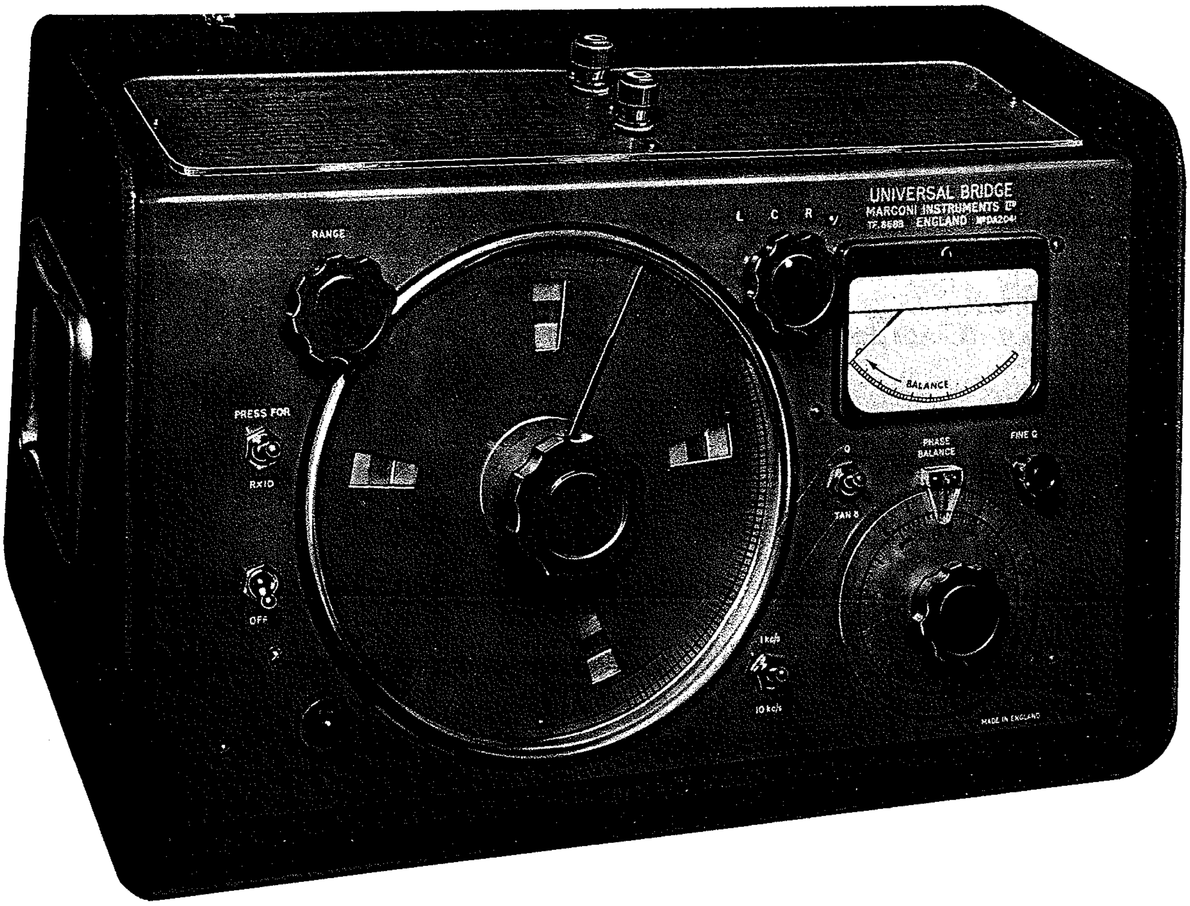

OPERATING
AND
MAINTENANCE
HANDBOOK
No. OM 868B

Universal Bridge

TYPE TF 868B

Serial Nos.	*JA 346/001 to JA 346/250* *JA 585/001 to JA 585/200* *JA 705/001 to JA 705/200*

MARCONI INSTRUMENTS LTD., ST. ALBANS, HERTS., ENGLAND

C.P. 5c 11/60

OM 868B
1*-10/60

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SCHEDULE OF PARTS SUPPLIED

1. One Universal Bridge Type TF 868B complete with valves, etc., as under:—

   Valves: One: 12AT7 (ECC81) Double Triode.
   Two: 12AX7 (ECC83) Double Triodes.
   One: 6X4 (EZ90) Full-Wave Rectifier.

   Lamps: One: 6·3-volt, 0·15-amp M.B.C. pilot lamp.

2. One Operating and Maintenance Handbook, No. OM 868B.

3. *When specially ordered,* D.C. Choke Adaptor Type TM 6113.

Data Summary

Range

INDUCTANCE:	1 μH to 100 henrys in 7 decades; at 1 and 10 kc/s.
CAPACITANCE:	1 μμF to 100 μF in 7 decades; at 1 and 10 kc/s.
RESISTANCE:	0·1 ohm to 100 MΩ in 8 decades; at d.c.
Q:	0·1 to 10 at 1 kc/s; 1 to 100 at 10 kc/s.
TAN δ:	0·001 to 0·1 at 1 kc/s; 0·01 to 1 at 10 kc/s.
	As Q = 1/tan δ, scales combined to give extended Q coverage up to 1,000 and tan δ up to 10.

Accuracy

INDUCTANCE:	At 1 kc/s: ± 1% ± 0·3 μH ± 0·1% of full scale. At 10 kc/s: ± 3%.
CAPACITANCE:	At 1 kc/s: ± 1% ± 0·3 μμF ± 0·1% of full scale. At 10 kc/s: ± 3%.
RESISTANCE:	± 1% ± 0·01 ohm ± 0·1% of full scale.
Q:	At 1 kc/s: ± 10% ± 0·2.
TAN δ:	At 1 kc/s and for capacitors of 50 μμF and over: ± 10% ± 0·002.
OSCILLATOR FREQUENCY:	± 2½%.

Bridge Energizing Source

L AND C:	Internal 1- and 10-kc/s oscillator; output level of the order of 350 mV.
R:	Internal d.c. supply; nominally 5 volts. When ×10 multiplier is used, voltage is increased to not more than 25 volts.

Power Supply: 200 to 250 volts, or 100 to 150 volts after adjusting internal links, 40 to 60 c/s, 25 watts approx. Models supplied ready for immediate 100- to 150-volt use if specified at time of ordering.

Dimensions and Weight:

Height	*Width*	*Depth*	*Weight*
11½ in	19½ in	10 in	26 lb
(30 cm)	(50 cm)	(26 cm)	(12 kg)

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1 Description

1.1 GENERAL

The Universal Bridge Type TF 868B is a direct-reading instrument which measures values of inductance from 1 μH to 100 henrys, capacitance from 1 μμF to 100 μF, and resistance from 0·1 ohm to 100 MΩ.

The instrument employs a single dial for the measurement of inductance, capacitance, and resistance values. Changing the setting of the LCR and RANGE selector switches automatically changes the dial calibration together with the bridge circuit conditions to suit the component under test.

For inductance and capacitance measurement the bridge is energized by an RC oscillator-amplifier that can be switched to 1 kc/s or 10 kc/s. The out-of-balance bridge voltage, after amplification and detection, is displayed by a moving-coil meter on the front panel. Measurement of inductance and capacitance is normally made at 1 kc/s; however, the use of 10 kc/s is an advantage, for example, when evaluating low-Q inductors.

When measuring resistance, a d.c. voltage is applied to the bridge. The out-of-balance bridge voltage is interrupted at twice the supply frequency by means of a vibrator (or chopper) before being applied to the amplifier-detector circuits. This system gives a high degree of sensitivity without the use of a high potential across the component.

A control, PHASE BALANCE, is provided for balancing out the resistive component when inductance and capacitance are being measured. This control has two scales which are calibrated in Q and tan δ respectively. The scale in use is determined by the setting of the Q-TAN δ switch. The Q scale is calibrated from 0·1 to 10, and the tan δ scale from 0·001 to 0·1.

Q is normally used for inductors and tan δ for capacitors.

Q, also known as magnification factor or storage factor, is the ratio of reactance to resistance in a series circuit, or susceptance to conductance in a parallel circuit.

Tan δ, also known as loss tangent, dissipation factor or D, is the reciprocal of Q.

$$Q = \frac{X}{R} = \frac{B}{G} \qquad \tan\delta = \frac{1}{Q} = \frac{R}{X} = \frac{G}{B}$$

Power factor, another term commonly used to express capacitor losses, is the ratio of resistance to impedance, or conductance to admittance, and differs from tan δ by less than 1 % when their values are less than 0.15.

For convenience, an instruction plate is fitted which interrelates values of Q and tan δ together with effective series and parallel values. The plate also gives summarized instructions for operating the Bridge.

The test terminals are located on top of the instrument; the flat top provides a useful insulated platform for supporting the component to be tested.

When measuring inductive components, the usefulness of the instrument may be extended by the use of the D.C. Choke Adaptor, described below.

1.2 OPTIONAL ACCESSORY

D.C. Choke Adaptor Type TM 6113

With this Adaptor fitted to the Bridge terminals, an inductor in the range 100 mH to 100 henrys can be measured at 1 kc/s while a d.c. current up to 200 mA is passed through it from an external source.

The essential function of the Adaptor is to isolate the Bridge from the d.c. supply, while at the same time preventing the external circuit from appearing as an undesirable load across the test terminals. When making a measurement, the introduced error is not likely to be greater than 3 %; this can be ignored, or eliminated by a simple substitution method.

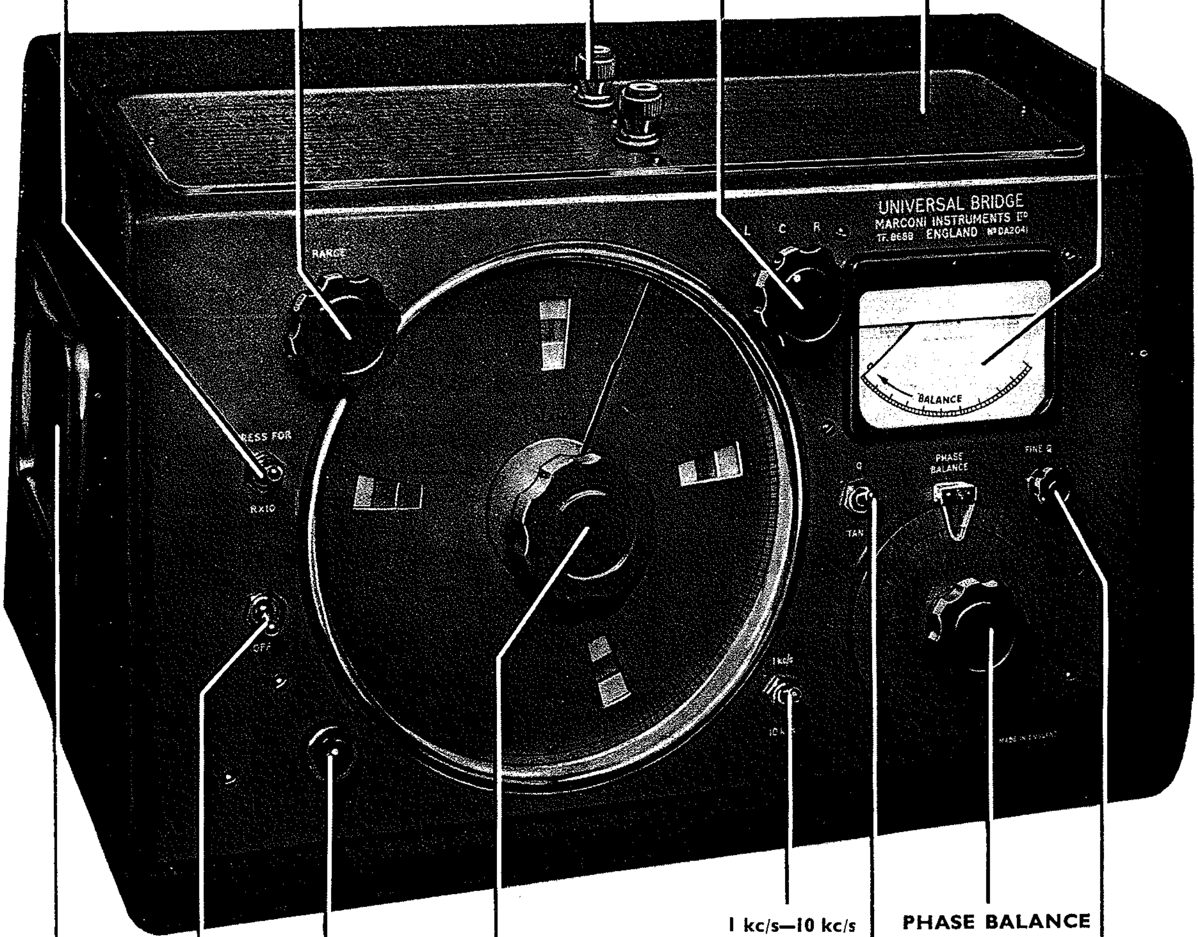


Fig. 2.1 *Universal Bridge controls.*

2 Operation

2.1 INSTALLATION

The Universal Bridge is normally dispatched with its valves in position and with its mains input circuit adjusted ready for immediate use on 240 volts, within the supply frequency range 40 to 60 c/s. If required, the instrument may be adjusted for operation from other supplies within the ranges 100 to 150, and 200 to 250 volts.

To check or alter the tappings on the mains transformer, refer to Section 4.2.

2.2 PRELIMINARIES

Having checked that the instrument is correctly adjusted to suit the particular supply voltage to which it is to be connected, proceed as follows:—

(1) If necessary, mechanically adjust the meter to indicate zero.

(2) Connect the mains lead to the supply socket. The lead is normally stowed in the left-hand case handle recess.

(3) Put the supply switch up; the red pilot light should now glow.

(4) Before proceeding further, allow a short warm-up period. Two minutes is sufficient for normal purposes.

2.3 USING THE BRIDGE

The following sections give detailed instructions for using the instrument. Concise reference information for use when making a measurement will be found on top of the instrument, and on the annotated photograph, Fig. 2.1.

2.3.1 Test Terminal Voltages

A feature of the TF 868B is the use of low bridge energizing voltages. Details of these voltages are included in the DATA SUMMARY, where it will be seen that there is little risk of damage to the test component, or need to switch off when handling the test terminals.

Curves showing variations in a.c. terminal voltage when measuring inductance and capacitance will be seen in Figs. 2.2 to 2.4. The employment of a.c. for capacitance measurements need not preclude the testing of electrolytic components.

2.3.2 Connecting the Component

Components to be measured are connected between the HIGH and LOW terminals. It is good practice always to keep the connecting leads as short as possible, thereby avoiding the risk of introducing unwanted capacitance and mains hum pick-up. Generally, the resistance of even long leads is very small, and, when compared with the value of the component under test, can usually be ignored.

Small components—which should not be held in the hand during measurement—can often be directly supported by the test terminals, or conveniently placed on the insulated top of the instrument.

When making measurements on physically large inductors and capacitors, the possibility of error due to the close proximity of the instrument case may be verified by raising the component above the Bridge platform on a suitable insulated support before repeating the measurement. Further checks may be made with the component orientated at different angles.

It is important when connecting reactive components that the significance of the HIGH and LOW terminals be observed. Large capacitance effects between the HIGH terminal and the case, or earth, must be avoided if the high accuracy of the Bridge is to be realized. Capacitors, for example, should have their inner electrode connected to the HIGH terminal, and the outer electrode and/or screening-can connected to the LOW terminal. The significance of the HIGH and LOW terminals is further explained in Section 2.5.2.

Although, as a general rule, it is not recommended that the Universal Bridge be used for *in situ* measurements, satisfactory results may be obtained provided that the user exercises care with respect to:—

(a) Stray capacitance,

(b) Mains hum pick-up,

(c) Earth connections to the component under test.

When making *in situ* measurements, the presence of an earth connection to either side of the component being tested would have the effect of short-circuiting the bridge. The method of making *in situ* measurements is further explained in Section 2.5.3.

2.3.3 Resistance Measurement

(1) Connect the component to the test terminals. (For notes on connections see Section 2.3.2.)

(2) Set the LCR switch to R.

(3) *If the approximate resistance is known*, set the RANGE switch so that the anticipated value is above the left-hand scale window (except for values less than 1 ohm), and carry on as in step (5).

If the resistance value is completely unknown, set the RANGE switch to the highest setting and continue as follows:—

(4) Turn the BALANCE pointer to the left-hand scale window and then turn it rapidly counter-clockwise, noting the meter indication.

If the meter reading increases, the correct range has been selected, that is, the resistance is greater than the value shown in the left-hand scale window.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat from (4); continue to do this until the meter reading increases. If it still decreases when the bottom range is reached, then the resistance value is less than 1 ohm.

(5) Starting from the left-hand scale window, rotate the pointer clockwise (or counter-clockwise for values below 1 ohm) to obtain a minimum meter indication. A meter indication in the region of the first two scale divisions should be obtained before reading the resistance value from the BALANCE dial.

For values above 10 MΩ, operate the PRESS FOR R × 10 switch while searching for balance, and multiply the scale reading by 10.

2.3.4 Inductance Measurement

(1) Connect the component to the test terminals. (For notes on connections see Section 2.3.2.)

(2) Set the LCR switch to L, the PHASE BALANCE and FINE Q controls about mid-way, and the Q TAN δ switch to Q.

(3) Normally set the oscillator frequency to 1 kc/s, but use 10 kc/s when measuring low-inductance low-Q coils. (For further information on the choice of frequency see Section 2.4.)

(4) *If the approximate inductance is known*, set the RANGE switch so that the anticipated value is above the left-hand scale window (except for values less than 10 μH), and carry on as in step (6).

If the inductance value is completely unknown, set the RANGE switch to the highest setting and continue as follows:—

(5) Turn the BALANCE pointer to the left-hand scale window and then turn it rapidly counter-clockwise, noting the meter indication.

If the meter reading increases, the correct range has been selected, that is, the inductance is greater than the value shown in the left-hand scale window.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat from (5); continue to do this until the meter reading increases. If it still decreases when the bottom range is reached, then the resistance value is less than 10 μH.

