INSTRUCTION MANUAL
No. OM 1313A
for

0.1% Universal Bridge
TF 1313A

M.I. Technical Publications

MARCONI INSTRUMENTS LIMITED

NOTES AND CAUTIONS

ELECTRICAL SAFETY PRECAUTIONS

This equipment is protected in accordance with IEC Safety Class 1. It has been designed and tested according to IEC Publication 348, 'Safety Requirements for Electronic Measuring Apparatus', and has been supplied in a safe condition. The following precautions must be observed by the user to ensure safe operation and to retain the equipment in a safe condition.

Defects and abnormal stresses

Whenever it is likely that protection has been impaired, for example as a result of damage caused by severe conditions of transport or storage, the equipment shall be made inoperative and be secured against any unintended operation.

Removal of covers

Removal of the covers is likely to expose live parts although reasonable precautions have been taken in the design of the equipment to shield such parts. The equipment shall be disconnected from the supply before carrying out any adjustment, replacement or maintenance and repair during which the equipment shall be opened. If any adjustment, maintenance or repair under voltage is inevitable it shall only be carried out by a skilled person who is aware of the hazard involved.

Note that capacitors inside the equipment may still be charged when the equipment has been disconnected from the supply. Before carrying out any work inside the equipment, capacitors connected to high voltage points should be discharged; to discharge mains filter capacitors, if fitted, short together the L (live) and N (neutral) pins of the mains plug.

Mains plug

The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action shall not be negated by the use of an extension lead without protective conductor. Any interruption of the protective conductor inside or outside the equipment is likely to make the equipment dangerous.

Fuses

Note that there is a supply fuse in both the live and neutral wires of the supply lead. If only one of these fuses should rupture, certain parts of the equipment could remain at supply potential.

To provide protection against breakdown of the supply lead, its connectors, and filter where fitted, an external supply fuse (e.g. fitted in the connecting plug) should be used in the live lead. The fuse should have a continuous rating not exceeding 6 A.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of mended fuses and the short-circuiting of fuse holders shall be avoided.

RADIO FREQUENCY INTERFERENCE

This equipment conforms with the requirements of IEC Directive 76/889 as to limits of r.f. interference.

Contents

Section I General information

1.1 INTRODUCTION

TF 1313A is a general-purpose impedance bridge with one tenth per cent measurement accuracy over a wide range of inductance, capacitance, and resistance values. It offers exceptional discrimination and resettability, wide-range loss balancing, and facilities for using an external oscillator and detector.

The single direct-reading dial used for L, C, and R measurements has coarse and fine concentric controls; the coarse one moves in 1% steps and the fine gives continuously variable interpolation between steps. The variable and non-linear sensitivity of the detector facilitates easy measurement of completely unknown components. An external audio oscillator can be plugged in where L and C measurements are required at frequencies other than the internal 1 and 10 kc/s; the detector output is available externally to allow an oscilloscope or headphones to be used for balance indication.

This bridge can be used for precision evaluation of resistance, capacitance and inductance, for measuring the dissipation factor of capacitors and Q of inductors, and for quickly identifying unknown components. Measurements on high-loss components are made easier by the low D and Q ranges of the loss balance control and the relative independence between the adjustment of the main and loss balance controls. Its high discrimination and resettability make it particularly suitable for comparative measurements such as checking the difference between an unknown and a standard component. Measurements on inductors carrying d.c. can be made by using Adaptor Type TM 6113, which is available as an optional accessory, while an external d.c. supply can be connected direct for polarizing capacitors.

