INSTRUCTION MANUAL
UNIVERSAL BRIDGE
TYPE UB1

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OPERATING INSTRUCTIONS

General operating principles.

The bridge circuit consists of two parallel connected branches, each containing two series connected impedances. The two common points of the branches are connected to an ac or dc source according to the measurement required.

The common points of the two impedances in each branch are connected to an indicator which indicates any voltage difference between the two points. By suitably adjusting the branch impedances, the indicator reading may be reduced to zero. If three of the impedances are now known, the fourth unknown impedance may be calculated.

Resistance measurement using dc.

Refer to circuit diagram Fig. 1

Link terminals "L", "C", and "0.1 µF" by connecting straps supplied.

Connect a suitable dc supply, either a battery or a low voltage supply to "Gen." terminals with "Gen" switch in left "off" position. The voltage required depends on the sensitivity of the zero indicator, but for most resistance values about 2 to 6 volts are suitable. Due to the balancing principle used the exact value does not matter. If accurate measurement of high resistance values is required, up to 100 volts may be applied limited by the permissible dissipation of the bridge resistors.

Connect a centre-zero microammeter or galvanometer to the "Det." terminals. The sensitivity of the indicator will determine the accuracy to which the balance may be set.

Using e.g. a centre-zero microammeter of ±50 µA sensitivity with 1 kΩ resistance and 4 volt supply, balance setting to at least 0.2% may be obtained over the range from about 5 Ω to 10 kΩ.

Set "P" & "Q" dials to 10^2 and the lower 4 dials to max. values. Leave "R" terminals open and switch "Gen." to 10^4. Check that meter gives right-hand deflection, else reverse "Gen." or "Det." leads.

The bridge is now ready for use.

Measurement

When measuring a resistor of totally unknown value, a systematic procedure is recommended.

Set "Gen." switch anti-clockwise to "Off". Connect unknown resistor to "R". Set "P" to 10^2. Set "Q" to 10^4. Set all lower dials to max. readings. Switch "Gen." to 10^4. Note right-hand meter deflection. Switch "Q" successively to lower values (down to 1) until meter deflection changes to left-hand.

If deflection direction does not change even in "1" position of "Q" switch "P" to 10^3 or 10^4 until deflection changes. This applies for resistor values above 110 kΩ. For low resistor values (below 11 Ω) and at the initial settings of "P" & "Q" (100 Ω & 10 kΩ respectively) left-hand meter deflection will result. In this case switch "P" to "10" and proceed as follows.

Adjust lower dials starting at the x100 dial, reduce each decade in turn to the position just before deflection changes direction.

When adjusting the lower decades, it may be necessary to increase sensitivity by switching "Gen." to 10^2 or 0 in order to obtain a visible deflection. For very accurate balance or at high or low resistance values where sensitivity is low, switch "Gen." repeatedly between "Off" and "0" positions and adjust for zero change or deflection. In this way a very sensitive balance indication is obtained.

Calculation of resistance value.

When balance is obtained (minimum or zero deflection on meter) the unknown resistance in ohms is found as the reading on the four lower dials multiplied by the ratio P/Q or

$$R = R_H \cdot \frac{P}{Q} \, \Omega$$

where R = unknown resistance

R_H = reading on lower dials

P = reading on "P" dial

Q = reading on "Q" dial

Note 1. When reading the four lower dials note that each dial reads up to 10 digits. Thus a reading of 10 on one dial corresponds to one digit on the next higher value dial and must be added to that dial reading e.g. if the two highest dials read 3 and 10 this corresponds to 4 and 0.

Note 2. When measuring low resistance values (below 10 Ω) the resistance of the bridge wiring must be taken into account. This may be done after measuring the unknown resistor by making a measurement with shorted "R" terminals and subtracting this result from the first result.

ac measurements

General information.

For measurement of capacitance, inductance etc. an ac power supply and zero detector are required. The UB1 may be used for measurements at full accuracy up to about 2 to 5 kHz depending on impedance value. Normally 1 kHz is employed except for iron-cored inductors and large electrolytic capacitors which are usually measured at power frequencies.

A normal audio oscillator is quite suitable as a power supply - preferably with floating output or battery operated. For measurements at power frequencies a low output power transformer is suitable.

For use as a zero detector the cheapest and simplest device is a headphone set. This provides an excellent detector when used in reasonably quiet locations due to its high sensitivity and good discrimination against unwanted signals such as hum and noise. It has the disadvantage that when operating far from balance it may be difficult to adjust the bridge due to the insensitivity of the ear to small variations in loudness. It is also only useful for frequencies in the range of about 400 Hz to 2 kHz due to the ear's frequency characteristics. For most purposes a high impedance headphone (1000 to 4000 Ohms) provides the best sensitivity.