(6) Starting from the left-hand scale window, rotate the BALANCE pointer clockwise (or counter-clockwise for values below 10 μH) to obtain a

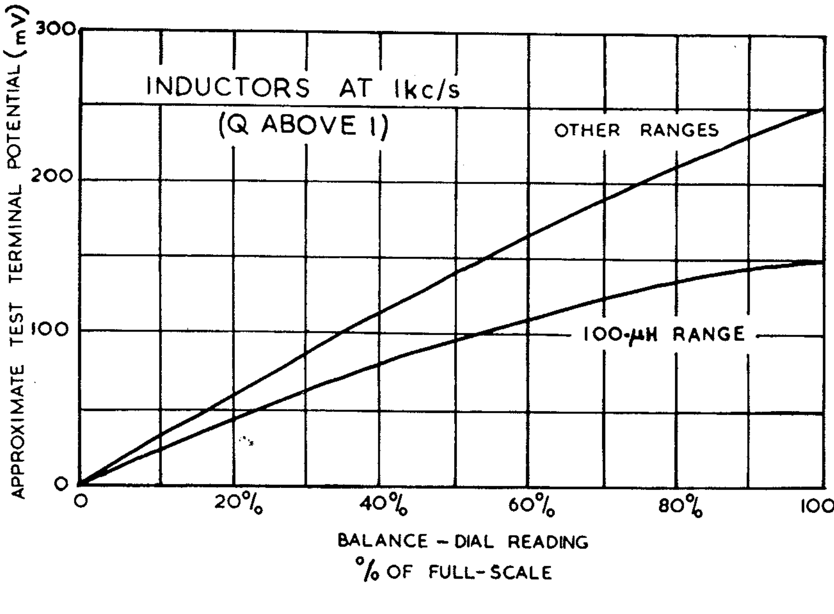
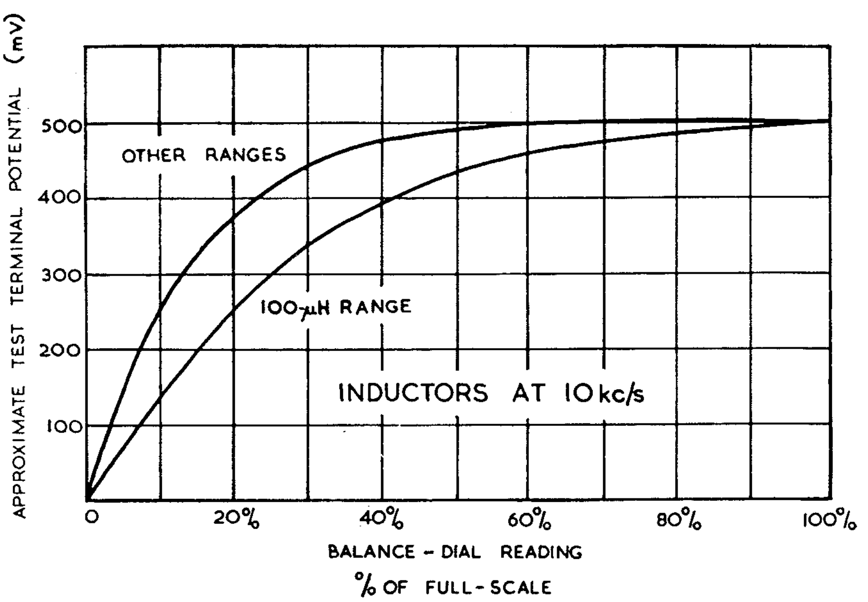


Fig. 2.2 Test Terminal Voltages at balance for Inductors.

Fig. 2.3 Test Terminal Voltages at balance for Inductors.



minimum meter indication. If no clear minimum is obtained—as may happen with low-Q r.f. coils—try again with the PHASE BALANCE control set to successively lower readings. This may necessitate re-setting the RANGE switch and therefore, if balance is still unobtainable, re-check the RANGE setting as in (4).

(7) For final balance adjust the main BALANCE and PHASE BALANCE controls alternately until a sharply-defined minimum reading is obtained in the region of the first two meter scale divisions.

When measuring low-Q coils, adjust the BALANCE and PHASE BALANCE controls carefully to obtain minimum meter deflection as described above, then adjust the BALANCE and FINE Q controls alternately to obtain a final balance point. As the value of Q increases, so the effect of the FINE Q control decreases. (For further details on low-Q and low-inductance measurements, see Sections 2.4.3 and 2.4.5.)

Note: *Correct balance should normally reduce the meter reading to approximately the second scale division. Spurious indications of balance may be experienced due to the short-circuiting effect of the bridge on the oscillator-amplifier output, when the* BALANCE *and* PHASE BALANCE *controls are turned towards minimum value and zero Q respectively.*

2.3.5 Using the D.C. Choke Adaptor (optional accessory)

The D.C. Choke Adaptor is specially designed for measurements on iron-cored inductors within the range 100 mH to 100 henrys, using the Bridge operating frequency of 1 kc/s. By means of the Adaptor—which fits on top of the instrument—d.c. up to 200 mA from an external source may be passed through the winding of the inductor while measurement is being made. To make such a measurement, proceed as follows:—

(1) Measure the inductor, using the Bridge normally as described in Section 2.3.4.

(2) Disconnect the test inductor and connect the Adaptor by means of the spade lugs. Earth the Adaptor terminal E to the nearest convenient place on the instrument case, and plug in the external d.c. supply, taking care to observe the polarity. Do not switch on the supply.

(3) Connect the test inductor to the HI and LO terminals of the Adaptor and adjust the Q TRIMMERS (switch and trimming capacitor) to restore the BALANCE meter reading to minimum. If it is necessary to further adjust the BALANCE control to restore balance, then the amount of adjustment necessary will represent the error introduced by the presence of the Adaptor and external circuit.

(4) Measurements involving core polarization may now be carried out by switching on the d.c. supply and adjusting the current flowing through the inductor winding to suit the test conditions.

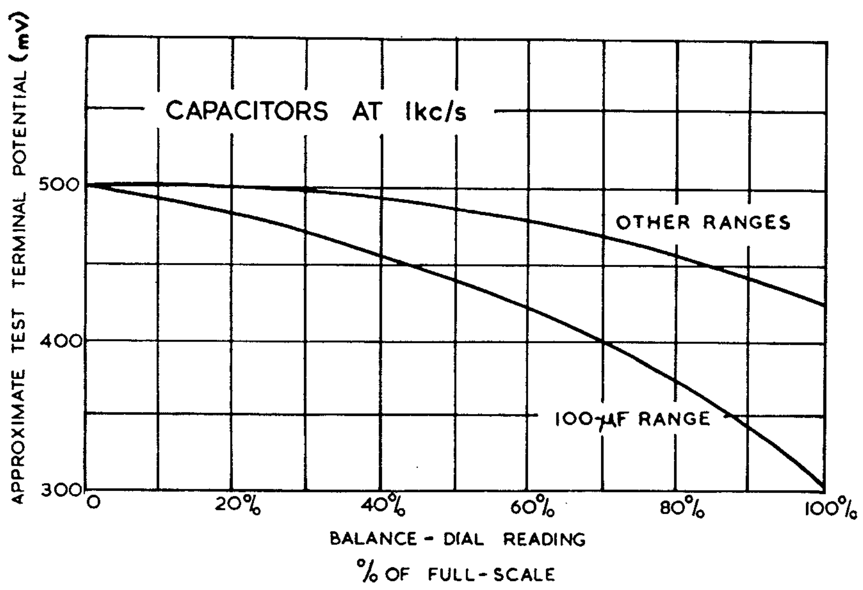


Fig. 2.4 *Test Terminal Voltage at balance for Capacitors.*

2.3.6 Capacitance Measurement

(1) Connect the component to the test terminals. (For notes on connections see Sections 2.3.2 and 2.5.)

(2) Set the LCR switch to C, the PHASE BALANCE and FINE Q controls about mid-way, and the Q-TAN δ switch to TAN δ. When measuring high-loss capacitors it may be preferable to set the Q-TAN δ switch to Q; for further information see Section 2.5.4.

(3) Set the oscillator frequency to 1 kc/s.

(4) *If the approximate capacitance is known,* set the RANGE switch so that the anticipated value is above the left-hand scale window (except for values less than 10 μμF), and carry on as in step (6).

If the capacitance value is completely unknown, set the RANGE switch to the highest setting and continue as follows:—

(5) Turn the BALANCE pointer to the left-hand scale window and then turn it rapidly counter-clockwise, noting the meter indication.

If the meter reading increases, the correct range has been selected, that is, the capacitance is greater than the value shown in the left-hand scale window.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat from (5); continue to do this until the meter reading increases. If it still decreases when the bottom range is reached, then the capacitance value is less than 10 μμF.

(6) Starting from the left-hand scale window, rotate the BALANCE pointer clockwise (or counter-clockwise for values below 10 μμF) to obtain a minimum meter indication.

(7) For final balance, adjust the PHASE BALANCE control and then the main BALANCE control. Continue to do this alternately until a sharply defined minimum meter reading is obtained within the region of the first two scale divisions.

2.4 NOTES ON INDUCTANCE MEASUREMENT

2.4.1 Use of the 1 kc/s–10 kc/s Switch

The Universal Bridge is primarily designed for the measurement of inductance and capacitance at 1 kc/s. However, the 10 kc/s position of the switch may be used with advantage for low-Q and low-inductance measurement, as described in Section 2.4.3. Greater discrimination and ease in initially balancing the circuit may then be obtained.

If final balance readings are taken at 10 kc/s, the main BALANCE scale is direct-reading, but the reading on the PHASE BALANCE dial must be multiplied by 10; this multiplication must also be made before use is made of the Conversion Chart on top of the instrument. The use of the Conversion Chart is dealt with in Section 2.4.5.

2.4.2 High Inductance Measurement

To avoid error in measurement, inductors having a low self-resonant frequency should not be tested at 10 kc/s. If their self-resonant frequency is lower than about 5 kc/s, then test results at even 1 kc/s will be in error—inductance will appear high, and magnification low. For example, a coil of 50 henrys true inductance, 20 $\mu\mu$F self-capacitance, and having a Q of 10 at 1 kc/s will appear, when measured at 1 kc/s, to have an inductance of about 51·5 henrys, and a Q of about 9·5. The self-resonant frequency of such an inductor is 5 kc/s.

These errors increase rapidly as the self-resonant frequency of the inductor approaches the frequency of the oscillator, and it is, of course, impossible to measure an inductor which resonates below 1 kc/s, since such a component will exhibit capacitive reactance. The effective capacitance of the component may be measured by the bridge, and will appear to have a poor power factor.

The inherent capacitance of the bridge at the test terminals is low—approximately 0·1 $\mu\mu$F—and will contribute little to lowering the self-resonant frequency of the test component.

2.4.3 Low Inductance Measurement

When measuring components possessing low values of Q and inductance, it will be noticeable that the setting of the main BALANCE and PHASE BALANCE controls are interdependent. This interdependence will, in general, be more apparent at 1 kc/s than at 10 kc/s. Therefore it usually assists if 10 kc/s is employed to obtain the initial balance point before using 1 kc/s for final balance. If, however, 10 kc/s is used for final balance, it should be remembered that the PHASE BALANCE dial reading must be multiplied by 10.

If the FINE-Q control is positioned in the centre of its range, and the PHASE BALANCE control adjusted for approximate balance in conjunction with the main BALANCE control, then further adjustment of the FINE-Q control in step with the BALANCE control will greatly facilitate final balance adjustment.

The residual inductance, L_o, of the bridge is approximately 0·1 μH; this value should be subtracted from the measured inductance for highest accuracy.

2.4.4 Phase Balance

When measuring inductance or capacitance, the PHASE BALANCE control must be adjusted in addition to the main BALANCE control (as described in Sections 2.3.4 and 2.3.6) in order to obtain balance. The final reading on the main BALANCE control dial will depend on the resistive loss—effectively in series or in parallel—associated with the component under test.

The position of the Q-TAN δ switch determines which corresponding PHASE BALANCE scale is in use, and whether effective series or parallel values are being measured. When the operating frequency is 1 kc/s, the calibrated range of the Q scale is from 0·1 to 10, and that of the tan δ scale from 0·001 to 0·1. Since $Q = 1/\tan\delta$, it will be appreciated that these two scales combine to give a Q coverage up to 1000, and tan δ up to 10. When the operating frequency is 10 kc/s, the reading on either scale must be multiplied by 10, and balance can as a rule be obtained on either scale.

Depending upon the position of the Q-TAN δ switch, the main BALANCE dial indicates either the effective series inductance or the effective parallel inductance. When Q is less than 10, or tan δ greater than 0·1, appreciably different points of balance will be obtained. Inductor measurements made with the Q-TAN δ switch at tan δ—especially at 10 kc/s where the tan δ range is 0 to 1—should be converted to the equivalent series value as described in Section 2.4.5.

The FINE-Q control is in series with the PHASE BALANCE control resistor when measuring Q, and is switched out of circuit when measuring tan δ. The usefulness of this control in obtaining a fine degree of balance is only apparent for low values of Q which brings the PHASE BALANCE control resistor to the coarse low-resistance end of its range. The range of the FINE-Q control is about 0·06 Q.

2.4.5 Q-tan δ and Series Parallel Conversion

A typical conductor can be regarded as a circuit consisting of inductance and resistance in series. When the Q-TAN δ switch is set at Q, the bridge is arranged so that the series value of inductance is indicated on the main BALANCE dial. This arrangement holds good for Q values up to 10 (100 at 10 kc/s).

For inductors of higher Q value, it is necessary to switch to tan δ which extends the upper limit of Q to infinity (tan δ is equivalent to $1/Q$; therefore when $\tan\delta = 0$, then $Q = \infty$). The inductor under test is now no longer measured as a series circuit, but rather as if the inductor loss is entirely due to a parallel resistor. This is not a realistic arrangement for the usual inductor, but the difference made to the measured value of inductance is quite small, and decreases in significance as Q increases.

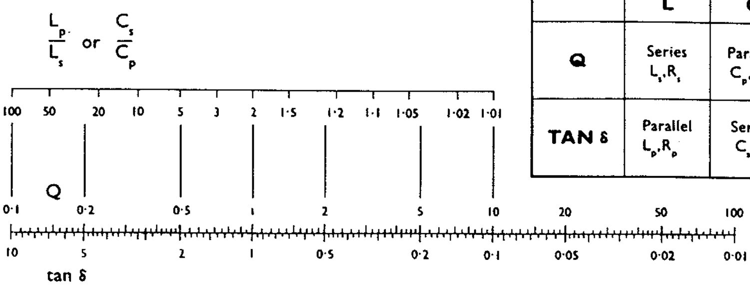
If L_s is the series inductance, and L_p the parallel

Fig. 2.5 *Q-tan δ Conversion Chart. This is also reproduced on top of the instrument.*

Q-TAN δ AND SERIES-PARALLEL CONVERSION

Q and tan δ scales direct reading at 1 kc/s. At 10 kc/s multiply by 10; then perform any necessary Q = 1/tan δ conversion.

Setting of Q-TAN δ switch determines whether result is in terms of series or parallel values. See table below.



	L	C
Q	Series L_s, R_s	Parallel C_p, R_p
TAN δ	Parallel L_p, R_p	Series C_s, R_s

cos φ = POWER FACTOR ≃ tan δ for values below 0·1.

equivalent indicated by the main BALANCE dial setting when switched to tan δ, then:—

$$L_s = L_p\left(\frac{1}{1 + \tan^2\delta}\right).$$

When tan δ = 0·1, it will be seen that L_s is 1% less than L_p. For smaller tan δ settings the difference is even less: for instance, at tan δ = 0·03 (Q = 33), the difference is 0·1%. When switched to tan δ, therefore, the fraction

$$\frac{1}{1 + \tan^2\delta}$$

represents the multiplying factor to be applied to the inductance value indicated on the main BALANCE dial in order to obtain the equivalent series value. The difference between these two values becomes increasingly apparent for Q values less than 10, or tan δ values greater than 0.1.

The scales given on the Conversion Chart on top of the instrument (and also reproduced in Fig. 2.5), interrelate values of Q and tan δ. For Q values less than 10, the series inductance value indicated on the main BALANCE dial may be conveniently converted to equivalent parallel value bv placing a straight-edge at right-angles to the scales, and using the multiplying factor obtained from the upper (L_p/L_s) scale. When the operating frequency is 10 kc/s, it must be remembered that the reading on the PHASE BALANCE dial must be first multiplied by 10.

2.5 NOTES ON CAPACITANCE MEASUREMENT

2.5.1 Residual Capacitance

With the LCR switch set at C, the residual capacitance, C_o, of the bridge is 0·1 μμF. When measuring low values of capacitance this amount should be subtracted. Capacitance between the leads to the test component must not be overlooked; its value may be measured and also subtracted from the reading of the Bridge.

2.5.2 Stray Capacitance

If reference is made to the Functional Diagram, it will be seen that any unwanted capacitance that exists between the LOW terminal and the case only shunts the amplifier-detector input. However, unwanted capacitance from the HIGH terminal to the case shunts the standard capacitor arm, and therefore gives rise to error.

The error due to stray capacitance between the HIGH side of the test capacitor and the case takes the form of an incorrectly-low capacitance reading on the Bridge at balance. Theoretically, this can be corrected, to a close approximation, by multiplying the capacitance reading by the factor $(1 + C_g)/C_s$, where C_g is the unwanted stray capacitance effectively between the HIGH terminal and the case, and C_s is the value of the standard capacitor in the bridge. The PHASE BALANCE reading is also in error due to C_g and can be similarly corrected by dividing or multiplying the indicated tan δ or Q, respectively, by $(1 + C_g)/C_s$. In practice there may be some difficulty in estimating C_g; however, since C_s = C10 = 0·1 μF, it will be seen that C_g must be considerable before correction is needed. Hence, errors due to this cause can usually be neglected provided that (i) the component under test is positioned so that stray capacitance to the case is minimized, and (ii) the component is connected so that the major part of the stray capacitance is effectively between the LOW terminal and the case.

In the case of screened capacitors that are employed with one electrode and screen earthed, a true representation of the operational conditions can be obtained if the screen and the electrode to be earthed are both joined to the LOW terminal when measuring the capacitor on the Bridge.