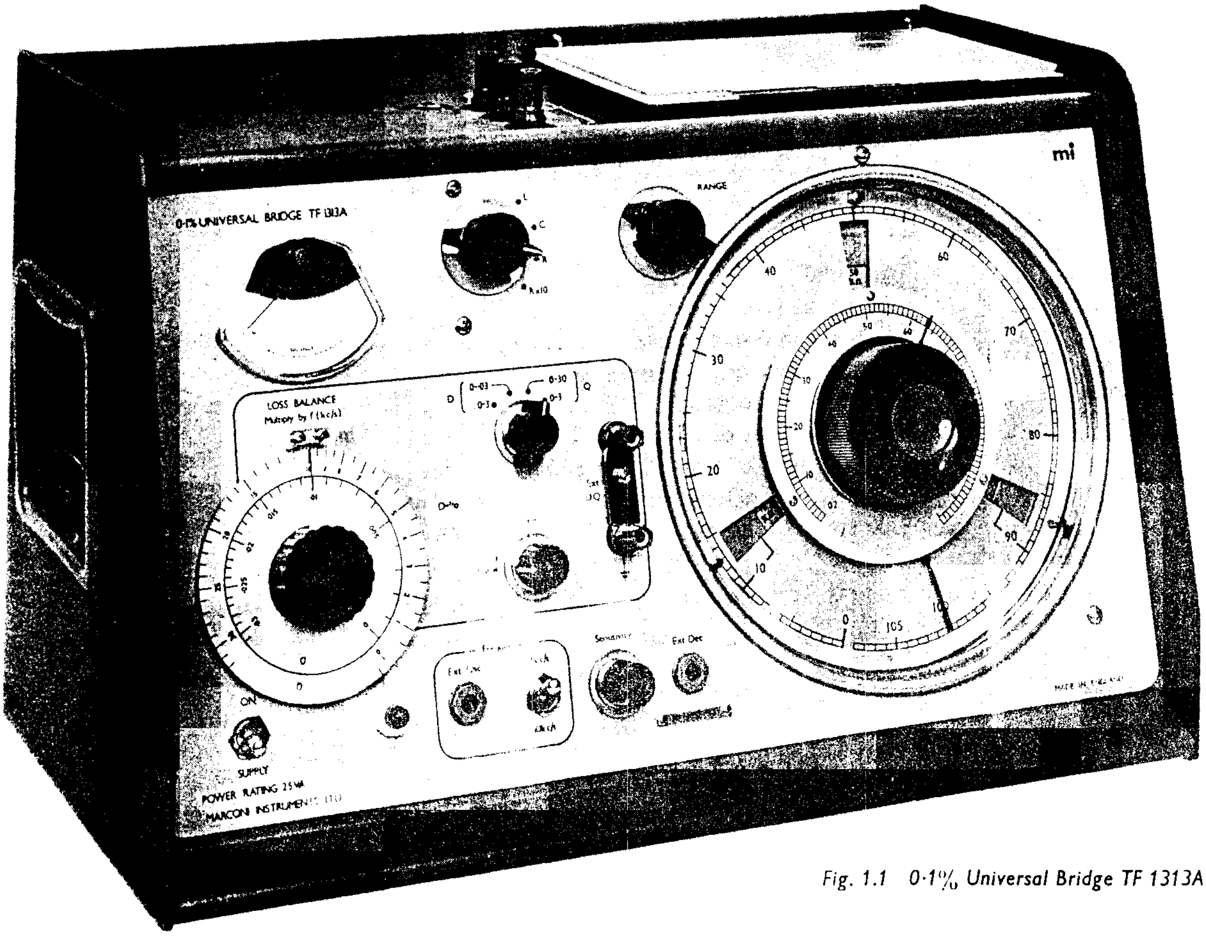


Fig. 1.1 0·1% Universal Bridge TF 1313A

1.2 DATA SUMMARY

Resistance measurement

Range :	3 mΩ to 110 MΩ in eight ranges with maxima of 11 Ω, 110 Ω, 1.1 kΩ, 11 kΩ, 110 kΩ, 1.1 MΩ, 11 MΩ, 110 MΩ.
Accuracy :	Basic measurement error : ±0.1% of reading, or ±0.015% of range maximum, whichever is greater. Range errors : 110 Ω to 1.1 MΩ ranges inclusive - basic errors only. 11 Ω and 11 MΩ ranges - basic errors, and additional ±0.1% of reading. 11 MΩ x 10 range - basic errors, and additional ±0.15% of reading.
Residual resistance :	Less than 0.003 Ω.

Inductance measurement

Range :	0.1 μH to 110 H in seven ranges, with maxima of 110 μH, 1.1 mH, 11 mH, 110 mH, 1.1 H, 11 H, 110 H.
Accuracy :	Basic measurement error at 1 kc/s : ±0.1% of reading, or ±0.015% of range maximum whichever is greater. Basic measurement error at 10 kc/s : ±0.2% of reading, or ±0.025% of range maximum, whichever is greater. Range errors : 1.1 mH to 11 H ranges inclusive - basic errors only. 110 μH and 110 H ranges - basic errors, and additional ±0.1% of reading. Additional errors at Low Q : $\pm\left(0.1 \times \frac{f}{Q}\right)\%$, where f is in kc/s.
Residual inductance :	Typically 0.05 μH.