A sensitive millivoltmeter or oscilloscope may also be used if available. Depending on the available supply voltage, and accuracy required the detector should provide a visible indication for inputs from 10 μV to 1 mV. When using a meter as detector any hum, noise or harmonics present may make it difficult to obtain an exact balance. In this case a tunable selective voltmeter is preferable.

When looking at the circuit diagrams it will be seen that the generator and the detector may not both be earthed simultaneously. If both are mains-operated they will be coupled mutually by the power transformer capacitances. It is then especially at high impedance measurements necessary to isolate the generator by a transformer, if the generator output is not floating.

The Danbridge oscillator and detector unit type OG1 is eminently suitable for use with the UB1, as it combines the functions of oscillator and detector and is completely self-contained.

The operation of balancing the bridge on ac to obtain a null on the detector is somewhat more complicated than with dc measurements, as normally two separate decades must be adjusted correctly for exact balance. These adjustments interact somewhat so that alternate adjustments are necessary to obtain exact balance. This interaction increases with increasing losses (lower Q) in the test object, and at very low Q values (1 or lower) it may become impossible to obtain balance by alternately adjusting to minimum. In this case the recommended procedure is for each balance adjustment to turn the respective dial one or two steps beyond the minimum position.

With some practice it is possible to find the balance setting with only a few alternate adjustments. If the value of the test object is quite unknown, the ratio resistor P or Q should be set to 10 kΩ and all dials on the decade resistor to x10. The auxiliary balance resistor B should be set for minimum loss (maximum Q), i.e. when connected in series with the standard capacitor C_N (Figs. 2 and 4), set B to zero, or when connected in parallel to C_N (Fig. 3), set B to maximum.

Switch P or Q successively to lower values until minimum detector output is obtained.

Adjust decade resistor for minimum.

Adjust B for minimum.

Repeat adjustments of decade resistor and B until zero detector output is obtained. If necessary, increase oscillator output or detector sensitivity to get better resolution.

In the following paragraphs the different types of measurement are described in detail.

<u>C-measurement</u> is best made with a ratio bridge on the Wiens series resistance principle as shown in Fig. 2. The terminals "L" are shorted and the ratio resistor P is set to 0. An external balance resistor B as e.g. a 4-Decade Resistance Box (our type DR4 with 10 x 0.1 - 10 x 1000 Ohms) or a wire-wound potentiometer is connected to the terminals "R". A zero-indicator and a low frequency oscillator are connected as shown. In order to supply the highest possible power to the bridge the output impedance of the generator is matched approximately to the input impedance between the terminals "Gen.". This varies with the adjustment of the bridge so that the matching is easiest done by trial.

The unknown capacity C is connected to the terminals "C" and the bridge is balanced by means of R_H and B. If C has smaller losses than the built-in standard condenser C_N, the dissipation factor of which is 2×10^{-4} the bridge may not be balanced completely with B but then it is possible to increase the losses of C by inserting a suitable resistor in series with C which may be done with the ratio resistor P. The measuring range of the bridge is from 1 pF - 111 μF. By measurement of capacities from 0 - 11000 pF $Q = 10^4$ ohms is used and in this case 0.1 ohm on R_H corresponds to 1 pF. Usually a measuring frequency of 800 or 1600 Hz is used, corresponding to an angular frequency of 5×10^3 or 10^4 respectively which simplifies evt. calculations.

L-measurement with Maxwell Bridge (Fig.3).

This is a frequency-independent product bridge, its greatest advantage being the use of a capacitance C_N as a standard. The capacitance and effective series resistance are unchanged over a much greater frequency range than would be the case with an inductance standard and in addition the disturbing influence of electromagnetic fields is eliminated. The terminals "C" and "R" are shorted and Q set to 0, detector and generator are connected as mentioned at C-measurement. A separate balance resistor B is connected to the terminals "0.1 μF". B may e.g. be a wirewound potentiometer of about 100 kohms eventual in series with a similar one of about 5 kohms for fine adjustment or a decade resistance (our type DR4 with 10 x 10 - 10 x 10.000 ohms). A measuring frequency of 400 - 1000 Hz usually 800 Hz is used - this should be suitable for most objects. The unknown inductance L is connected to the terminals "L" by twisted leads so that the field of L is sufficiently removed from the iron case.
The bridge is balanced with R_H and B, P is chosen so that a suitable value for R_H results. The formula gives the value of L in Henry with C measured in Farad, the value of C_N in this case is 10^{-7} Farad. The measuring range of the bridge is about 0.1 mH - 1.11 Hy. When measuring greater inductances shunt C_N with a corresponding greater condenser e.g. 0.9 or 9.9 μF and use a smaller value for B.