2.5.3 *In Situ* Measurements

The ' capacitor ' under test may actually be a structure of some kind in which one ' electrode ' is large (e.g. chassis). The latter may pick up so much field at mains frequency and its harmonics that, if it is connected to the LOW terminal, and therefore to the amplifier-detector input, balance cannot be found easily. In this case, the ' large ' electrode may be connected instead to the HIGH terminal. Having read the capacitance in this way, the effect of unwanted capacitance between the HIGH terminal and the case due to the ' large ' electrode may be checked, and if necessary, a correction applied.

The following precautions are recommended, assuming, for example, that the component to be measured is a ganged capacitor in a receiver, where the body of the capacitance is bonded to the chassis.

(1) Disconnect the receiver and coil up the mains lead.

(2) Position the receiver so that its metal work, e.g. chassis or case, is at least 3 in. from the case of the Bridge, metal bench top, or any other ' earth ' metal object on the bench.

(3) Disconnect all other components associated with the capacitor to be tested; then, using leads of not more than about 2 ft. long, connect the HIGH terminal to the receiver chassis, and the LOW terminal to the appropriate stator of the capacitor.

(4) Proceed to make the measurement, finally subtracting the separately measured capacitance between the connecting leads.

Should stray interference mask the balance point, the lead connected to the LOW terminal should be screened—the screen being connected to the case of the TF 868B.

It must be left to the user to decide if the test conditions suggest, or justify, correction for unwanted shunt capacitance. If this is thought to be comparatively large, then the incurred percentage error can be found in the following way.

After balance has been achieved, note the capacitance reading, and then, without disturbing the test arrangement, disconnect (without moving) the leads from the Bridge terminals. Substitute a capacitor of similar value to the capacitor under test, but of smaller physical size: connect this directly to the test terminals and balance the bridge. With this capacitor still connected, reconnect the lead to the HIGH terminal and note the percentage change when the bridge is adjusted for balance again. This percentage error should then be applied to the original measurement.

2.5.4 Q-tan δ and Series Parallel Conversion

When measuring capacitance, with the Q-TAN δ switch set at TAN δ, the bridge arrangement measures the test component as a series circuit of capacitance and resistance. Such an arrangement would be normal for the measurement of good quality capacitors possessing a tan δ (power factor) of less than 0·1.

If it is thought that the capacitor actually has predominant shunt loss, and may be more accurately represented by a parallel circuit of capacitance and resistance (C_pR_p), then the indicated BALANCE dial value, C_s, may be converted by using the formula:—

$$C_p = \frac{C_s}{1 + \tan^2\delta}.$$

The difference between C_p and C_s in terms of parallel or series equivalents is 1% for tan δ = 0·1, and 0·1% for tan δ = 0·03.

Capacitors possessing a tan δ value greater than 0·1 (low Q) require the Q-TAN δ switch to be set at Q in order to obtain balance. With the bridge arranged in this way, the main BALANCE dial will now indicate the parallel value of capacitance (C_pR_p), whereas a low-Q capacitor such as an electrolytic may actually possess a predominant series loss so that the equivalent circuit C_sR_s is the truer condition. Under these circumstances, a conversion from the BALANCE dial reading to equivalent series value may be obtained from:—

$$C_s = C_p\left(\frac{1 + Q^2}{Q^2}\right)$$

or by using the Conversion Chart on top of the instrument. If a straight-edge is placed at right-angles to the scales and aligned with the Q value obtained directly from the PHASE BALANCE dial, the figure obtained from the upper (C_sC_p) scale is the multiplying factor necessary to convert the BALANCE dial capacitance reading from parallel to series equivalent.

It is important to note the large difference between C_s and C_p as the Q of the test component is reduced, viz.:—

$Q = 5$ . . . . $C_s = C_p + 4\%$
$Q = 3$ . . . . $C_s = C_p + 11\%$
$Q = 2$ . . . . $C_s = C_p + 25\%$

With electrolytic capacitors in particular, it is found that, provided that the Q is greater than 5, the results are fairly reliable. As Q decreases, the interpretation of the measurement after applying the C_s/C_p relationship does not necessarily give results having any great degree of accuracy.

3 Technical Description

The following description is intended to be read in conjunction with the Functional Diagram, Fig. 3.1, and the Circuit Diagrams in Section 6. Detailed information concerning components and their circuit references will be found in the SPARES ORDERING SCHEDULE, Section 7, which also lists certain mechanical items.

3.1 CIRCUIT SUMMARY

Two separate energizing sources are available to the measuring bridge circuit for evaluating reactive and resistive components. When measuring inductance and capacitance, the 1-kc/s or 10-kc/s output from the oscillator-amplifier is applied to the measuring bridge via a coupling transformer. When measuring resistance, a d.c. supply, available at two levels, is obtained from the rectified output of the secondary windings on the mains transformer. Applicable voltage values will be found in the DATA SUMMARY at the front of this handbook.

The change between the a.c. and d.c. energizing inputs is effected by the operation of the LCR switch which simultaneously alters the arrangement of the measuring bridge circuit to suit the type of component under test.

For inductance and capacitance measurements, the unbalanced output from the bridge is applied directly to the input of the first amplifying valve, V3a. For resistance measurement, where the unbalanced output is d.c., this output is first interrupted, or chopped, by the contacts of a vibrator.

After amplification by V3 and V4a, the amplified voltages are applied to the diode detector, V4b, and the BALANCE meter. A system of a.g.c. prevents meter overloading while at the same time retaining bridge sensitivity.

3.2 FUNCTION OF CONTROLS

3.2.1 Balance Control

The BALANCE control variable resistor RV9, is a special-quality high-precision component which forms one arm of the measuring bridge circuit. The adjustment of this control enables the value of the component under test to be balanced against accurately known circuit values.

The resistance track of RV9—which conforms to a semi-log law—is individually calibrated on the BALANCE dial before being fitted into the instrument. The spindle of RV9 which carries the moving

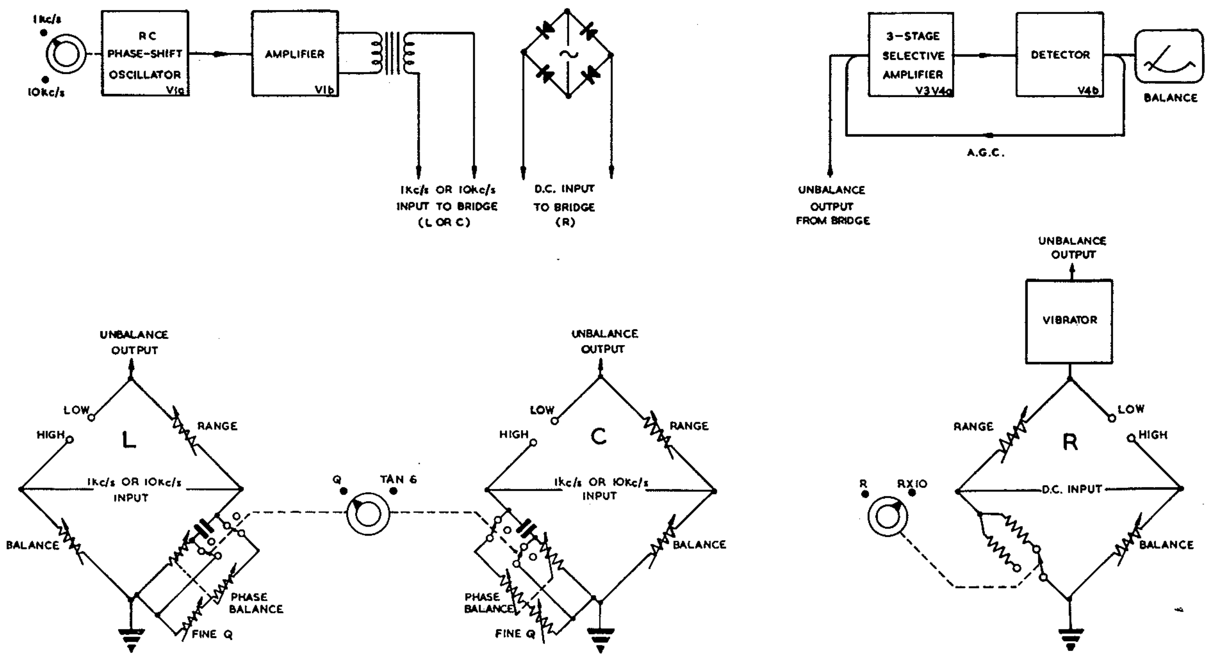


Fig. 3.1 *Functional Diagram of TF868B.*

parts of the BALANCE dial assembly, is driven by the control knob via a slow-motion drive. An exploded view of this complete assembly and associated linkage and cord drive with the LCR and RANGE switches, can be seen in Fig. 5.5.

3.2.2 Press for R × 10 Switch

The switch, SB, is spring-loaded and contacts SBb normally select the R23 arm of the bridge. With this resistor in circuit, the BALANCE dial is direct-reading. When SB is depressed, the resistance scale reading of the BALANCE dial must be multiplied by 10. In the latter position, contacts SBa select increased d.c. voltage automatically, in order to maintain bridge sensitivity when using the R × 10 facility.

3.2.3 Phase Balance Control

This control provides the main variable resistive (phasing) element in the standard arm of the bridge. It consists of ganged variable resistors RV5 and RV6, only one of which is placed in circuit at a time by the operation of the Q-TAN δ switch.

When Q is selected, RV6 is placed in series with the FINE-Q resistor, RV10, and both shunt the standard capacitor C10. When TAN δ is selected, RV6 and RV10 are disconnected and, instead, RV5 is placed in series with C10.

As in the case of the main BALANCE dial, the PHASE BALANCE dial is individually calibrated for Q and tan δ against the variable resistance values of RV5 and RV6 before being fitted into the instrument.

3.2.4 Fine-Q Control

This control, RV10, serves as an extension to the PHASE BALANCE variable resistor, RV6. For normal operation when measuring Q, the value of RV10 is insignificant when compared with the value of RV6. For very low measured Q values, however, when the sliding contact of RV6 is in position at the low-value coarse end of its movement, the FINE-Q control provides a fine adjustment to the remaining resistance in the circuit.

3.2.5 Q-tan δ Switch

Associated with the PHASE BALANCE control, the function of this switch, SF, is to alter the arrangement of the standard arm of the bridge in order to provide either a parallel or series resistance capacitance arm. The purpose of this is to simulate the loss in the component under test, as further explained in Sections 2.4.4 and 2.4.5.

When switched to Q, the RV6 section of the ganged PHASE BALANCE control is placed in series with the FINE-Q variable resistor, RV10, and both shunt the standard capacitor, C10. When switched to TAN δ, RV6 and RV10 are disconnected and, instead, the RV5 section of the PHASE BALANCE control is placed in series with C10.

3.2.6 1 kc/s–10 kc/s Switch

Switch SA selects 1 kc/s or 10 kc/s by appropriately switching the RC ladder networks in the grid circuits of the oscillator valve, V1a. The operational use of this switch is described in Sections 2.4.1 and 2.4.3.

3.2.7 LCR Switch

This three-position, 7-pole switch, SD, performs the following functions. When switched for inductance and capacitance measurements it:—

(1) Selects the bridge-energizing a.c. supply, and adjusts the measuring bridge circuit to suit the type of component to be tested.

(2) Selects the 1-kc/s and 10-kc/s tuned circuits which include L1 and L2, into the grid circuit of V3b.

(3) Mechanically alters the title of the BALANCE dial calibration.

When switched for resistance measurement it:—

(1) Selects the bridge d.c. energizing supply, and also the a.c. supply for the vibrator coil L3.

(2) Rearranges the measuring bridge circuit to that of a Wheatstone bridge, and exchanges the tuned circuits in the grid circuit of V3b for C28. (C28 in conjunction with R35 provides a low-pass filter.)

(3) Mechanically changes the BALANCE scale title to read ohms.

The mechanical linkage between the BALANCE dial and the RANGE and LCR switches can be seen on the exploded illustration Fig. 5.5 at the back of this handbook.

3.2.8 Range Switch

The function of the RANGE switch, SE, is to select the correct value of bridge arm resistance appropriate to a particular range setting. It is a two-pole, seven-position switch controlled by the front panel RANGE knob and selects any one of the resistors R13 to R23 together with associated compensating capacitors and preset resistors.

A drive cord and pulley arrangement between the switch shaft and the BALANCE dial mechanism changes the dial-window calibration figures to indicate the selected range. Fig. 5.4 shows the front and rear views of the complete RANGE switch assembly and its associated components.

3.3 CIRCUIT DESCRIPTION

3.3.1 Bridge A.C. Supply (Oscillator-Amplifier)

The double triode valve, V1, performs the combined function of oscillator and amplifier. Section V1a is connected as a RC phase-shift oscillator. Switched RC ladder networks provide the necessary circuit constants for the maintenance of oscillatory conditions at 1 kc/s and 10 kc/s.

The three-stage network including preset resistor RV1 controls the 1-kc/s oscillations. Similarly, the 10-kc/s oscillation is controlled by the four-stage network which includes preset resistor RV2. Selection of these circuits is by means of the 1 KC/S–10 KC/S panel switch, SA.

Output from the oscillator is applied to the grid of V1b which functions as an amplifier. Transformer T1 couples the output of the amplifier section to the bridge input; it is a step-down transformer of specialized design which affords efficient matching into the bridge impedance, and possesses the properties of low self-capacitance and small external magnetic field. The resistor, R10, shunted across the primary winding of T1, minimizes the pulling effect on the oscillator due to the changes in bridge impedance which are reflected back to the input by Miller effect.

3.3.2 Bridge D.C. Supply

The d.c. voltage required by the bridge when measuring resistance, is obtained from the rectified outputs of secondary windings LT3 and LT5 on the mains transformer. The PRESS FOR R × 10 panel switch SB is spring-biased and normally selects winding LT3 alone. The output is then applied to the bridge circuit via the full-wave rectifier MR1.

When the PRESS FOR R × 10 switch is operated, the switch section SBa selects secondary windings LT3 and LT5 in series, and the d.c. supply to the bridge is increased. At the same time, the switch contacts SBb change the resistance in one arm of the bridge as described in Section 3.2.2.

3.3.3 Measuring Bridge Circuits

The choice of bridge circuit is effected by the LCR selector switch. Operation of this switch brings into use the circuit arrangement to suit the type of component under test.

Resistance Bridge. For resistance measurement, the circuit is connected as a Wheatstone Bridge (Figs. 3.2 and 6.2) where the component under test forms one resistive arm via the test terminals. Switched resistors R13 to R21 in a second arm of

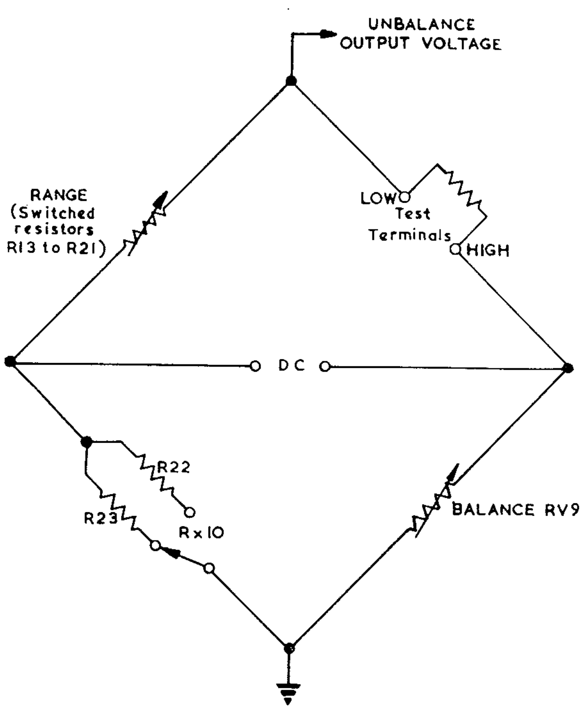


Fig. 3.2 Simplified Resistance Bridge.

the bridge, and the variable resistor RV9 in a third arm, are operated by the RANGE and BALANCE controls respectively.

One of the two resistors, R22 or R23, in the fourth arm, is selected by the PRESS FOR R × 10 switch SB. This switch, which is spring-biased to the R position, also performs the function of selecting increased d.c. supply to the bridge in order to restore sensitivity when using the R × 10 facility.

Inductance Bridge. Inductance is measured by comparison with a standard capacitance, C10, in an opposing (standard) arm of the bridge, while loss in the component under test is balanced out by equivalent resistance introduced into the arm, either in series, or in parallel, with C10.

Such an arrangement is shown in Figs. 3.3 and 6.2, where the PHASE BALANCE resistor RV6 (with associated FINE-Q resistor RV10) is shown in parallel with C10, for the measurement of inductance and Q.

An alternative method is for the PHASE BALANCE resistor RV5 to be connected in series with C10, when the Q-TAN δ switch, SF, is set to the TAN δ position. With this method of connection, the main BALANCE indications represent the equivalent parallel inductance. (See Figs. 3.4 and 6.2.)