Capacitance measurement

Range :	0.1 pF to 110 μF in seven ranges, with maxima of 110 pF, 1100 pF, 0.011 μF, 0.11 μF, 1.1 μF, 11 μF, 110 μF.
Accuracy : (when D is not greater than 0.031)	Basic measurement error at 1 kc/s : ±0.1% of reading, or ±0.015% of range maximum, whichever is greater. (When D is greater than 0.031 additional error is typically $\pm 0.3D^2\%$).

Accuracy : (when D is not greater than 0.031) - continued -	Basic measurement error at 10 kc/s : ±0.2% of reading, or ±0.025% of range maximum, whichever is greater. (When D is greater than 0.031 and less than 0.31, additional error is typically $\pm 6D^2\%$.)
	Range errors : 1100 pF to 11 μF ranges inclusive - basic errors only. 110 pF and 110 μF ranges - basic errors, and additional ±0.1% of reading.
Residual capacitance :	Less than 0.05 pF.

Temperature range : 18°C to 28°C for the stated accuracies.

Temperature coefficient : Additional error of ±0.01% per degree C, for temperatures between 10°C and 18°C, and 28°C and 35°C.

Q and D measurement

Range :

	1 kc/s	10 kc/s
Low Q range :	0 to 3	0 to 30
Normal Q range :	0.5 to 31	5 to 310
Normal D range :	0.0005 to 0.031	0.005 to 0.031 (limited)
High D range :	0.005 to 3	Not required

Accuracy :

Normal Q : ±5% of reading, ±0.5% of full scale.
Normal D : ±5% of reading.
Low Q and High D : ±10% of reading, ±3% of full scale.

Additional D or $\frac{1}{Q}$ error at 1 kc/s and below :
less than ±0.0005 with correction supplied (on top of instrument), or
less than ±0.0015 without correction.
(Above 1 kc/s multiply by f kc/s.)

Bridge sources and detector

Internal sources :

1 kc/s and 10 kc/s oscillators for L and C measurement, accuracy ±2.5%; output level, depending on loading, up to 750 mV.

D. C. supply for R measurement; less than 100 mW component loading.

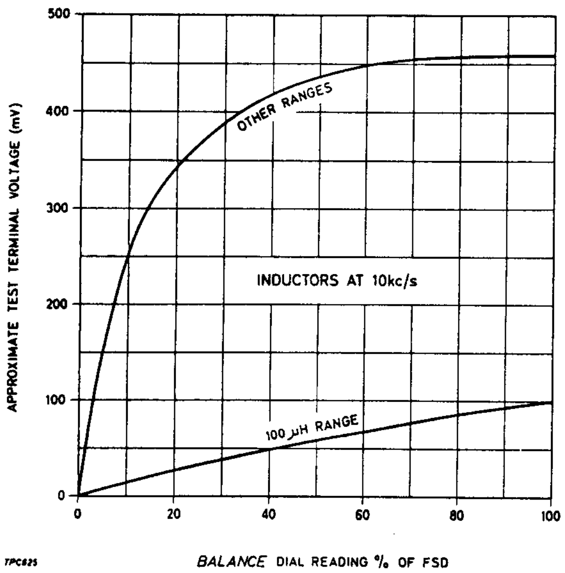
External oscillators :

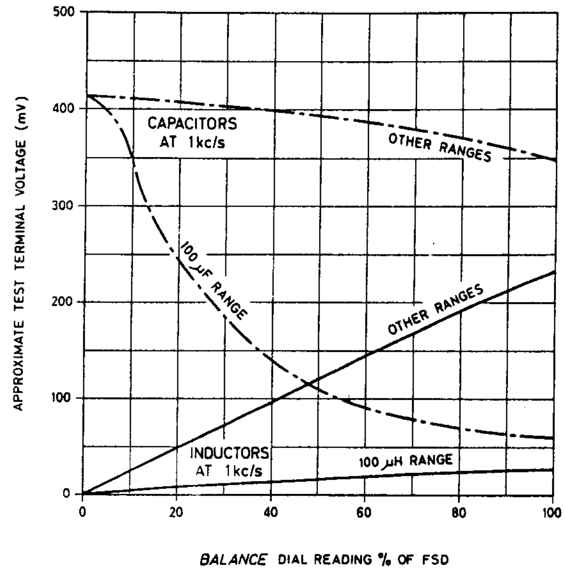
Frequency range: 20 c/s to 30 kc/s.
Input level required : 3 to 20 V depending on frequency.
(An external tuned detector is also necessary to achieve the quoted measurement accuracies.)