The effective resistance R_L of the inductance may easily be calculated, one of the conditions of balance being equality of the two time constants $\frac{L}{RL}$ and $B \cdot C_N$.

L-measurement with Hay bridge (Fig.4)

which also is a product bridge but differs from the Maxwell bridge in that the balancing resistance B is connected in series with C_N. This makes the bridge especially useful for measurement of iron cored inductors with superposed dc, as the dc source may easily be inserted in the generator circuit. If a condenser of about 1 μF is connected in series with the detector all the dc current will pass through P and L. The ac voltage for L may eventually be measured with a vacuum tube voltmeter. The bridge is frequency dependent and the formulas rather complicated, but in actual practice the denominator only seldom differs seriously from one so that the formula for L approximately acquires the same simple appearance as that used with the Maxwell bridge. The resistor P may in short periods (one or two minutes) dissipate up to 2 watts, max. continuous dissipation should not exceed 1 watt.

Measurement of effective resistance and frequency etc. are possible using a series-resonant bridge as shown in Fig. 5. To find the effective resistance R_L of a coil with inductance L tune L by means of a capacity C - in this way either a shunt or series resonant circuit results which may be tuned to resonance with the measuring frequency f. For the measurements a low frequency oscillator is used providing either a fixed or a variable frequency.

If a fixed frequency is used the capacity C must be continuously variable which is easiest obtained by a decade condenser (e.g. Danbridge types DK4A or DK4S) alternatively a decade capacitor with variable air-capacitor for fine adjustment (Danbridge types DK4AV or DK4SV). Fig. 5 shows as an example the series resonant connection which usually is preferable on account of the lower impedance level resulting. Ther terminals "L", "C", and "0.1 µF" are shorted. The measuring bridge is balanced by means of C and R_H and the series resonant resistance (impedance) R_L of the circuit of LC is simply expressed by R_H and the ratio between P and Q. The calculated value for R_L incorporates the loss in C but this as a rule will be so small compared to the effective resistance of the inductance L that it may be ignored.

By connecting C in parallel to L, the parallel resonant resistance of the LC circuit is found in a similar way. From this effective resistance R_L of L or the Q of the circuit may be calculated. If the values of L and C at resonance are known the measuring frequency f may also be found.

If a variable frequency is used the inductance L may in some cases be tuned to series resonance with the built-in standard condenser C_N of the measuring bridge by removing the shorting strap from the terminals "0.1 µF" and balancing the bridge by adjusting R_H and the frequency f. The effective resistance R_L of the circuit is then calculated at the resonant frequency f as previously described. The value of R_L at any other frequency may be found by connecting suitable capacity in series with L or in parallel to C_N.

Measurement of the turns ratio of transformers

may be performed by the method shown in Fig. 6 if they have a lamellated iron core. The primary and secondary winding of the transformer are connected to the terminals "C" and "R" while "L" and "0.1 µF" are shorted and P set to zero. Suitable frequencies will be 400 - 1000 Hz. The measuring bridge is balanced by means of R_H. If no balance results the leads to the primary winding are reversed. Sharpness of the balance adjustment depends on the coupling between windings - the best results obtaining with a very close coupling.

LIST OF COMPONENTS

Description	Part No.
Knob with dial "0 - 10"	38003
Knob with dial "0 - 10^4"	38004
Knob with dial "off - 10^4 - 10^2 - 10 - off"	38005
Screw terminal with nut	37680
Insulating washer	37681
Decade switch unmounted	49015
"P" - "Q" switch unmounted	49022
"Gen." switch unmounted	49021
Shorting strap	41100
End Casting	32003
Cabinet Cover Panel	37101

Decade Units complete (switch and resistors)

10 x 0.1 Ω	74100
10 x 1 Ω	88210
10 x 10 Ω	88211
10 x 100 Ω	88212
"P" or "Q" switch unit complete	88213
"Gen." switch unit complete	88214