A Conversion Chart for converting parallel inductance to equivalent series inductance, and tan δ to Q on parallel scales, is printed on top of

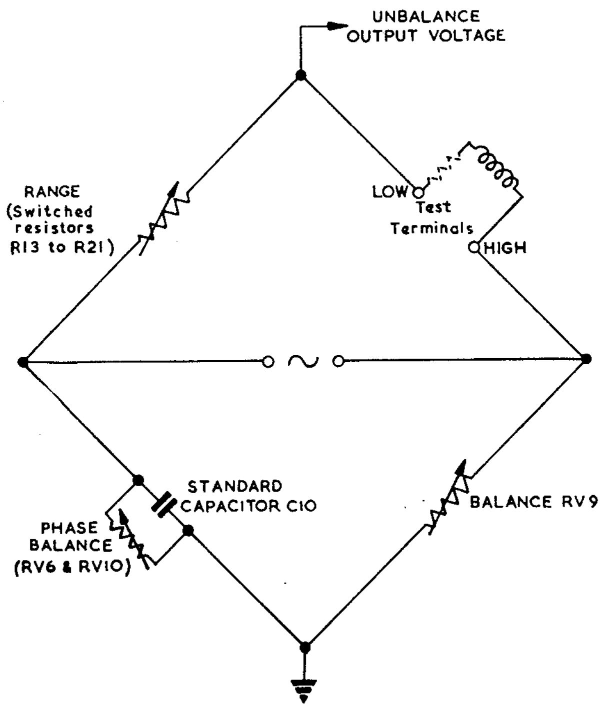


Fig. 3.3 *Simplified Inductance Bridge (measuring inductance with series loss).*

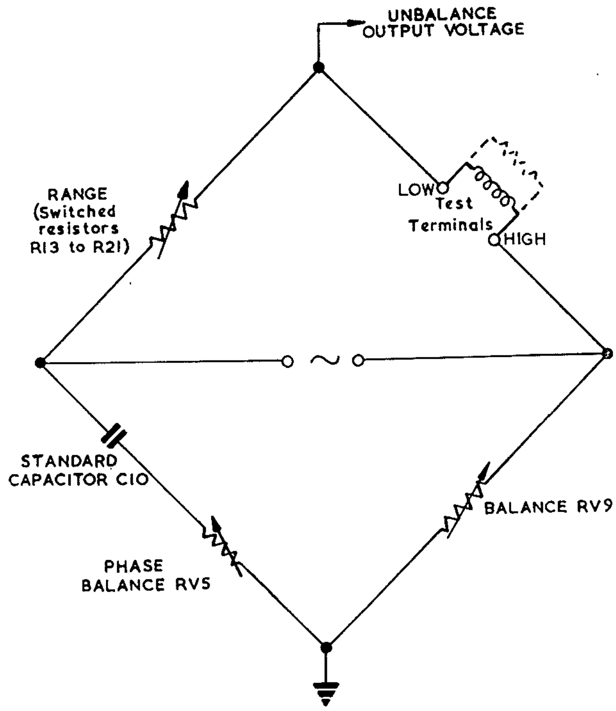


Fig. 3.4 *Simplified Inductance Bridge (measuring inductance with parallel loss).*

the instrument, and also reproduced in Fig. 2.5. The use of the scales is described in Section 2.4.5.

Switched resistors R13 to R21, together with their compensating components, and variable resistor RV9, provide the RANGE and BALANCE controls respectively as in the Wheatstone arrangement. Details concerning the bridge-energizing a.c. supply will be found in Section 3.3.1.

Capacitance Bridge. When changing from inductance to capacitance measurements, the standard capacitance arm (C10 and PHASE BALANCE resistor) is interchanged in position with the BALANCE resistor, RV9, by the contacts of the LCR switch. (See Fig. 3.5.)

As for inductance, the arrangement for the standard arm of the bridge will depend upon the loss in the capacitor under test. A typical arrangement of the measurement of capacitance and power factor (tan δ) where the resistive loss can be considered as a series component, is shown in the simplified circuit, Fig. 3.5, and Fig. 6.2. Switched resistors (with compensating components) R13 to R21, and variable resistor RV9, provide the RANGE and BALANCE controls as in the inductance bridge; in fact, if comparison is made between the two bridges, it will be seen that they offer exactly the same operational functions.

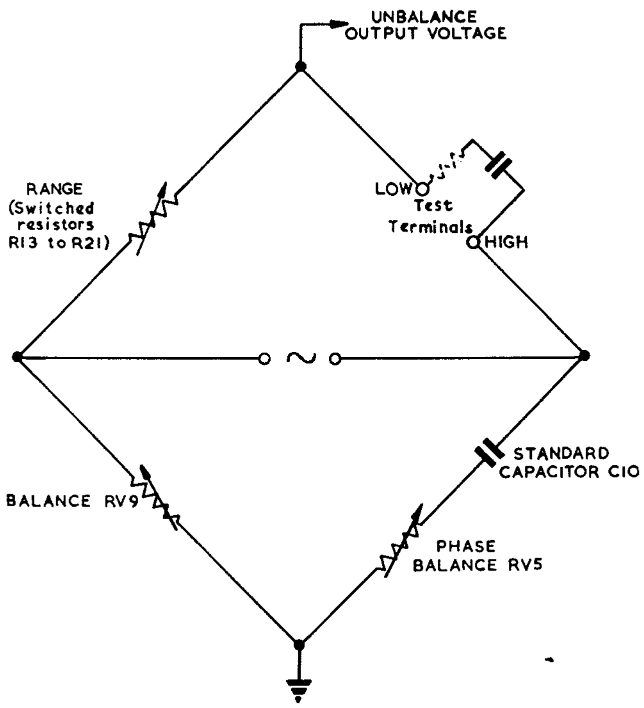


Fig. 3.5 *Simplified Capacitance Bridge.*

3.3.4 Amplifier-Detector

This circuit employs two double-triode valves, V3 and V4, in an arrangement consisting of three stages of amplification, followed by a detector feeding a BALANCE meter, M1.

When resistance is measured, the out-of-balance d.c. voltage from the bridge is applied via an RC filter network to the vibrating contacts, SG, and the grid of V3a. The RC filter network affords smoothing of the bridge out-of-balance voltage while, at the same time, attenuating any supply-frequency hum pick-up on the test component. The vibrator contacts perform a chopping action at twice the supply frequency, thereby converting the out-of-balance voltage from d.c. to a.c. at approximately 100 c/s; this is then applied to the grid of V3a via R29 and C21. The vibrator coil is energized by the secondary winding LT2—the circuit to the coil being completed when the LCR switch, SD, is turned to R.

Adjustment of the potentiometer, RV4, across the vibrator coil minimizes the effect of mains hum pick-up via the vibrator contacts.

When measuring inductance and capacitance, the out-of-balance 1-kc/s or 10-kc/s voltage from the bridge is applied to the grid of the first amplifier stage, V3a, via the contacts of the LCR switch, and capacitors C20 and C21.

The double-triode sections V3a and V3b function as conventional RC-coupled amplifiers with the addition of switch-selected tuned circuits between them. These circuits are automatically brought into use by the action of the LCR switch, SD. When switch SD is set to R, the filter consisting of C28 and R35 gives a low-pass frequency response. During resistance measurement, this eliminates the high frequency components in the wave-form produced by the vibrator. When the LCR switch is moved to either L or C, capacitor C28 is replaced by two tuned circuits in tandem. These circuits, which consist of coils L1 and L2, shunted by appropriate capacitors, offer maximum circuit sensitivity at the oscillator frequencies of 1 and 10 kc/s. Precise preset tuning of L1 and L2 is achieved by means of tapes coated with a graded film of iron powder; adjusting these tapes varies the effective air-gap in the ferrite cores. The method of adjusting these tapes when new coils are fitted is described in Section 4.6.5.

The double-triode section V4a provides a further stage of amplification, the output of which is applied via C29 to V4b. Section V4b is diode connected; it performs the function of a detector supplying d.c. to the BALANCE meter M1, and also provides voltage for a.g.c. purposes.

The BALANCE meter has a 100-μA moving-coil movement which forms part of the diode load of V4b together with resistors R42 and R43, and indicates the state of balance of the bridge.

The a.g.c. voltage, which is approximately one-third of the total voltage developed across the detector load, is tapped off at the junction of R42 with R43 and applied to the grid of the input amplifier via resistors R41 and R30. Resistor R41 and capacitor C23 produce a time constant such that the a.g.c. delay is 10 seconds. This arrangement has the advantage that comparatively fast changes in bridge out-of-balance voltage are fully displayed initially on the BALANCE meter, and then the gain of the amplifier is slowly and automatically adjusted by the a.g.c. to suit the new conditions. Standing current due to the diode, which would normally produce a reading on the meter, is balanced out by a reverse voltage applied from the cathode of V4a.

It will be observed from the SPARES ORDERING SCHEDULE that the value for R48 is a nominal one. The actual resistance value for R48 is adjusted during initial calibration of the instrument in order to obtain, as near as possible, zero-reading on the BALANCE meter when the bridge is balanced.

3.3.5 Power Supplies

The internal power supply for the TF 868B is provided by the power transformer, T2. Two tapped primary windings permit a series, or series-parallel, arrangement in order to cover the input ranges 100 to 150 volts and 200 to 250 volts at 40 to 60 c/s.

The h.t. supply is derived from a full-wave rectifier V2 via resistance capacitance smoothing. V2 is separately heated from winding LT1. The panel light is connected across the heater winding LT4 via a dropping resistor, R46. Secondary winding LT2 supplies 6·3 volts a.c. for the vibrator coil.

Windings LT3 and LT5 together with the full-wave metal rectifier MR1, provide d.c. for the bridge during resistance measurement, as described in Section 3.3.2.

3.3.6 D.C. Choke Adaptor

This Adaptor, which is supplied as an optional accessory, is also described in Sections 1.2 and 2.3.5.

Referring to the Simplified Circuit Fig. 3.6, it will be seen that the external d.c. supply is applied across the winding of the inductor under test via coils L1 and L2. The tuned circuits which include L1 and L2 are tuned to resonance at 1 kc/s, and at this bridge frequency, serve the purpose of significantly isolating the load due to the d.c. supply from the test terminals of the Bridge. The d.c. is prevented from flowing through the measuring bridge circuit by the presence of the capacitor C10.

To account for the variation in frequency between different instruments, tuned circuit L1/C7 (see the complete Circuit Diagram Fig. 6.3 at the end of this handbook) is made variable by means of the switched capacitors C1 to C6, and the trimmer capacitor, VC1. Fixed tuning only is employed for L2/C8, since this circuit only shunts the amplifier-detector input of the Bridge, and therefore does not affect the accuracy.

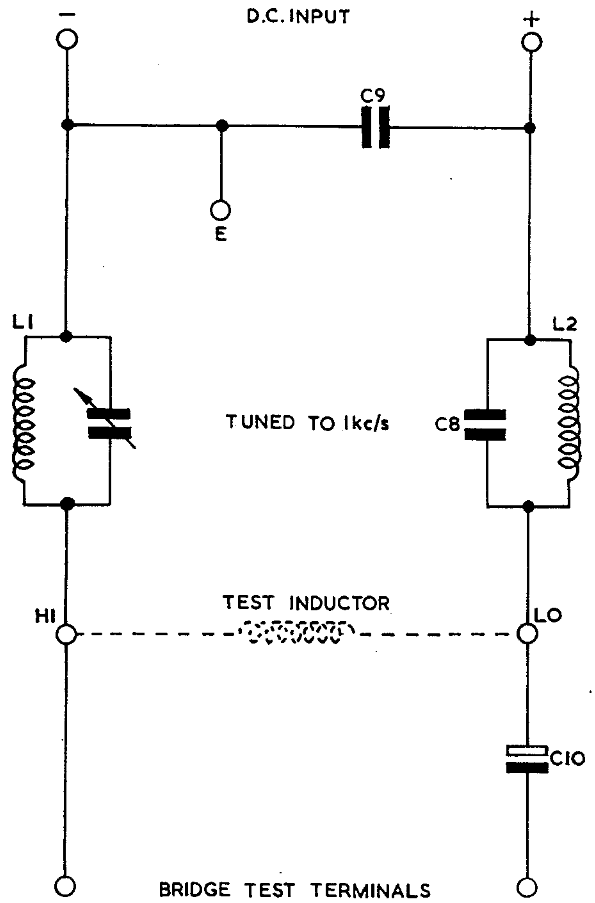


Fig. 3.6 *Simplified Circuit of D.C. Choke Adaptor.*

4 Maintenance

4.1 REMOVAL FROM CASE

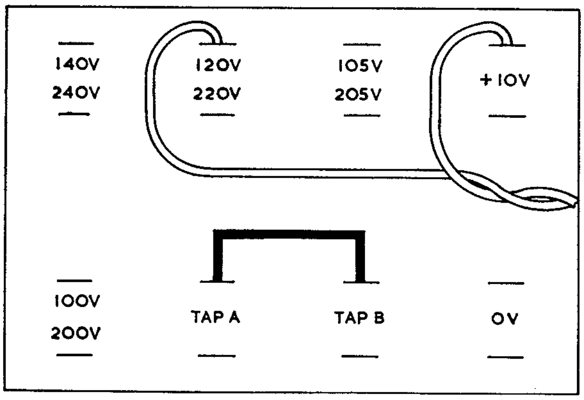
To remove the chassis—complete with the front and top panel—from the case, place the instrument on its back and withdraw the four screws from the centre of the moulded feet of the case. Return the instrument to its upright position so that by tilting it forward, the rear edge of the platform may be grasped prior to the removal of the panel and chassis assembly from the case. The mains lead should be free to run through the case-handle recess.

4.2 MAINS INPUT ADJUSTMENTS

Before making any adjustments, ensure that the mains lead is disconnected from the supply.

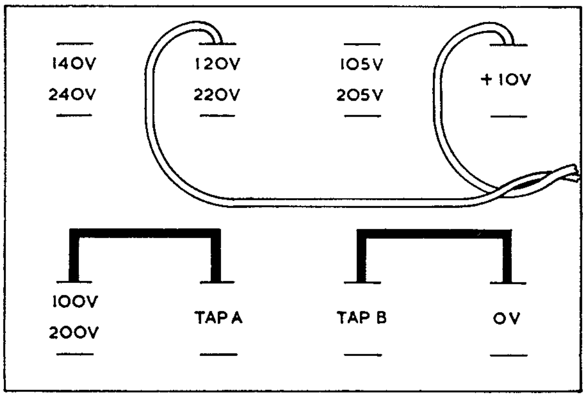
The TF 868B is normally dispatched with its mains transformer tappings adjusted for use on 240 volts within the supply frequency range of 40 to 60 c/s. Adjustment to suit other voltages can be made by altering the tappings on T2.

The two tapped sections of the double wound primary winding are connected in series for 200- to 250-volt operation, and in series-parallel for 100- to 150-volt operation. To change from one input voltage to another, proceed as follows:—



(a) 200- to 250-volt range

TAP A is linked directly to TAP B; this increases the output at certain tags by 100 volts, i.e. the ' 140 V ' tag is now used for 240-volt working. One fly-lead must be connected to either ' 0 V ' or ' +10 V ', and the other to the tag whose designation added to 0 or 10 as appropriate, matches the supply voltage. The illustration above shows the transformer adjusted for 230-volt operation.



(b) 100- to 150-volt range

TAP A is linked to the ' 100 V ' tag, and TAP B to that marked ' 0 V '. One fly-lead must be connected to either ' 0 V ' or ' +10 V ' and the other to the tag whose designation added to 0 or 10 as appropriate, matches the supply voltage. The illustration above shows the transformer adjusted for 130-volt operation.

4.3 WORKING VOLTAGES

The voltages given in Tables 3 and 4, for guidance when servicing the instrument, are representative of the readings to be expected if measurements are made with a meter having a resistance of 20,000 ohms-per-volt, e.g. Avometer model 8.

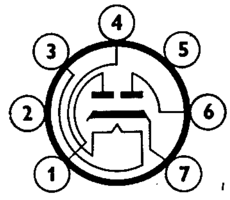
On individual instruments some difference in voltage readings may be expected due to normal variations in valve performance and component values. The supply voltage and that for which the instrument is adjusted should be as nearly as possible in agreement.

4.4 REPLACEMENT OF VALVES

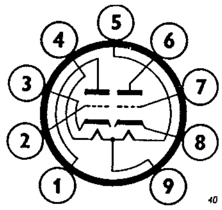
All valves are easily accessible after first removing the instrument from its case. A list of valves fitted, together with suitable equivalent types, will be found in Table 1. Any valve which becomes faulty should preferably be replaced by a valve of the type originally supplied in the instrument. If this is not possible, then Table 1 should provide a useful guide to suitable alternatives.

OM 868B
1*-10/60

When replacing valves, this may be done without special selection with the exception of V3. In the case of this valve, it is possible that the introduction of mains hum may be experienced even with an exact replacement type. If several of these valves are available, then this difficulty may be overcome by substitution. (See Amplifier Hum-Level, Section 4.6.5.)



a
(B9A)



b
(B7G)

TABLE 1

Any valve which becomes faulty should preferably be replaced by a valve of the type originally supplied in the instrument and designated in the following table. If this is not possible, the additional data given by the table may be used as a guide to suitable alternatives.

Valve	*Type*	*Base*	*British Commercial Equivalent*	*British Services Equivalent*	*U.S. Equivalent*
V1	Brimar 12AT7 Double Triode	a	ECC81 B309 B152 M8162*	CV455 CV4024*	12AT7 12AT7WA* 6060*
V3 **V4**	Brimar 12AX7 Double Triode	a	ECC83 B339 M8137*	CV492 CV4004*	12AX7 6057*
V2	Brimar 6X4 Full-Wave Rectifier	b	EZ90 U78	CV493 CV4005	6X4

* *High-reliability type*

4.5 ADJUSTMENT AND LOCATION OF PRESET COMPONENTS

During factory calibration, the performance of the Bridge is brought to within close limits by means of preset controls. Following the replacement or ageing of certain components, it may be necessary to repeat the procedure by which these presets were originally adjusted.

The Section dealing with the calibration procedure appropriate to each preset is given in Table 2.

Before attempting adjustment to any of these preset controls, it is important that after switching on, the instrument should be allowed at least a 15-minute warm-up period.

The 1-kc/s and 10-kc/s adjustment preset resistors, RV1 and RV2, will be found fixed on the centre chassis together with the hum-neutralizing preset resistors, RV3 and RV4. The preset components—resistors RV7, RV8, and RV11, together with capacitors C11, C12, and C13—associated with the RANGE control—are attached to the plate at the rear of the RANGE switch assembly.

All the above components are marked with their circuit references as can be seen from the annotated photographs Figs. 5.1 and 5.4.

TABLE 2

Preset Component	*Section Describing Adjustment*
RV1	4.6.3
RV2	4.6.3
RV3	4.6.5
RV4	4.6.5
RV7	4.6.4
RV8	4.6.4
RV11	4.6.4
C11	4.6.4
C12	4.6.4
C13	4.6.4
L1	4.6.5
L2	4.6.5

TABLE 3

Valve Electrode Voltages

Valve	*Anode*		*Cathode*	
	Pin No.	*Voltage*	*Pin No.*	*Voltage*
V1a	1	150	3	0·9
V1b	6	280	8	3·1
V2	1 and 6	300 a.c.	7	370
V3a	1	135	3	0·5
V3b	6	110	8	0·65
V4a	1	200	3	0·8
V4b	6	—	8	0

All voltages shown above are d.c. with respect to the chassis, unless otherwise specified; test terminals open-circuited.