Additional L and C errors : Typically :

Frequency	% error
20 c/s	±.05
100 c/s	±.03
20 kc/s	±0.2
30 kc/s	±0.35

Test terminal voltage at balance:





CAPACITOR BIAS :	Up to 350 V d. c. may be applied for polarizing electrolytic capacitors.
POWER SUPPLY	
A. C. mains :	100 to 130 V and 200 to 250 V, 45 to 180, 275 to 300, 366 to 400 c/s. 25 VA.

DIMENSIONS & WEIGHT :

Height	*Width*	*Depth*	*Weight*
$11\frac{1}{2}$ in (30 cm)	$19\frac{1}{2}$ in (50 cm)	10 in (26 cm)	29 lb (13.2 kg)

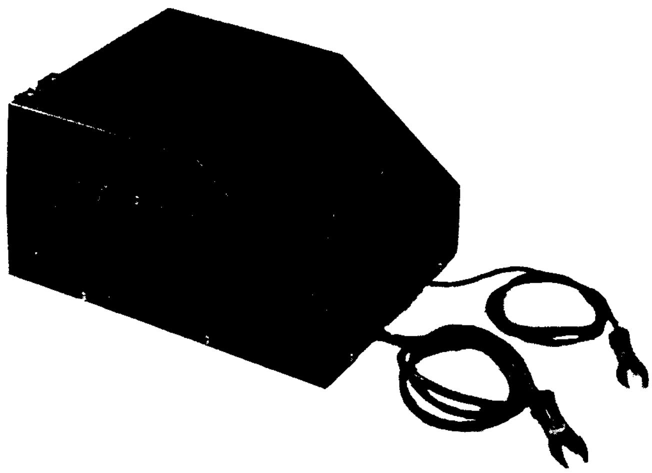
1.3 ACCESSORIES

Supplied

Three telephone plugs, type P40, for external oscillator and detector and bias jacks.

Available

D. C. Choke Adaptor, type TM 6113 ; enables d. c. currents up to 200 mA from an external supply to be passed through inductors under test at 1 kc/s in the range 100 mH to 100 H; fitted with test leads for attaching to bridge terminals. Errors introduced by the adaptor do not generally exceed 3% and may be eliminated by simple substitution methods.



Section 2 Operation

2.1 INSTALLATION

The 0.1% Universal Bridge is normally dispatched with its valves in position and with its mains input circuit adjusted ready for immediate use on 240 V within the basic supply frequency range 45 to 400 c/s. Note that harmonics of supply frequencies of 200, 250 and 333 c/s may give rise to interference which will obscure the balance point.

If required, the instrument may be adjusted for operation from other supplies within the ranges 100 to 130 and 200 to 250 V. To check, or alter the tappings on the mains transformer, refer to Section 4.4.

2.2 CONTROLS AND CONNECTIONS

(1) TEST TERMINALS. Connect the component between the HI and DET terminals.

(2) COMPONENT PLATFORM and ABRIDGED OPERATING INSTRUCTIONS. Supports components, isolating them from chassis.

