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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

THE CONVENIENT MEASUREMENT OF *C, R,* AND *L*

THE important considerations in the large majority of bridge measurements made in the average experimental laboratory are the ease and speed of making the readings, and the ability to measure any values of resistance, inductance, or capacitance, as they may exist in any piece of equipment. A completely satisfactory bridge should immediately indicate the answer to such questions as the following:

Is the maximum inductance of this variable inductor at least 5 mh, its minimum inductance 130 μh, and its direct-current resistance less than 4 Ω?[1]

Has this choke coil at least 20 h inductance and an energy factor Q of at least 20?

Has this tuning condenser a maximum capacitance of 250 μμf and a 20 to 1 range?

Has this filter condenser at least 4 μf capacitance and a power factor of only 0.5%?

Is the resistance of this rheostat 200 kΩ?

Is the zero resistance of this decade-resistance box only 5 mΩ?

The TYPE 650-A Impedance Bridge will furnish the answers to all these questions and many others. It will measure direct-current resistance over 9 decades from 1 mΩ to 1 MΩ, inductance over 8 decades from 1 μh to 100 h, with an energy factor $(Q = \frac{\omega L}{R})$ up to 1000, capacitance over 8 decades from 1 μμf to 100 μf, with a dissipation factor $(D = R\omega C)$ up to unity.[2]

These results are read directly from dials having approximately logarithmic scales similar to those used on slide rules. The position of the decimal point and the proper electrical unit are indicated by the positions of two selector switches. Thus the CRL multiplier switch in Figure 1 points to a combined multiplying factor and electrical unit of 1 μf so that the indicated ca-

[1] These are the standard abbreviations of the Institute of Radio Engineers. Note that 1 mΩ is 0.001 ohm and that 1 MΩ is 1,000,000 ohms.

[2] The fact that this bridge is capable of measuring a condenser with large energy losses makes it necessary to distinguish between its dissipation factor $\frac{R}{X}$ and power factor $\frac{R}{Z}$. The two are equivalent when the losses are low. Since the bridge measures $R\omega C$ directly, the term dissipation factor has been used, even though the two terms are, for most condensers, synonymous.

pacitance as shown on the CRL dial is 2.67 μf, because the D-Q multiplier switch has been set on C for the measurement of capacitance. It also shows that the DQ dial is to be read for dissipation factor D with a multiplying factor of 0.1 yielding 0.26.

If the condenser had a smaller dissipation factor, this D-Q multiplier switch would have been set for the D dial with a multiplying factor of 0.01. Thus the D dial, as shown in Figure 1, indicates a dissipation factor of 0.0196 or a power factor of 1.96%.

For the measurement of pure resistance the D-Q multiplier switch would be set at R so that the CRL dial indicates a resistance of 2.67 Ω.

For the measurement of inductance the D-Q multiplier switch would be set at L and the CRL dial indicates 2.67 mh. Using the DQ dial the multiplier is 1 and the energy factor Q as shown in Figure 1 is 2.6. Had the coil under measurement been a large iron-core choke coil, the CRL multiplier switch might have been set at the 10 h point, thus indicating 26.7 h. Then the D-Q multiplier switch would have been set to indicate the Q dial with a multiplier of 100 and an energy factor Q of 41 as read on the Q dial.

The ease of balancing the bridge depends on the use of the logarithmically tapered rheostats and the two multiplier switches. To illustrate this, take first the measurement of direct-current resistance.

With the unknown resistor connected to the R terminals, the D-Q multiplier switch is set at R, the GENERATOR switch at DC, and the DETECTOR switch at SHUNTED GALV. The galvanometer immediately deflects, indicating by the direction of its deflection which way the CRL multiplier switch should be turned to obtain approximate balance. The CRL dial is then turned for exact balance, having thrown the DETECTOR switch to the GALV. position.

Because the calibration of the CRL dial extends to 0, the bridge can be balanced for a number of different settings of the CRL multiplier switch. This is very helpful in ascertaining the approximate value of a resistor. Obviously greatest accuracy of reading is obtained when the balance point on the CRL dial is within the main decade which occupies three-quarters of its scale length.

An inductor or condenser is measured by connecting it to the CL terminals. The GENERATOR switch is set at 1 KC. and the DETECTOR switch at EXT, head telephones being connected to the EXTERNAL DETECTOR terminals. The D-Q multiplier switch is set on L or C as the case demands, pointing to the DQ dial. The CRL dial is swept rapidly over its range to indicate the direction of balance. The CRL multiplier switch is then moved in the direction indicated and balance obtained on the CRL dial. The DQ dial is then turned for balance. From its setting the desirability of using the D dial or the necessity of using the Q dial will be indicated.

The reactance standards are mica condensers having all the excellent characteristics of the TYPE 505 Condensers described in the *Experimenter* for January.

The bridge circuit used for measuring condensers is the regular capacitance bridge having pure resistances for its ratio arms. Maxwell's bridge is used for inductors, whose energy factors Q are less than 10. Above this value Hay's bridge is used. The interdependence of the two balances of these last two