TABLE 4

Power Supply Voltages

Supply	*Measured between*	*Voltage*
H.T. a.c.	Each H.T. tag on T2 and chassis.	300 V a.c.
H.T. d.c.	Capacitor C30 positive tag and chassis.	370 V d.c.
H.T. d.c.	Capacitor C31 positive tag and chassis.	290 V d.c.
H.T. d.c.	Capacitor C22 positive tag and chassis.	265 V d.c.
L.T. 1 a.c.	L.T.1 tags on transformer T2.*	6·3 V a.c.
L.T. 2 a.c.	L.T. 2 tags on transformer T2.	6·3 V a.c.
L.T. 3 a.c.	L.T. 3/L.T. 5 and L.T. 3 tags on T2.	6·3 V a.c.
L.T. 4 a.c.	L.T. 4 tags on transformer T2.	6·3 V a.c.
L.T. 5 a.c.	L.T. 3/L.T. 5 and L.T. 5 tags on T2.	27 V a.c.
Bridge d.c.	Output from MR1 (LCR switch at R, test terminals open-circuited).	3·8 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at R, range switch at 1 Ω, test terminals short-circuited).	0·4 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at R, R×10 switch pressed, BALANCE control at full scale, test terminals open-circuited).	21 V d.c.
Bridge a.c.	Secondary tags of T1 (LCR switch at L or C, Q-TAN δ switch at TAN δ, test terminals short-circuited, RANGE switch rotated from lowest to highest range at 1 kc/s and 10 kc/s).	200–500 mV a.c.

* **Warning:** *Tags L.T.1 on transformer T2 are at h.t. potential with respect to the chassis.*

4.6 SCHEDULE OF TESTS

The following information is based on extracts from the internal Factory Test Schedule, and is included to enable the user to carry out a series of tests by which the main points of performance of the instrument may be checked. Details concerning the adjustment of preset components is also included.

4.6.1 Apparatus Required

(a) 500-Volt Insulation Tester.

(b) Avometer model 8, or similar multi-range meter; 20,000 ohms/volt.

(c) Simple Oscilloscope—for displaying Lissajous figures.

(d) B.F.O. or RC Oscillator, with a range of 1 kc/s to 10 kc/s; e.g. Marconi Audio Tester Type TF 894A, or RC Oscillator Type TF 1101.

(e) Wheatstone Bridge—to measure 16 kΩ.

(f) Resistance standards; 10Ω, 1 MΩ, and 10 MΩ.

4.6.2 Insulation

(Apparatus required: Item a.)

The measured insulation between each live pin of the supply plug and the chassis, with the mains switch set to ON is normally about 50 MΩ or greater.

4.6.3 Oscillator-Amplifier

(Apparatus required: Items b, c, and d.)

Checking Oscillator Frequency. Adjustments to the preset resistors RV1 and RV2, in the 1-kc/s and 10-kc/s oscillator circuit are made before the instrument is dispatched. It is not normally expected that further adjustment will be necessary. To check the oscillator frequency:—

(1) Select the 10 mH range; short-circuit the HIGH and LOW terminals; then connect the oscilloscope 'Y' input between the terminals and the case.

(2) Connect the 'X' input terminals to the b.f.o.; then, by the Lissajous method, check the 1 kc/s and 10 kc/s bridge oscillator frequencies. Adjust the frequency if necessary by means of RV1 and RV2.

In order to obtain a frequency accuracy that will compare with the original factory calibration, a suitable frequency standard should be connected to the 'X' deflection input of the oscilloscope instead of the b.f.o. detailed above. Changing the setting of any of the controls should not alter the frequency by more than 2% at 10 kc/s. The change at 1 kc/s should be negligible.

In the absence of the necessary test equipment for adjusting RV1 and RV2, as described above, an alternative method may be resorted to whereby the resonant frequencies of the tuned circuits in the amplifier-detector are used as standards. The procedure is as follows:—

(1) Connect a 1000-ohm resistor between the LOW terminal and the case.

(2) Adjust the LCR and RANGE switches for 100 henrys full-scale calibration.

(3) Adjust RV1 at 1 kc/s and RV2 at 10 kc/s to obtain maximum meter reading.

Oscillator-Amplifier Output. Connect the meter across the secondary winding of T1. For all settings of the bridge controls, the voltage measured at 1 kc/s and 10 kc/s should be of the order of 200 to 500 mV.

4.6.4 Measuring Bridge

(Apparatus required: Items e and f.)

Bridge Preset Resistors. To secure good accuracy, the bottom and two top resistance values switched into the RANGE arm of the bridge are adjusted by preset controls RV11, RV8, and RV7, respectively. The setting of these controls can be checked as follows:—

(1) Set the RANGE and LCR switches to the 10 ohms full-scale calibration.

(2) Connect a 10-ohm standard resistor across the test terminals, and check that the bridge balances with the BALANCE pointer indicating 10 ohms accurately. Adjust RV11 if necessary.

(3) Turn the RANGE switch to obtain 1 MΩ full-scale calibration. Connect a 1-MΩ standard resistor across the test terminals and proceed in a similar manner to (2) above, but adjust RV8 to obtain balance when the BALANCE pointer indicates 1 MΩ.

(4) Turn the RANGE switch to obtain the 10 MΩ full-scale calibration. Connect a 10-MΩ standard resistor, using the same procedure, but adjusting RV7 for accurate indication.

If standard resistance values are not available when carrying out the above procedure, an alternative method may be employed using suitable available resistors. The resistance values are first measured on the lower bridge ranges, making use of (and at the same time testing the accuracy of) the R × 10 facility. An example of this alternative method is shown below.

(1) Connect a resistor of about 100 kΩ across the test terminals; measure its resistance accurately on the 100-kΩ full-scale calibration range.

(2) Turn the RANGE switch to obtain 10-kΩ full-scale calibration, and measure the resistance on this range with the R × 10 switch pressed. This checks the multiplying facility.
(3) Connect a suitable resistor of about 1 MΩ across the test terminals. Measure this accurately on the 100-kΩ range with the R × 10 switch pressed.
(4) Release the R × 10 switch and turn the RANGE switch to obtain 1-MΩ full-scale calibration. Adjust RV8 if necessary to obtain balance with the pointer indicating the correct resistance value.
(5) Connect a resistor of about 10 MΩ across the test terminals. Measure the resistance accurately on the 1-MΩ full-scale calibration range with the R × 10 switch pressed.
(6) Release the R × 10 switch and turn the RANGE switch to obtain 10 MΩ full-scale calibration. Proceed in a similar manner to (4) above, but adjusting RV7, if necessary, for accurate indication.

Bridge Preset Capacitors. To secure good tan δ accuracy when making capacitance measurements, the three top resistance values which are switched into the RANGE arm of the bridge have reactance compensation added by means of preset capacitors C11, C12, and C13. The setting of these capacitors can be checked as follows:—

(1) Set the LCR and RANGE switches for 100-μμF full-scale calibration.
(2) Select TAN δ and 1 kc/s; then turn the PHASE BALANCE control to zero tan δ.
(3) Connect a suitable value of capacitor across the test terminals to permit balance near the full-scale end of the calibration. The component selected should be of high grade, with air dielectric.
(4) Balance the bridge for minimum meter reading, using the BALANCE control and adjusting C11 if necessary.
(5) Repeat the procedure for 0·001-μF full-scale calibration, selecting a suitable air dielectric capacitor. Adjust C12 if necessary.
(6) Repeat a similar procedure for 0·01-μF full-scale calibration. Adjust C13 if necessary, using an insulated tool. A high quality capacitor known to have an approximately zero value of tan δ should be used.

4.6.5 Amplifier-Detector

(Apparatus required: Item d.)

1-kc/s and 10-kc/s Inductors. The preset tuning adjustment of inductors L1 and L2 in the grid circuit of V3b is made before the instrument is dispatched. Accurate tape adjustment is made, the surplus being cut off and the remaining ends stuck down. It is not expected that the user will normally find it necessary to adjust these inductors.

To check the tuning of these inductors, remove the oscillator-amplifier valve V1, and connect the test oscillator—adjusted to give an output of approximately 1 mV—between the LOW terminal and the chassis. Switch to 1 kc/s and verify by observing the TF 868B meter indication while the b.f.o. frequency is being varied, that the amplifier is correctly tuned. Repeat at 10 kc/s.

Should it be found necessary to replace either L1 or L2, first ensure that the frequency of the oscillator is accurately adjusted as described in Section 4.6.3.

Before fitting the replacement inductor into the instrument, check first that the coated tape is free to pass between the core air gap. After the inductor is fitted allow sufficient warm-up period—at least 15 minutes—then connect a 1000-ohm resistor between the LOW terminal and the chassis and switch to 100 henrys full-scale calibration.

Pull the tape through the core and observe its approximate position for maximum meter indication, then continue to pull the tape for a further 3 in. Coat both sides of this 3-in. length of tape with a suitable adhesive before returning it to its previous position. Finally adjust for an accurate maximum meter indication. Cut off the surplus tape, stick down the free ends, and allow to dry.

Amplifier Hum-Level. The existence of excessive hum-level is indicated by a high value of minimum meter indication at balance. The procedure for reducing this effect is as follows:—

(1) Set the LCR and RANGE switches to the 10-MΩ full-scale calibration range. Short-circuit the test terminals and earth them to the nearest point on the instrument. Use the minimum amount of connecting wire to ensure that there is no hum pick-up as a result of this connection.
(2) Adjust RV3 and RV4 for minimum meter deflection.
(3) Balance the bridge using a low-value resistor across the test terminals, and check that the meter reading will fall within approximately the first two scale divisions of zero.

Note: Replacement of the first amplifier valve, V3, may necessitate the above procedure.

4.6.6 Calibration of Main Balance Dial

Checking Existing Calibrated Dial. First check that the pointer, when turned fully counter-clockwise, aligns with the mechanical-stop mark a little below the scale zero. Then: (i) remove the earth connections from the potentiometer RV9 and connect the Avometer between the ' earthy ' end and the sliding contact. Check that upon rotating the BALANCE pointer clockwise, the ' hop off ' point corresponds to the scale zero. (ii) Remove the Avometer and connect the Wheatstone Bridge. Check that, starting from zero scale, each calibration mark is separated by 5 ohms up to a resistance of 200 ohms, and then by 10-ohm divisions up to 1080 ohms. (4 on the scale should equal 400 ohms.)

If an error is found to be consistent all round the dial, and confirmed by the pointer not properly aligning with the mechanical stop mark, then remove the BALANCE knob, felt washer, and Perspex cover, and adjust the slow motion drive.

If the error is not constant, it may be necessary to replace RV9. When ordering a replacement for RV9, it will be noted from the Spares Ordering Schedule that a replacement BALANCE dial must also be obtained.

Calibrating a Replacement Balance Dial. It is normal, when replacing RV9, to obtain also a ready-calibrated BALANCE dial. Should, however, a blank dial be obtained, the method of calibration is as follows:—

(1) Switch to the maximum capacitance range so that 30 μF appears in the top calibration window.

(2) Using the exploded view, Fig. 5.5, as a guide, dismantle the BALANCE dial assembly, and then reassemble to include the replacement potentiometer and blank dial. Leave off the Perspex window.

(3) Rotate the control fully counter-clockwise and mark the dial to correspond with the position of the pointer.

(4) Connect the Avometer across RV9. Slowly rotate the pointer clockwise (and hence the sliding contact of RV9), to find the ' hop off ' point and mark the scale zero.

(5) Remove the Avometer and connect instead the Wheatstone Bridge. Commencing at the scale zero mark (which is commencement of the resistive track of RV9) mark the scale in increments of 5 ohms up to a resistance of 200 ohms, and then in 10-ohm divisions to 1080 ohms.

(6) Remove the Wheatstone Bridge and solder the circuit connections to RV9. Remove the dial for permanent engraving, or marking in black ink.

4.6.7 Checking the Phase Balance Dial Calibration

Q Scale. To check the scale, rotate the control to its maximum clockwise position, and ensure that the cursor hair-line coincides with the limit mark on the left of the Q-scale zero. If the cursor does not coincide with the limit mark, then the dial should be moved relative to the spindle of the ganged potentiometers RV5 and RV6.

Connect the Avometer across RV6 (front gang) and switch to tan δ. Check that when moving the dial counter-clockwise the ' hop off ' point corresponds with the scale zero. Remove the Avometer and connect the Wheatstone Bridge. Check that, commencing from 0, the scale markings correspond with the resistance values given in Table 5.

Tan δ. Disconnect the earth connection from RV5 (rear gang) and connect the Wheatstone Bridge. Commencing from 0, check that the scale markings correspond with the resistance values given in Table 6.

TABLE 5

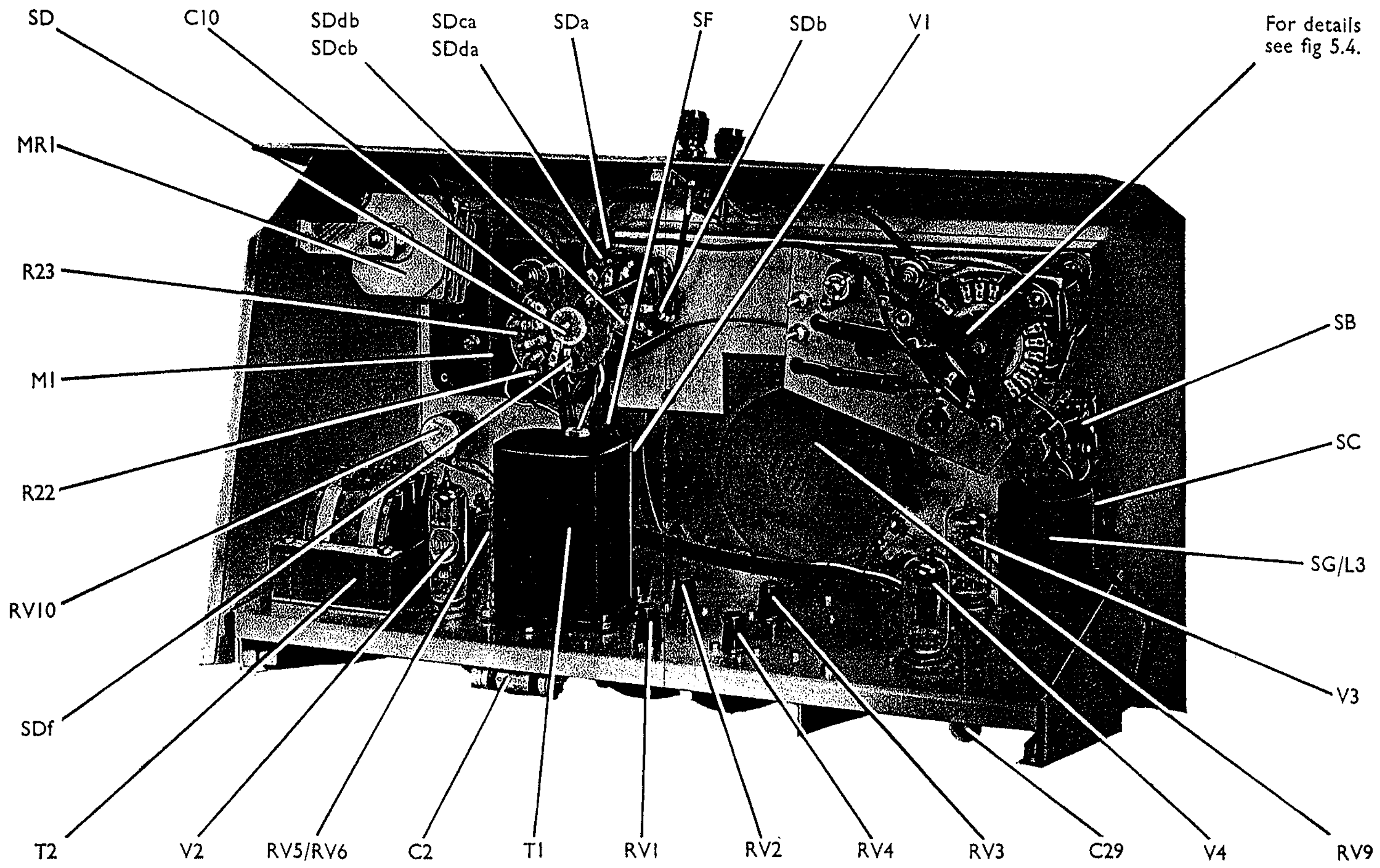
Q	*RV6* *R; ohms*
0·5	796
1	1592
1·5	2390
2	3190
2·5	3980
3	4780
3·5	5580
4	6370
5	7960
6	9560
7	11140
8	12770
9	14360
10	15920