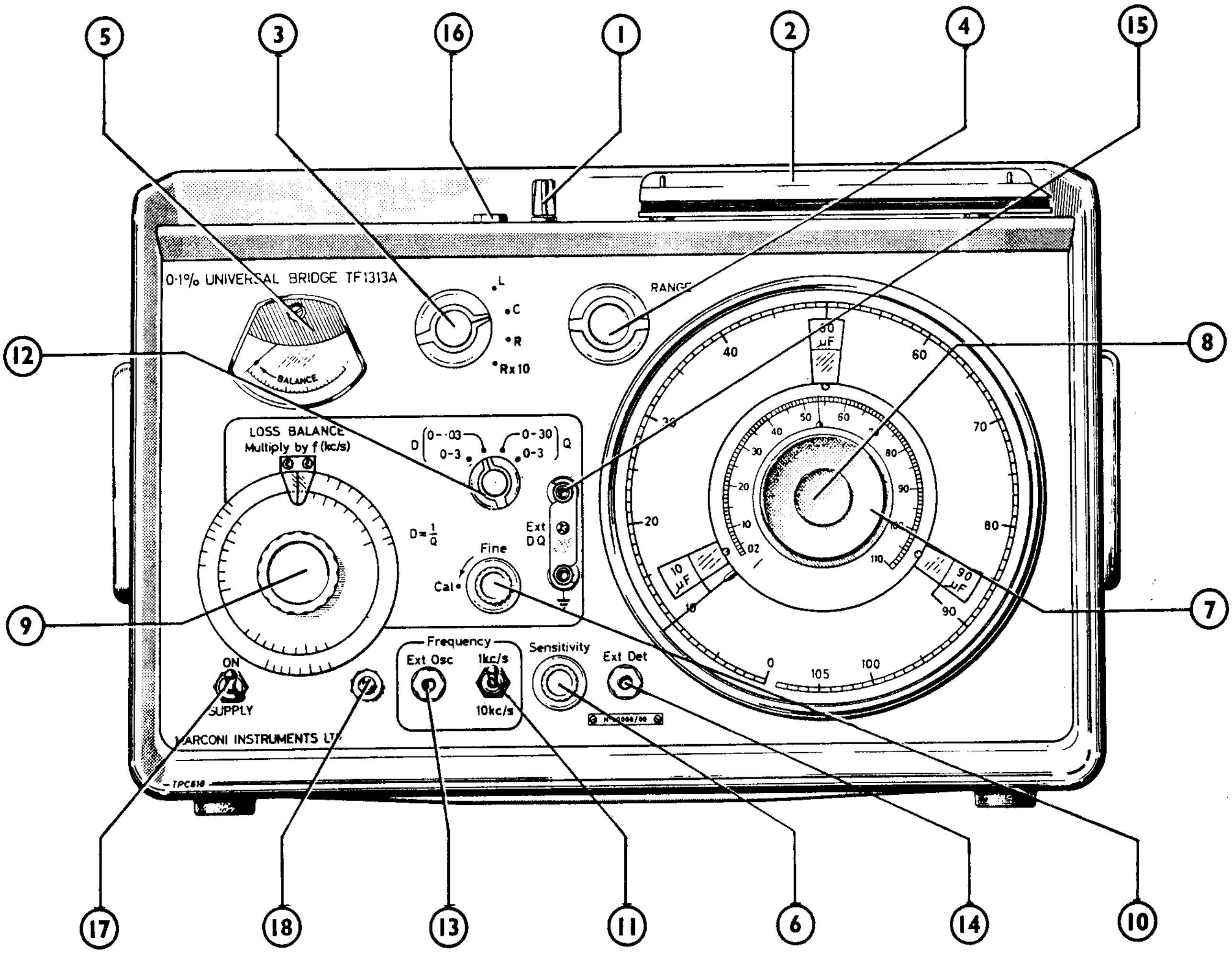


Fig. 2.1 Controls and connectors

(3) L C R switch. Adjust for appropriate measurement.

(4) RANGE switch. Adjust to suit component. If approximate value unknown, set BALANCE controls to half scale, and then select range giving lowest meter reading.

(5) BALANCE METER. Adjust controls for minimum reading.

(6) SENSITIVITY control. Adjust initially to give half scale meter reading. As balance is approached increase sensitivity to give required discrimination.

(7) COARSE BALANCE control. Set to half scale while searching for correct range, and then adjust for minimum meter reading.

(8) FINE BALANCE control. Adjust for minimum meter reading once minimum for COARSE BALANCE control has been found. Note that when the instrument has been idle for some time the protective oil film may, before dispersion, cause erratic balance. A number of brisk rotations will restore the contact surface.

(9) LOSS BALANCE control. Adjust to obtain final balance, (minimum meter reading) in conjunction with FINE BALANCE control.

(10) FINE D-Q control. Adjust for final balance only when LOSS BALANCE control is too coarse.

(11) 1 kc/s - 10 kc/s switch. Select 1 kc/s except for low value inductors. LOSS BALANCE dial readings multiplied by 10 when this switch is at 10 kc/s. Inoperative for resistance measurements.

(12) D-Q switch. Select range appropriate to component under test. Inoperative for resistance measurements.

(13) EXT OSC. Connect an external oscillator with frequencies from 20 c/s to 35 kc/s.

(14) EXT DET socket. Connect an external detector to monitor output, when using an external oscillator.

(15) EXT D-Q terminals. Linked for measurements at 1 kc/s to 10 kc/s; connect to external potentiometer, to give continuous coverage when using an external oscillator at frequencies below 1 kc/s.

(16) BIAS jack. Connect external d. c. supply of up to 350 V for polarizing capacitors.

(17) SUPPLY switch.

(18) PILOT LAMP.