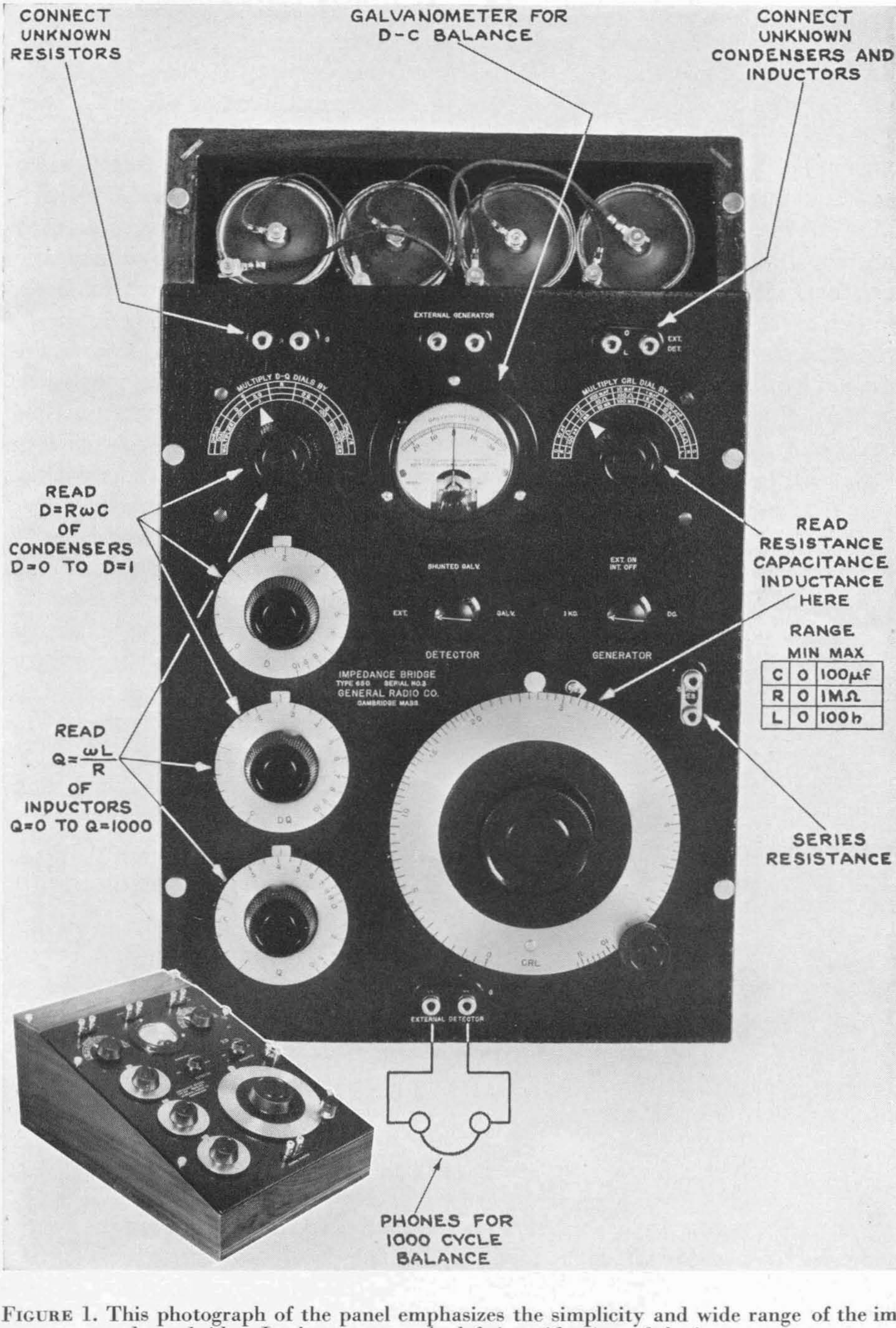

FIGURE 1. This photograph of the panel emphasizes the simplicity and wide range of the impedance bridge. In the corner at the left is a side view of the instrument

bridge circuits cannot, of course, be prevented, but the use of the logarithmic rheostats for balancing makes it very easy to follow the drift of the balance points.

The accuracy of calibration of the CRL dial is 1% over its main decade. It may be set to 0.2% or a single wire for most settings of the CRL switch. The accuracy of readings for resistance and capacitance is 1%, for inductances 2%, for the middle decades. The accuracy falls off at small values because the smallest measurable quantities are 1 mΩ, 1 μμf, and 1 μh, respectively. Zero readings are approximately 10 mΩ, 4 μμf, and 0.1 μh, respectively. The accuracy falls off at the large values, becoming 5% for resistance and capacitance and 10% for inductance. The accuracy of calibration of the DQ dials is 10%. The accuracy of readings for dissipation factor and energy factor is either 20% or 0.005, whichever is the larger.

The power for the bridge is drawn from four No. 6 dry cells mounted at the back of the cabinet. The liberal size of these batteries assures a very long life. External batteries of higher voltage may be used to increase the sensitivity of the bridge for the measurement of the highest resistances. The internal batteries operate a microphone hummer for the production of the 1-kc current. The capacitance of this hummer to ground is small and has been allowed for in the bridge calibration.

An external generator may be used, though its capacitance to ground may introduce considerable error. Subject to this limitation, the frequency may be varied over a wide range from a few cycles to 10 kc. The reading of the CRL dial is independent of frequency. The readings of the D and DQ dials must be multiplied by the ratio of the frequency used to 1 kc to give the correct values of dissipation and energy factors, while the reading of the Q dial must be divided by this ratio. For frequencies other than 1 kc the ranges of the DQ dials are altered so that they will no longer overlap. Additional resistance may be inserted by opening the SERIES RES. terminals. The TYPE 526 Rheostats, described on page 7, are quite satisfactory for this use.

—ROBERT F. FIELD

SPECIFICATIONS

Dimensions: Panel, (width) 12 x (depth) 16 inches. Entire instrument, (width) 12 x (depth) 23 x 9 inches, over-all.

Net Weight: 22 pounds. Batteries, 8¼ pounds additional.

Code Word: BEAST.

Price: $175.00, without batteries.

THE SKELETON-TYPE IMPEDANCE BRIDGE

THERE are many individual bridge measurements for which the wide range of the TYPE 650-A Impedance Bridge is unnecessary, while its ease and speed of making readings are essential. Examples of these uses are the following:

Limit bridges for resistance, inductance, and capacitance, whose ranges may be changed easily, though not in-