TABLE 6

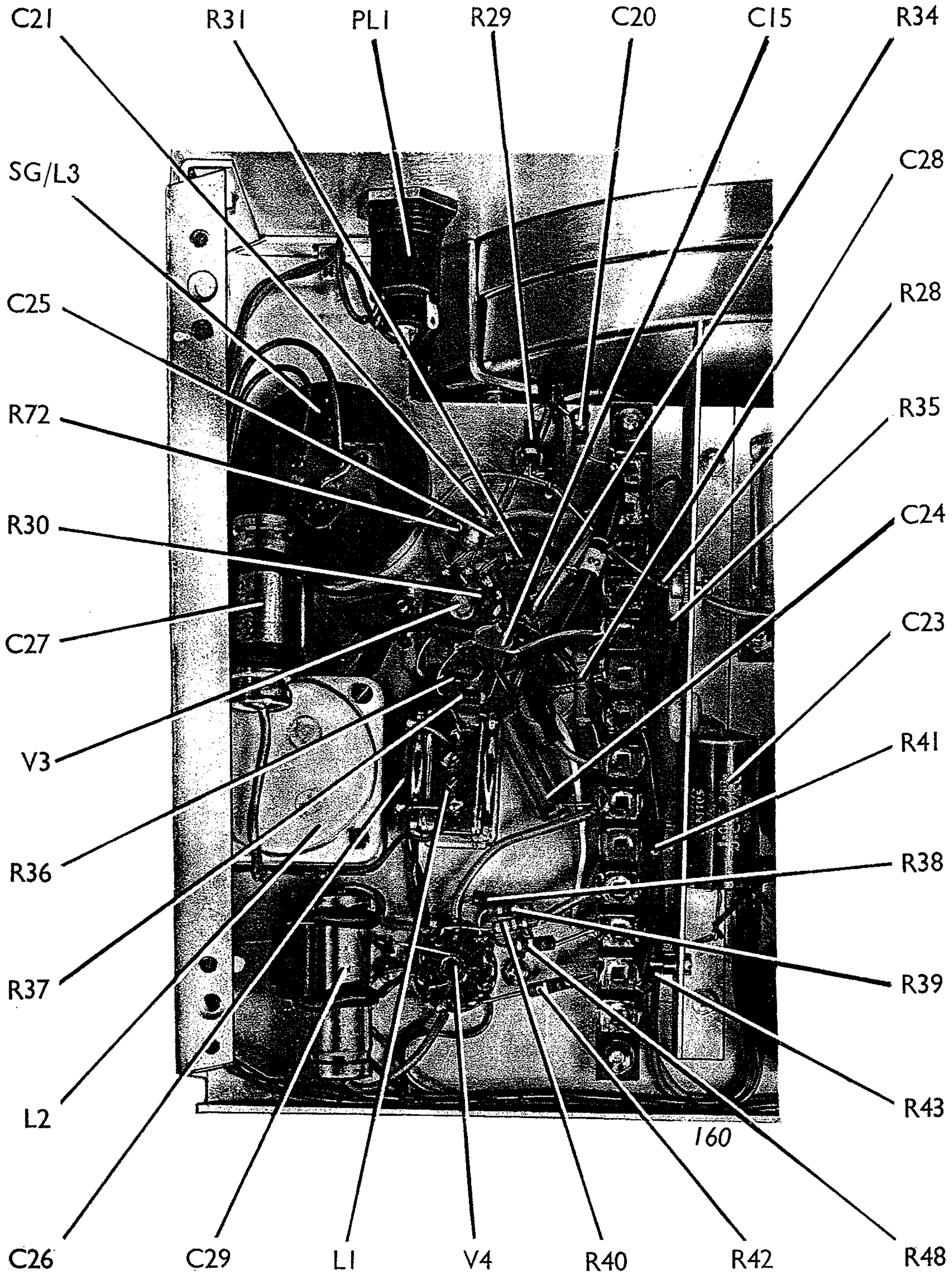
tan δ	*RV5* *R; ohms*
0·005	7·96
0·01	15·92
0·015	23·90
0·02	31·90
0·025	39·8
0·03	47·8
0·035	55·8
0·04	63·7
0·05	79·6
0·06	95·6
0·07	111·4
0·08	127·7
0·09	143·6
0·1	159·2

4.6.8 Calibrating the Phase Balance Dial

In the event of a failure of either RV5 or RV6, it will be noted from the SPARES ORDERING SCHEDULE that a complete ganged assembly must be obtained, together with a calibrated PHASE BALANCE dial. Should a blank dial be obtained, or if the user prefers to reverse the existing dial, then calibration can be effected by referring to the information given in Section 4.6.7 above, and Tables 5 and 6. After the calibration marks have been made, the dial should then be removed for permanent engraving, or marking in black ink.

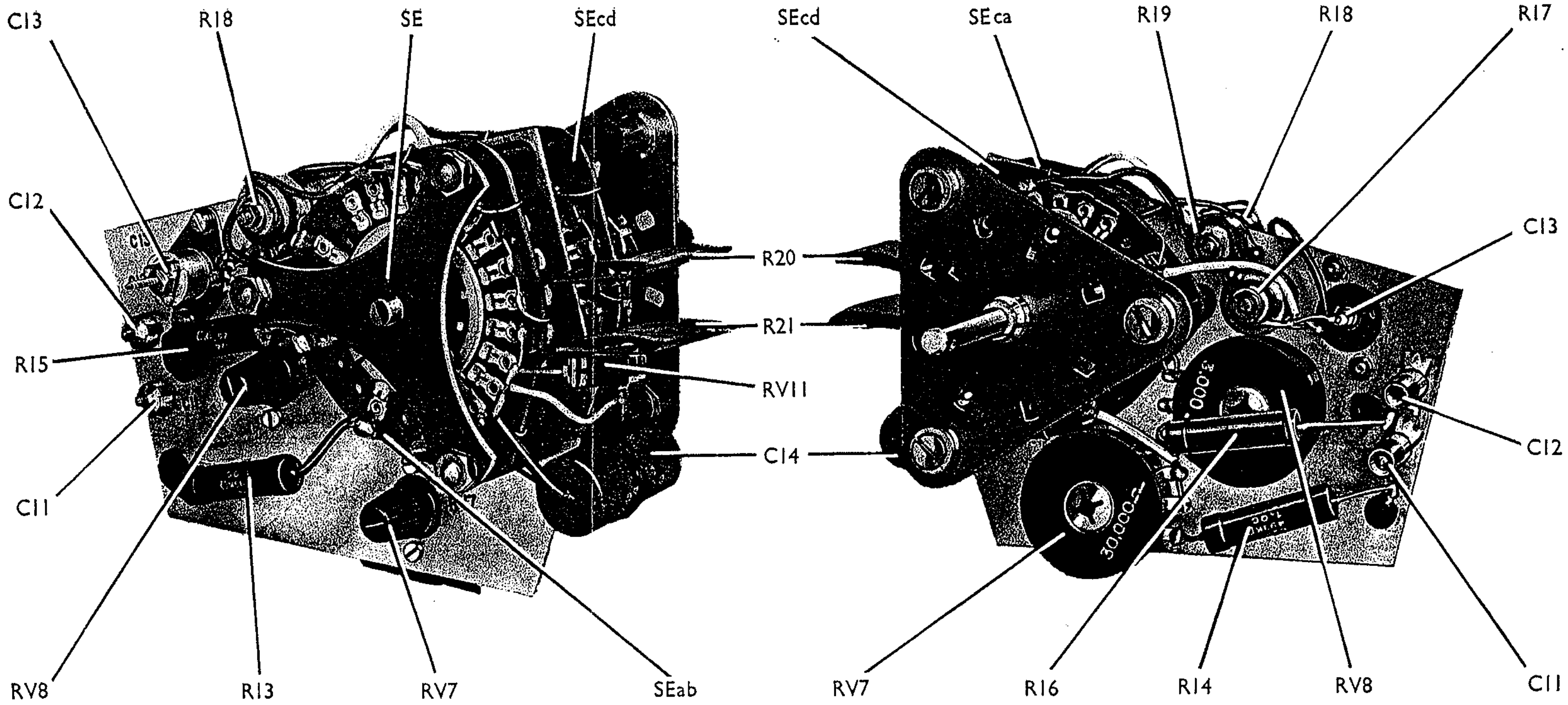


GENERAL VIEW FROM REAR



UNDERSIDE OF CHASSIS
AMPLIFIER-DETECTOR

Fig. 5.2

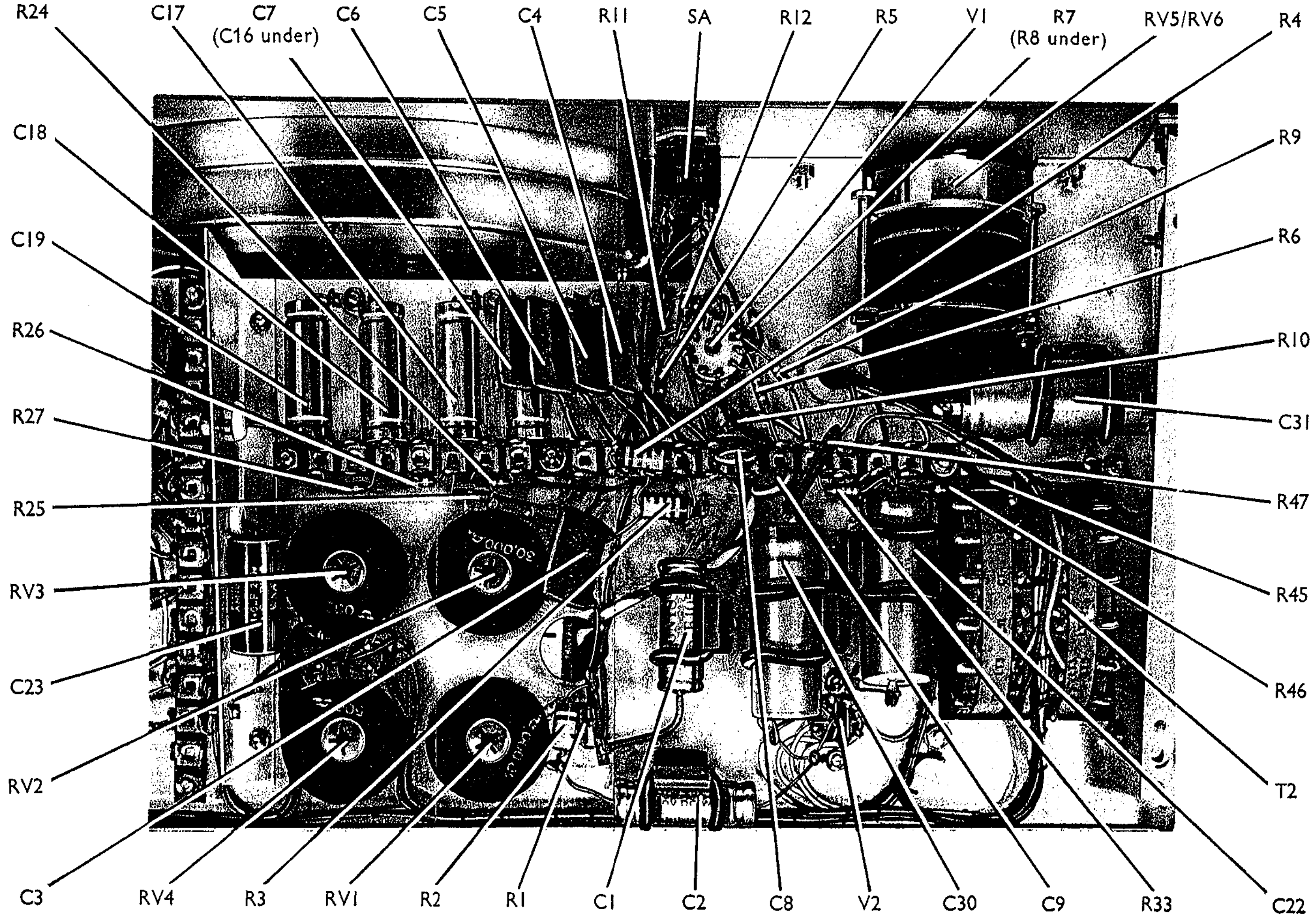


REAR VIEW

FRONT VIEW

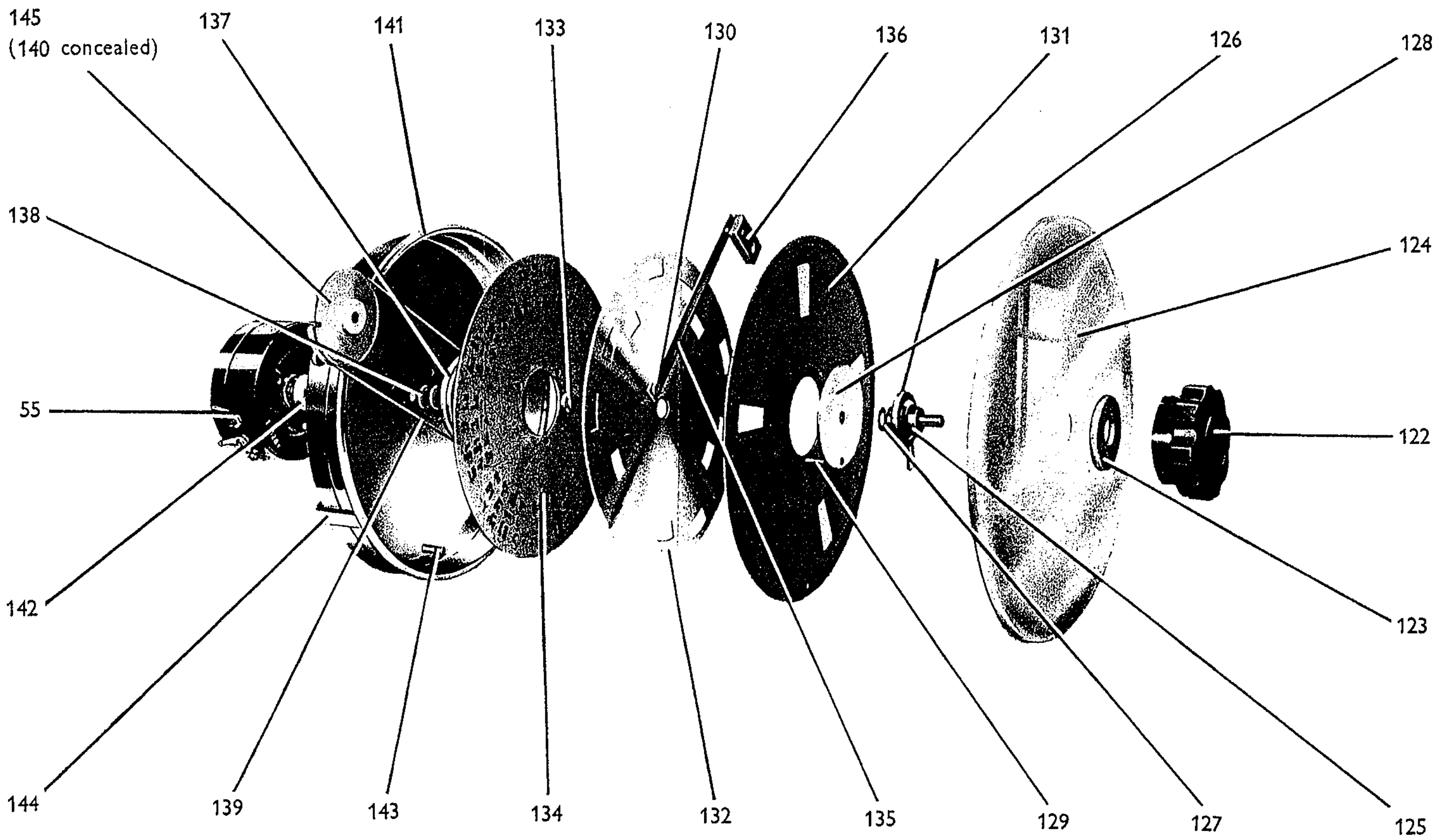
RANGE SWITCH ASSEMBLY

Fig. 5.4



UNDERSIDE OF CHASSIS
OSCILLATOR-AMPLIFIER AND POWER SUPPLY

Fig. 5.3



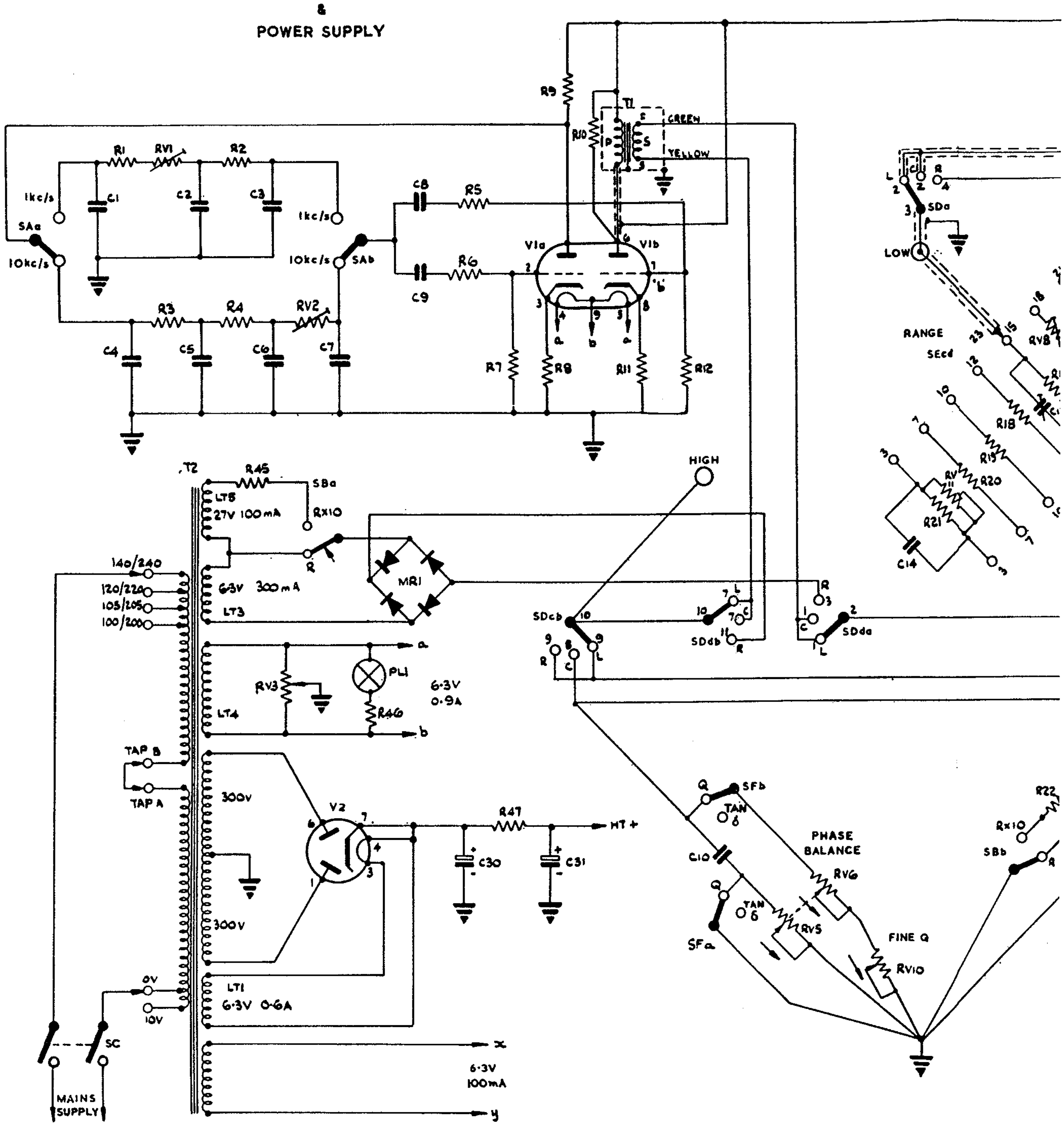
The annotation numbers are SOS Item Numbers as given in the Spares Ordering Schedule

