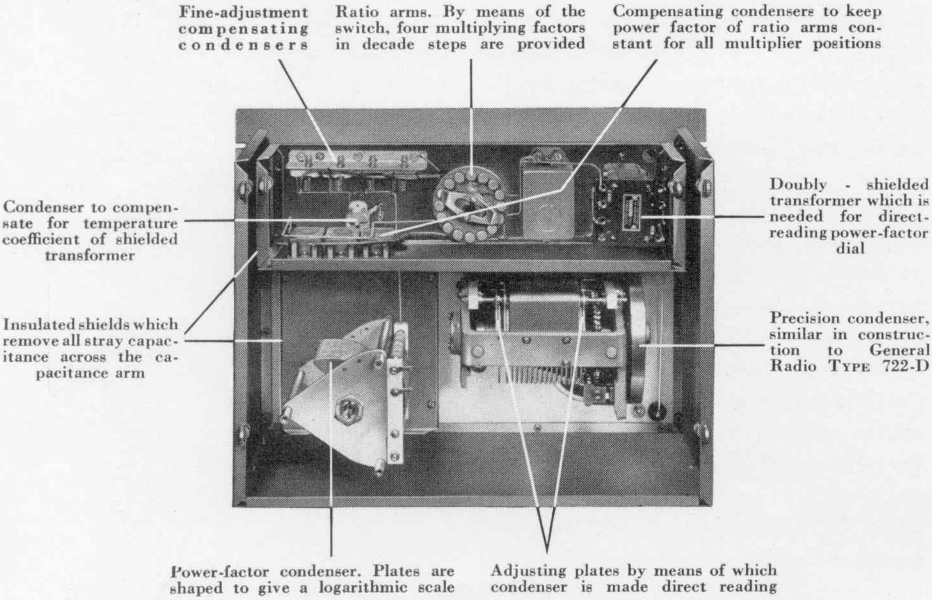


FIGURE 4. Rear view of the bridge with outer and inner shields removed, identifying the principal components

As a result of these design features the accuracy of the direct readings of the bridge at a frequency of 1 kc over the capacitance range of 100 $\mu\mu$f to 1 μf is for capacitance $\pm 0.2\%$ or ± 2 $\mu\mu$f times the MULTIPLIER setting, and for power factor ± 0.0005 or $\pm 2\%$ of the dial reading. For substitution measurements the accuracy in the power factor readings is improved to ± 0.00005 or $\pm 2\%$ for the change in power factor observed. Two condensers can be compared to an accuracy of ± 0.2 $\mu\mu$f or $\pm 0.02\%$.

While the bridge is designed to be used at a frequency of 1 kilocycle, it may be used over the whole audio-frequency range from 60 cycles to 10 kc. Since the readings of the power factor dial are proportional to frequency, its range is restricted at the low frequencies and extended at the high frequencies.

The input and output terminals are marked GENERATOR and DETECTOR for the connections which place the input voltage across the ratio arms and give maximum sensitivity under most conditions. The voltage thus placed across the bridge is limited to 100 volts. By interchanging generator and detector connections, a maximum of 700 volts, the safe voltage of the standard condenser, can be applied across the DETECTOR terminals for equal ratio arms and for 1 kc.

Being provided with a dust cover, this bridge may be mounted on a panel rack with its oscillator and amplifier as shown in Figure 6. The TYPE 508-A Oscillator and TYPES 714-A or 814-A Amplifier are available for this use. This assembly conserves bench space and is particularly desirable for permanent installations and production testing. The bridge is also available mounted in a walnut cabinet and may be used with its panel either vertical or horizontal, as is found most convenient.

— R. F. FIELD

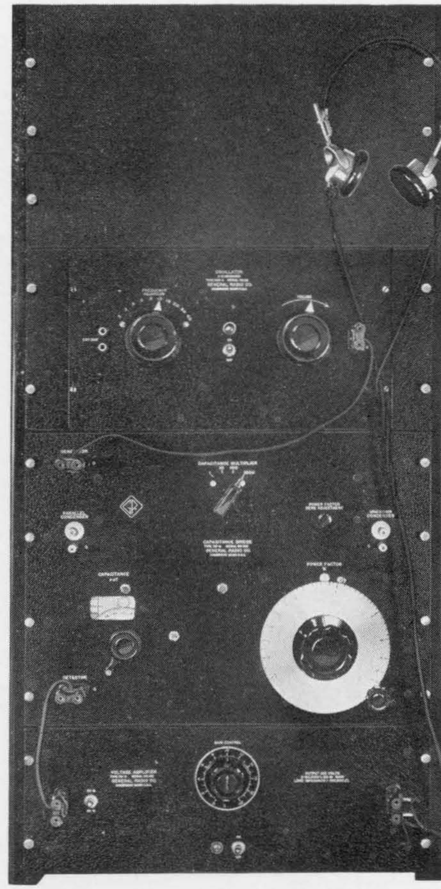


FIGURE 6. Showing how the bridge can be mounted in a relay rack with TYPE 508-A Oscillator and TYPE 714-A Amplifier

Complete specifications for TYPE 716-A Capacitance Bridge are given on pages 79 and 80 of Catalog J. Prices are as follows:

Type	*Mounting*	*Code Word*	*Price*
716-AR	Relay Rack	BONUS	$335.00
716-AM	Cabinet	BOSOM	360.00