Decade Resistors unmounted

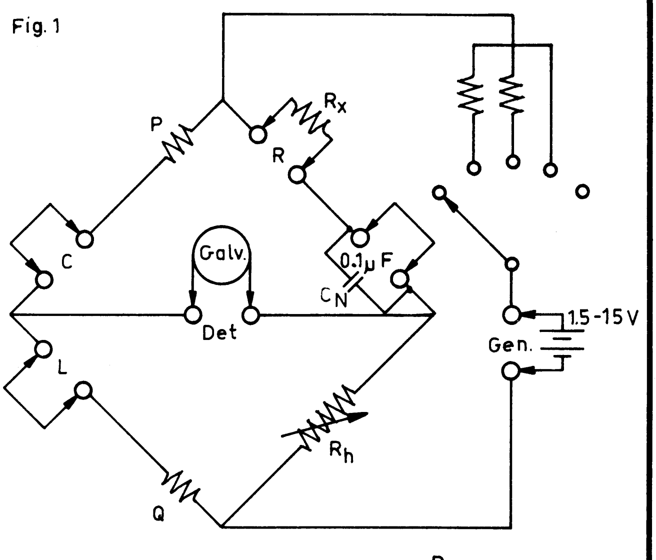
10 x 0.1 Ω resistor assempby without switch	85510
5 x 1 Ω	85516
5 x 10 Ω	85521
5 x 100 Ω	85526
1 + 10 + 10^2 + 10^4Ω for "P" - "Q" switch	85900
10^2 + 10^4Ω for "Gen." switch	85901

UNIVERSAL BRIDGE TYPE UB1

MEASURING CIRCUITS FOR R, L, C

RESISTANCE

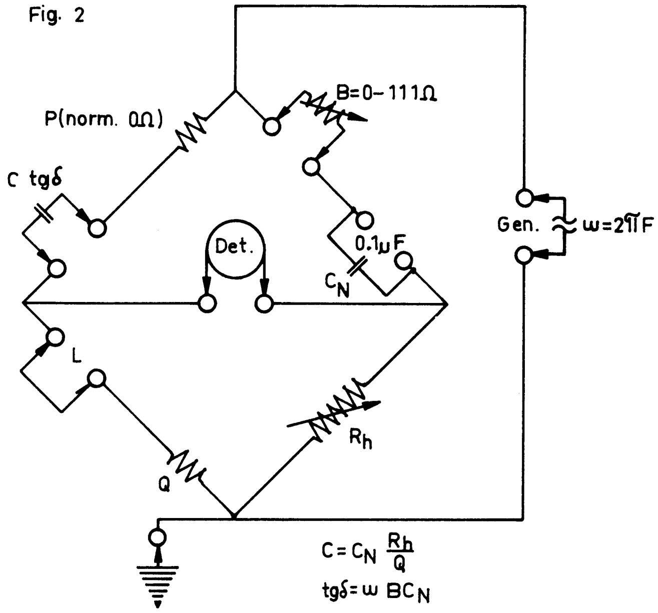
Fig. 1



$$R = R_h \frac{P}{Q}$$

CAPACITANCE

Fig. 2

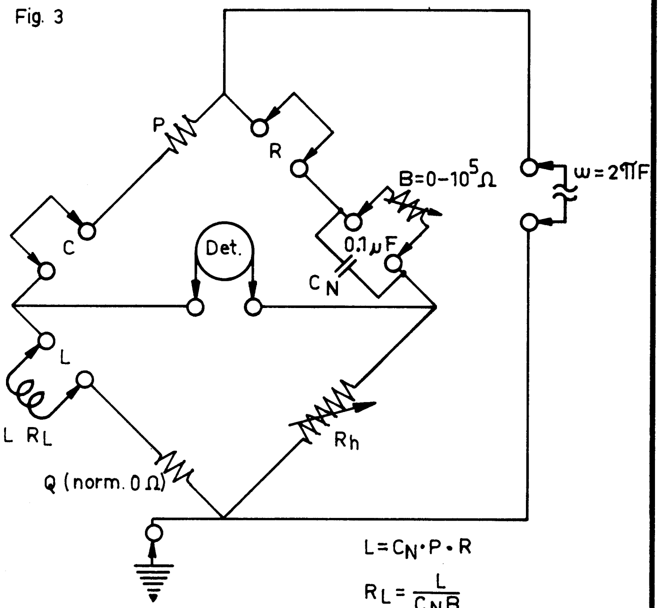


$$C = C_N \frac{R_h}{Q}$$

$$tg\delta = \omega B C_N$$

INDUCTANCE (Maxwell)