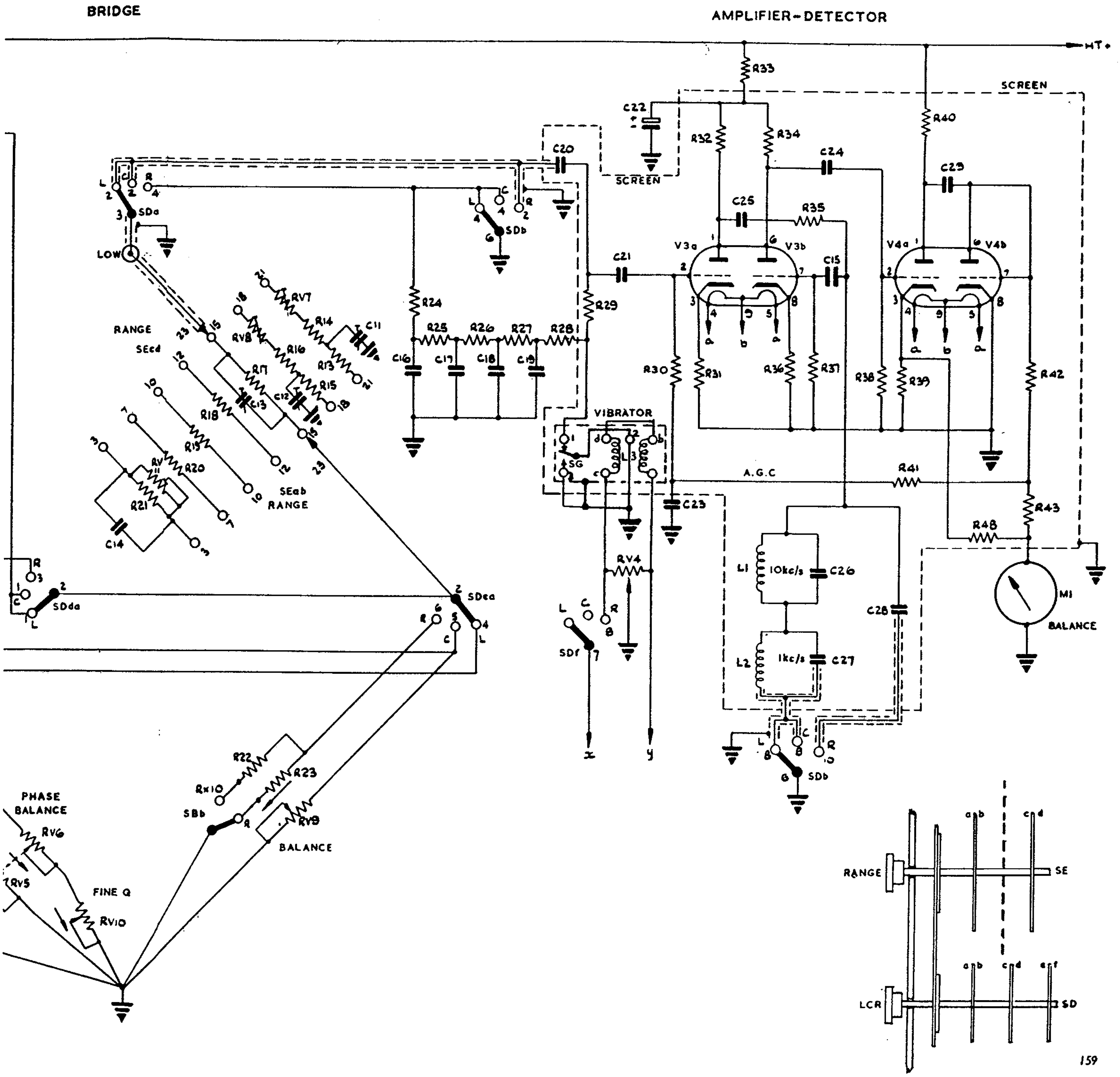
BALANCE DIAL ASSEMBLY

Fig. 5.5

OSCILLATOR-AMPLIFIER
&
POWER SUPPLY

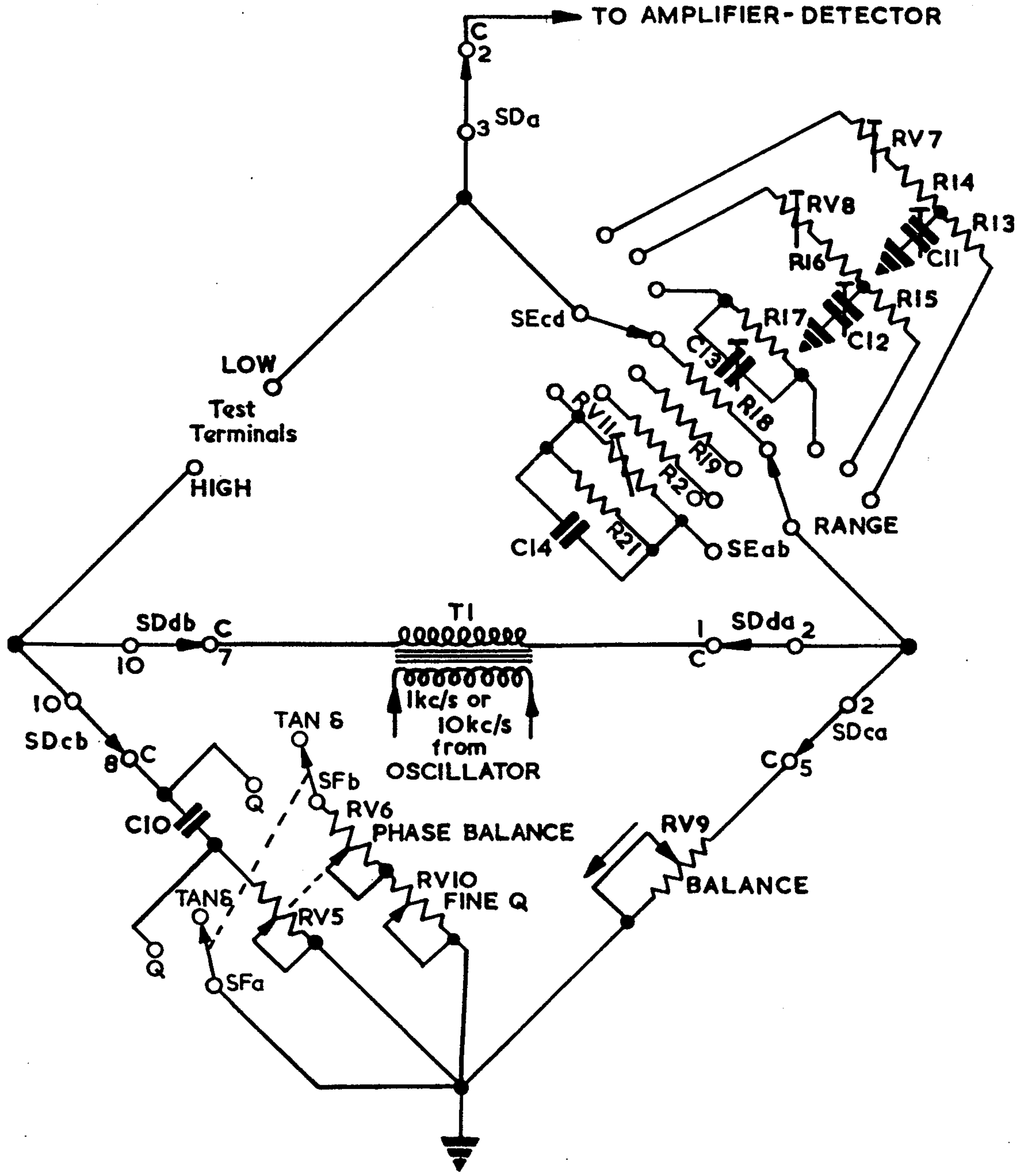
BRIDGE





COMPLETE CIRCUIT DIAGRAM

Fig. 6.1

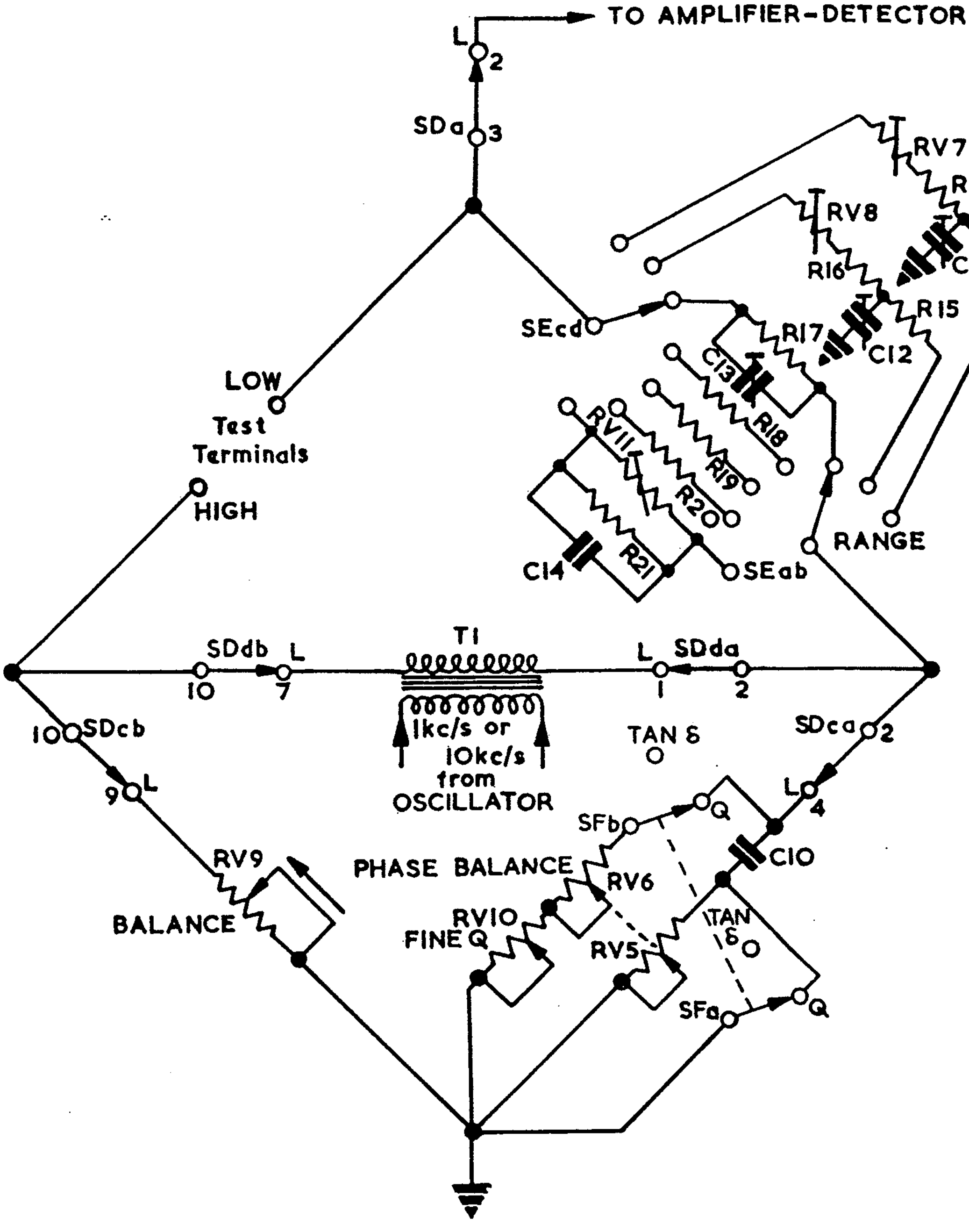


SWITCHED FOR CAPACITANCE MEASUREMENT

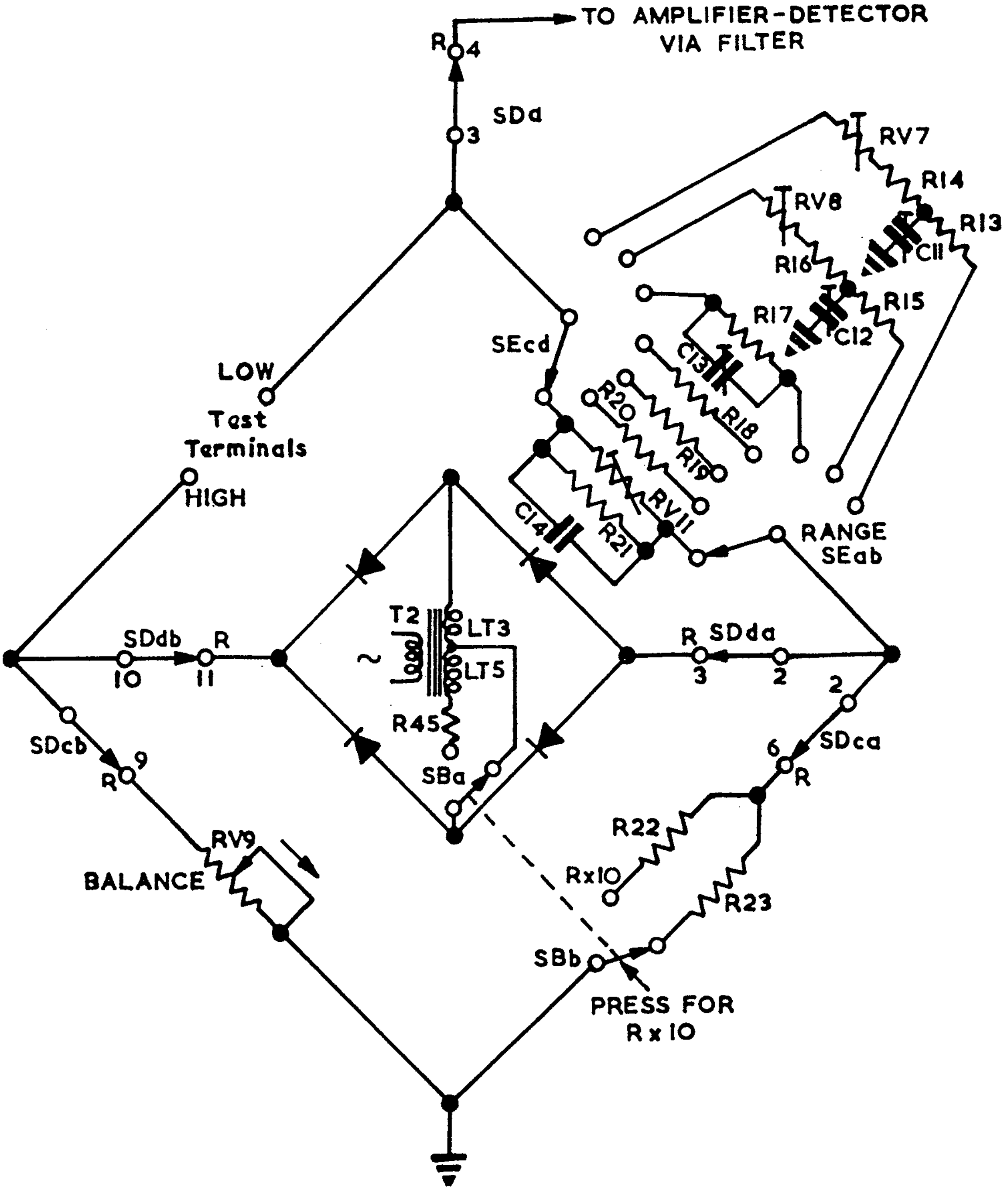
MEASURING BRIDGE CIRCUITS

Fig. 6.2

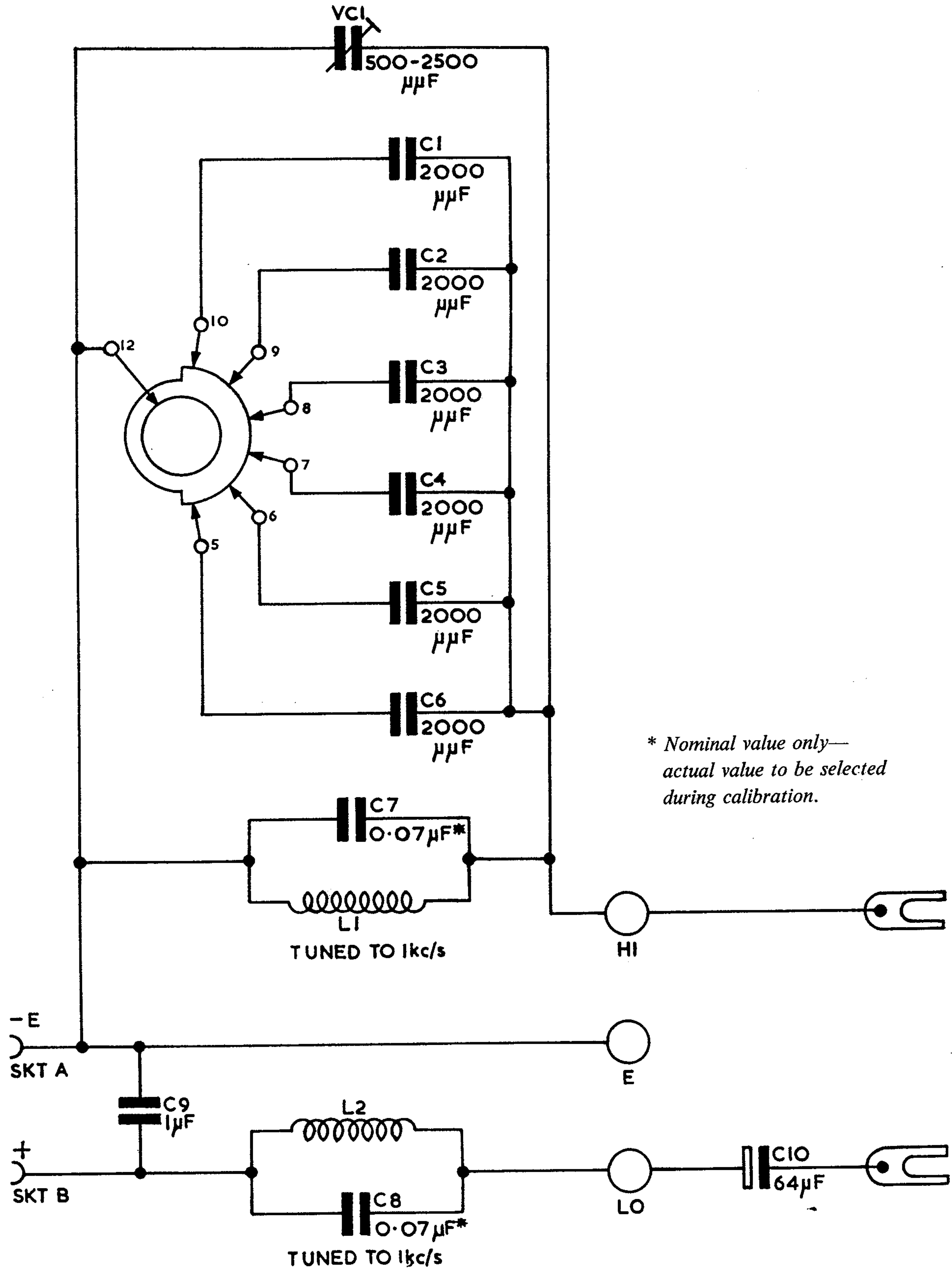
3



SWITCHED FOR INDUCTANCE MEASUREMENT



SWITCHED FOR RESISTANCE MEASUREMENT



D.C. CHOKE ADAPTOR

OM 868B
1–2/60

Fig. 6.3

7

Spares Ordering Schedule
No. SOS/868 B

for UNIVERSAL BRIDGE TYPE TF 868 B

When ordering replacement parts, always quote the TYPE NUMBER and SERIAL NUMBER of the instrument concerned.

To specify the individual parts required state for each part the QUANTITY required and the appropriate SOS ITEM NUMBER.

For example, to order replacement for the 12 kΩ resistor, R3, and the 0·01-μF capacitor, C27, quote as follows:—

Spares required for TF 868B, Serial Number 000000
1 off, SOS Item 3
1 off, SOS Item 83

It is most important that the code ' SOS ' preceding each item number should not be omitted.

SOS Item No.	*Circuit Ref.*	*Description*	*Works Ref.*
		FIXED RESISTORS	
1	R1	Composition, 10 kΩ ± 10%, ½W.	91–TF868B
2	R2	Composition, 100 kΩ ± 5%, ¼W. High stability	92–TF868B
3	R3	Composition, 12 kΩ ± 5%, ¼W. High Stability.	93–TF868B
4	R4	Composition, 12 kΩ ± 5%, ¼W. High Stability.	93–TF868B
5	R5	Composition, 330Ω ± 10%, ½W.	94–TF868B
6	R6	Composition, 330Ω ± 10%, ½W.	94–TF868B
7	R7	Composition, 2·2 MΩ ± 10%, ½W.	95–TF868B
8	R8	Composition, 220Ω ± 10%, ½W.	96–TF868B
9	R9	Composition, 33 kΩ ± 10%, ½W.	97–TF868B
10	R10	Composition, 22 kΩ ± 10%, ½W.	98–TF868B
11	R11	Composition, 330Ω ± 10%, ½W.	94–TF868B
12	R12	Composition, 470 kΩ ± 10%, ½W.	99–TF868B
13	R13	Carbon, High Stability, 493 kΩ ± 1%, 1W.	19–TM3961/2
14	R14	Carbon, High Stability, 493 kΩ ± 1%, 1W.	19–TM3961/2
15	R15	Carbon, High Stability, 49·3 kΩ ± 1%, 1W.	20–TM3961/2
16	R16	Carbon, High Stability, 49·3 kΩ ± 1%, 1W.	20–TM3961/2
17	R17	Wire-wound, Special Non-Inductive, 10 kΩ ± 0·1%.	21–TM3961/2
18	R18	Wire-wound, Special Non-Inductive, 1 kΩ ± 0·1%.	22–TM3961/2
19	R19	Wire-wound, Special Non-Inductive, 100Ω ± 0·1%.	23–TM3961/2
20	R20	Wire-wound, Special Non-Inductive, 9·99Ω ± 0·1%.	24–TM3961/2

SOS Item No.	*Circuit Ref.*	*Description*	*Works Ref.*
21	R21	Wire-wound, Special Non-Inductive, 1Ω ± 0·5%.	25–TM3961/2
22	R22	Wire-wound, 9·97Ω ± 0·1%.	TB20012/38
23	R23	Wire-wound, 99·95Ω ± 0·1%.	TC9638A
24	R24	Composition, 150 kΩ ± 10%, ½W.	102–TF868B
25	R25	Composition, 150 kΩ ± 10%, ½W.	102–TF868B
26	R26	Composition 150 kΩ ± 10%, ½W.	102–TF868B
27	R27	Composition, 150 kΩ ± 10%, ½W.	102–TF868B
28	R28	Composition, 1 MΩ ± 10%, ½W.	103–TF868B
29	R29	Composition, 1 MΩ ± 10%, ½W.	103–TF868B
30	R30	Composition, 4·7 MΩ ± 10%, ½W.	107–TF868B
31	R31	Composition, 1 kΩ ± 10%, ½W.	105–TF868B
32	R32	Composition, 220 kΩ ± 10%, ½W.	106–TF868B
33	R33	Composition, 33 kΩ ± 10%, ½W.	97–TF868B
34	R34	Composition, 220 kΩ ± 10%, ½W.	106–TF868B
35	R35	Composition, 1 MΩ ± 10%, ½W.	103–TF868B
36	R36	Composition, 1 kΩ ± 10%, ½W.	105–TF868B
37	R37	Composition, 4·7 MΩ ± 10%, ½W.	107–TF868B
38	R38	Composition, 1 MΩ ± 10%, ½W.	103–TF868B
39	R39	Composition, 330Ω ± 10%, ½W.	94–TF868B
40	R40	Composition, 33 kΩ ± 10%, ½W.	97–TF868B
41	R41	Composition, 10 MΩ ± 10%, ½W.	104–TF868B
42	R42	Composition, 100 kΩ ± 10%, ½W.	108–TF868B
43	R43	Composition, 68 kΩ ± 10%, ½W.	109–TF868B
44	R45	Wire-wound, fibre-cored, 330Ω ± 5%, 3W.	110–TF868B
45	R46	Composition, 15Ω ± 10%, ½W.	111–TF868B
46	R47	Wire-wound, fibre-cored, 5·6 kΩ ± 5%, 3W.	112–TF868B
47	R48	Composition, 220 kΩ ± 10%, ½W.*	106–TF868B

* *Nominal value, Actual value determined during calibration.*

VARIABLE RESISTORS

48	RV1	Wire-wound, 30 kΩ ± 10%, 3W, Linear.	83–TF868B
49	RV2	Wire-wound, 30 kΩ ± 10%, 3W, Linear.	83–TF868B
50	RV3	Wire-wound, 500Ω ± 10%, 3W, Linear.	84–TF868B
51	RV4	Wire-wound, 500Ω ± 10%, 3W, Linear.	84–TF868B
52	RV5 and RV6	Ganged assembly. Each section wire-wound, semi-log law, 4W. RV5 is 160Ω and RV6 is 16 kΩ. Order item 120 also.	TB29395
53	RV7	Wire-wound, 30 kΩ ± 10%, 3W, Linear.	16–TM3961/2
54	RV8	Wire-wound, 3 kΩ ± 10%, 3W, Linear.	17–TM3961/2
55	RV9	Wire-wound, 1100Ω semi-log law. Order item 131 also.	TB17655/2
56	RV10	Wire-wound, 100Ω ± 10%, 2W.	87–TF868B
57	RV11	Wire-wound, sub-min. Preset, 300Ω ± 10%, ½W.	18–TM3961/2

SOS Item No.	*Circuit Ref.*	*Description*	*Works Ref.*
		CAPACITORS	
58	C1	Paper, 0·05 μF ± 10%, 500 V d.c.	118–TF868B
59	C2	Paper, 0·01 μF ± 5%, 1000 V d.c.	119–TF868B
60	C3	Mica, 0·003 μF ± 2%, 350 V d.c.	120–TF868B
61	C4	Mica, 1500 μμF ± 2%, 350 V d.c.	121–TF868B
62	C5	Mica, 1500 μμF ± 2%, 350 V d.c.	121–TF868B
63	C6	Mica, 1500 μμF ± 2%, 350 V d.c.	121–TF868B
64	C7	Mica, 1500 μμF ± 2%, 350 V d.c.	121–TF868B
65	C8	Disc Ceramic, 0·01 μF + 80% —20%, 300 V d.c.	122–TF868B
66	C9	Disc Ceramic, 0·01 μF + 80% —20%, 300 V d.c.	122–TF868B
67	C10	Polystyrene, 0·1 μF ± 0·1%, 350 V d.c.	123–TF868B
68	C11	Air, Preset, 0·5–5 μμF, 500 V d.c.	28–TM3961/2
69	C12	Air, Preset, 0·5–5 μμF, 500 V d.c.	28–TM3961/2
70	C13	Air, Preset, 3–30 μμF, 75 V d.c.	29–TM3961/2
71	C14	Melinex, 1 μF ± 20%, 250 V d.c.	30–TM3961/2
72	C15	Disc Ceramic, 0·01 μF + 80% —20%, 300 V d.c.	122–TF868B
73	C16	Paper, 0·1 μF ± 20%, 500 V d.c.	124–TF868B
74	C17	Paper, 0·1 μF ± 20%, 500 V d.c.	124–TF868B
75	C18	Paper, 0·1 μF ± 20%, 500 V d.c.	124–TF868B
76	C19	Paper, 0·1 μF ± 20%, 500 V d.c.	124–TF868B
77	C20	Ceramic, 470 μμF ± 20%, 500 V d.c.	125–TF868B
78	C21	Ceramic, 470 μμF ± 20%, 500 V d.c.	125–TF868B
79	C22	Electrolytic, 8 μF, 450 V d.c.	126–TF868B
80	C23	Melinex, 1 μF ± 20%, 250 V d.c.	127–TF868B
81	C24	Ceramic, 3000 μμF ± 20%, 500 V d.c.	128–TF868B
82	C25	Ceramic, 1000 μμF ± 20%, 500 V d.c.	129–TF868B
83	C26	Mica, 2540 μμF ± 2%, 350 V d.c.	130–TF868B
84	C27	Paper, 0·01 μF ± 5%, 1000 V d.c.	119–TF868B
85	C28	Ceramic, 1000 μμF ± 20%, 500 V d.c.	129–TF868B
86	C29	Paper, 0·1 μF ± 20%, 350 V d.c.	124–TF868B
87	C30	Electrolytic 8 μF, 450 V d.c.	126–TF868B
88	C31	Electrolytic 8 μF, 450 V d.c.	126–TF868B
		TRANSFORMERS AND INDUCTORS	
89	T1	Oscillator Output Transformer.	TM5873
90	T2	Mains transformer.	TM5149/8
91	L1	Ferroxcube Inductor, 0·1 H, complete with adjustable tape.	TM5871
92	L2	Ferroxcube Inductor, 2·5 H, complete with adjustable tape.	TM5872

SOS Item No.	*Circuit Ref.*	*Description*	*Works Ref.*
		VIBRATOR RELAY AND HOLDER	
93	L3/SG	Siemens Type 130G.	80–TF868B
94		Holder for Relay.	TB28515
		VALVES AND VALVE HOLDERS	
95	V1	Double Triode Type 12AT7.	137–TF868B
96		Holder for V1, B9A with skirt.	TB26905
97		Screening can for V1.	PC17502/1
98	V2	Full-wave Rectifier, Type 6X4.	138–TF868B
99		Holder for V2, B7G.	TB26904/4
100	V3	Double Triode, Type 12AX7.	139–TF868B
101		Holder for V3, B9A.	TB26905/4
102	V4	Double Triode, Type 12AX7.	139–TF868B
103		Holder for V4, B9A.	TB26905/4
		RECTIFIER AND BRACKETS	
104	MR1	Rectifier.	81–TF868B
105		Rectifier bracket.	TB28496
		PILOT LAMP AND HOLDER	
106	PL1	Pilot Lamp, Tubular, 6·3-volt, 0·15-amp, M.B.C.	14–TF868B
107		Holder for PL1.	13–TF868B
		METER	
108	M1	Moving Coil, 0–100 μA, 500Ω nominal.	TM3970/87
		SWITCHES	
109	SA	Toggle, 2 pole, 2 position changeover.	TB23903/2
110	SB	Toggle, 2 pole, 2 position changeover, biased to one position.	TB23903/1
111	SC	Toggle, 2 pole, 2 position changeover.	TB23903/2
112	SD	Rotary, 8 pole, 3 position, 3 wafer.	TC4428/492
113		Complete RANGE switch assembly including items 53, 54, 57, and 113, also items 13 to 21, and 68 to 71 inclusive.	TM3961/2
114	SE	Rotary, 2 pole, 7 position, 2 wafer complete with screen.	1–TM3961/2
115	SF	Toggle, 2 pole, 2 position changeover.	TC23903/2

KNOBS, DRIVES, AND DIALS

SOS Item No.	*Circuit Ref.*	*Description*		*Works Ref.*
116		Knob for LCR switch, SD.		TB23920/46
117		Knob for RANGE switch, SE.		TB23920/34
118		Knob for PHASE BALANCE control, RV5/RV6.		TB23920/34
119		Knob for FINE Q control, RV10.		TB23920/1
120		Calibrated PHASE BALANCE dial. Order Item 52 also.		TB29394
120/1		Blank PHASE BALANCE dial.		TB29394
120/2		Cursor for PHASE BALANCE dial.		TB25273/4
121		Complete BALANCE dial assembly comprising Item 55 and Items 122 to 145 inclusive.		
122		Knob.		TC26605/10
123		Felt Spacer.		TB25002/114
124		Perspex Window.		TC18378/4
125		Slow Motion Drive.		TA17746
126		Pointer.		TB28487
127		Shim Washer.		TB6775/211
128		Cover Plate.		TB28482
129		Stud.		TB28484
130		Shoulder Screw.		TB28485
131		Calibrated Dial. Order Item 55 also.		TC28499
132		RANGE Shutter.		TC28500
133		Bush.	*To identify these parts see exploded view of main* BALANCE *dial, Fig.* 5.5	TB28486
134		Engraved RANGE Dial.		TE17646 TC28497
135		Link.		TB28495
136		Lever Assembly.		TB29405
137		Pulley.		TB28488
138		Washer, ¼ in. B.S.F. (2 used)		73–TF868B
139		Drive Cord.		TB18892
140		Tension Spring.		TB15342/12
141		Drum.		TC28498
142		Spacer.		TB25001/367
143		Spacer.		TB25001/310/P34
144		Fixing Bracket (2 used).		TE17645/15
145		Pulley.		TB22703/1B

SOS Item No.	*Circuit Ref.*	*Description*	*Works Ref.*
		MISCELLANEOUS	
147		Front Panel.	TE28509
148		Chassis.	TE28510
149		Chassis Component Screen.	TC28506
150		Screen Cover.	TB28520
151		Chassis Side Plate (L.H.).	TD28504/1
152		Chassis Side Plate (R.H.).	TD28504
153		Instrument Case.	TE24711/3
154		Case Handle.	TC17659
155		Rubber Bush for Moulded Feet.	TA17718
156		Mains Lead Assembly.	TM2650AQ
157		HIGH or LOW Terminal.	TB23482/26
158		Support Plate for LRC and RANGE switches.	TC28507
159		Condenser Cleat and Retention Band, Size 3.	74–TF868B
160		Condenser Cleat and Retention Band, Size 4.	60–TF868B
161		Abridged Operating Instructions Plate.	46–TF868B
162		Set of three Hexagonal Wrenches for Socket Set Screws, Sizes 2, 4, and 6BA; complete in linen bag.	143–TF868B

SOS Item No.	Circuit Ref.	Description	Works Ref.
		D.C. CHOKE ADAPTOR	
163		Chassis.	TD31305
164		Cover.	TD31306
165		Terminals, Type B (3 used).	TB23482/28
166		Connecting Lug (2 used).	TB31313
167		Tag Strip (2 used).	TC29515/15
168	S1	Switch, Rotary.	TC4428/545
169		Knob for S1.	TC17848/4
170	VC1	Variable Capacitor, 500–2500 μμF.	30–TM6113
171		Knob for VC1.	TB28666
172	C1	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
173	C2	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
174	C3	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
175	C4	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
176	C5	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
177	C6	Capacitor, Ceramic 2000 μμF ± 20%, 500 V d.c.	29–TM6113
178	C7	Capacitor, 0·07 μF (nominal value).*	—
179	C8	Capacitor, 0·07 μF (nominal value).*	—
180	C9	Capacitor, Electrolytic 1 μF, 350 V d.c.	27–TM6113
181	C10	Capacitor, Electrolytic 32–32 μF, 350 V d.c.	26–TM6113
182	L1	Coil Assembly.	TB31309
183		Ferroxcube Cores for L1 (2 pairs used).	33–TM6113
184	L2	Inductor Assembly, including Items 185 and 186.	TM6147
185		Coil Assembly.	TB31309
186		Ferroxcube Cores for L2 (2 pairs used).	33–TM6113

**Adjust this capacitance value to achieve resonance at 1 kc/s with associated inductor.*