Fig. 3

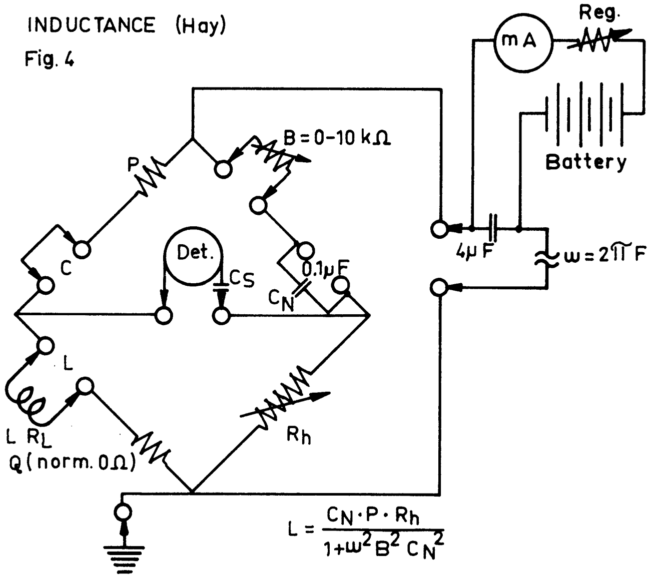


$$L = C_N \cdot P \cdot R$$

$$R_L = \frac{L}{C_N B}$$

INDUCTANCE (Hay)

Fig. 4

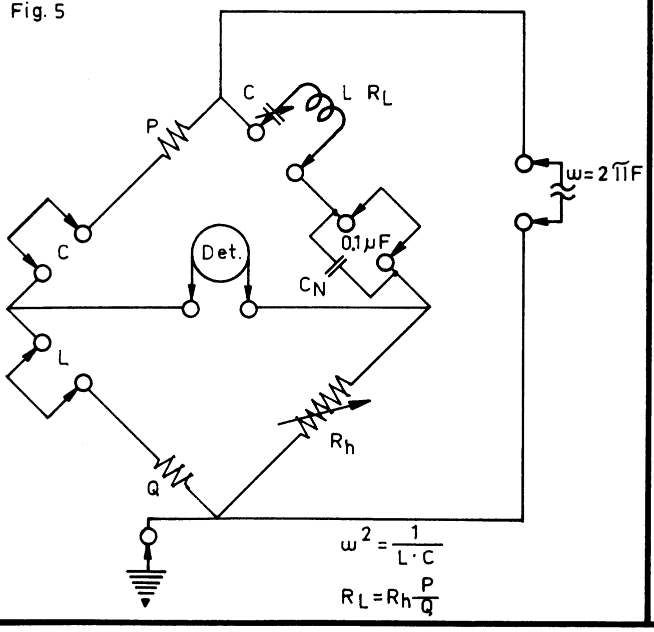


$$L = \frac{C_N \cdot P \cdot R_h}{1+\omega^2 B^2 C_N^2}$$

$$R_L = \frac{\omega^2 B C_N^2 P R_h}{1+\omega^2 B^2 C_N^2}$$

SERIES RESONANT BRIDGE

Fig. 5

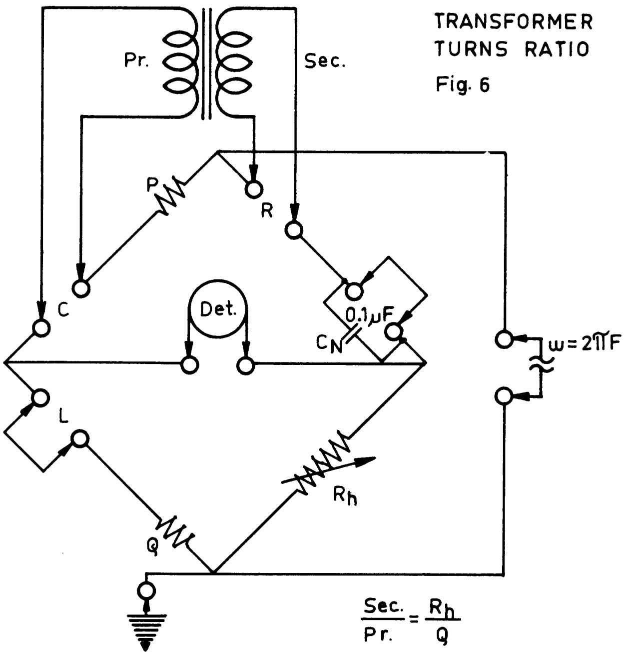


$$\omega^2 = \frac{1}{L \cdot C}$$

$$R_L = R_h \frac{P}{Q}$$

TRANSFORMER TURNS RATIO

Fig. 6



$$\frac{Sec.}{Pr.} = \frac{R_h}{Q}$$