2.3 PRELIMINARIES

Having checked that the instrument is adjusted for the supply voltage it will use, proceed as follows :-

1. If necessary, mechanically zero the meter.
2. Connect the mains lead to the power supply.
3. Set the SUPPLY switch to ON; the pilot light should now glow.
4. Before using the instrument, allow a short warm-up period. Two or three minutes is normally sufficient for most purposes.

If you are using this Bridge for the first time, it will be helpful at this stage to get to know the recommended technique of reading the main dial, before making a measurement.

The coarse control moves the pointer of the outer dial in steps equal to one dial division; the fine control for the inner dial is continuously variable, and the range 0 to 100 of the inner scale is equivalent to one division of the outer scale. The coarse control is a switch with light indexing for ease of operation; no attempt should be made to obtain a setting between the marks.

The value of a component is most easily found by first noting the reading of the outer scale followed by the reading of the inner scale, and then putting in the decimal point by referring to the figure displayed in the nearest scale window. Typical examples are shown in Fig. 2. 2.

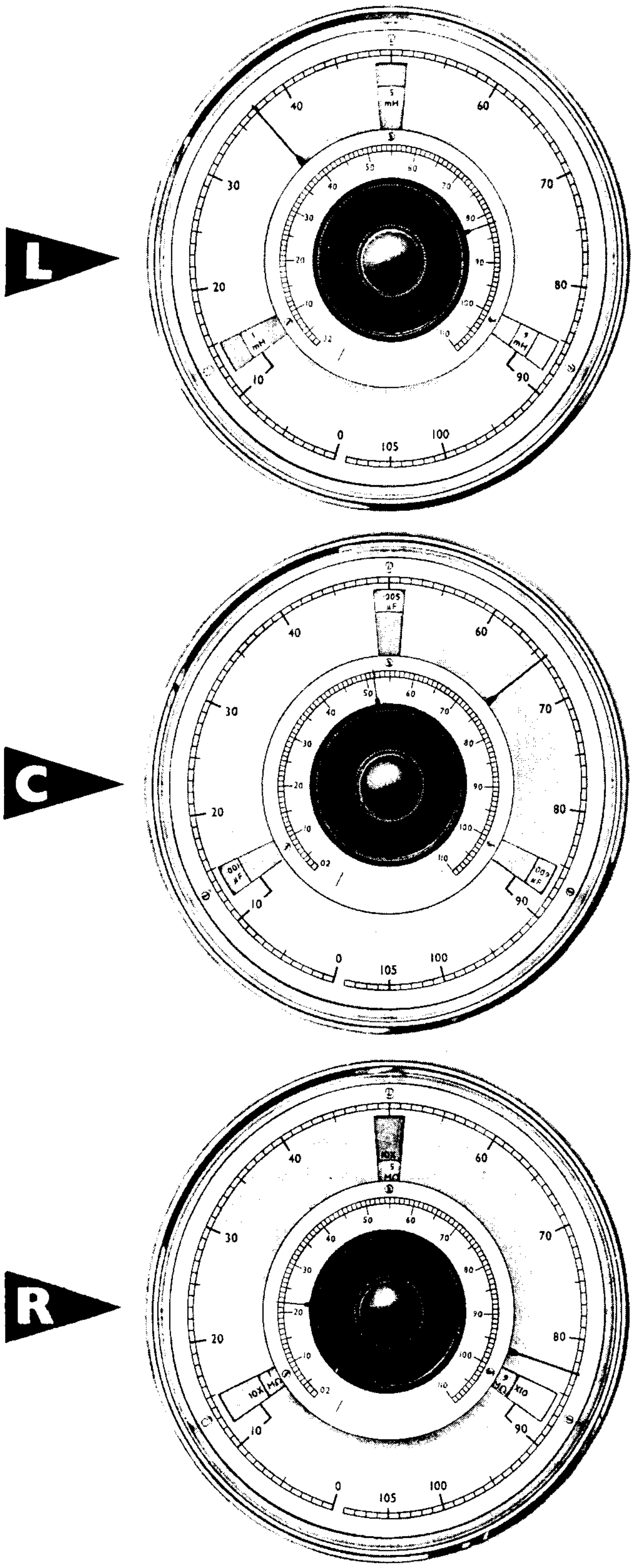


Fig. 2.2 L: Reading 3·782 mH
C: Reading 0.006657 μF
R: Reading 83·22 M Ω

2.4 CONNECTING THE COMPONENT

Connect the component between the HI and DET terminals, using short leads where possible. Small components can often be directly supported by the test terminals; those which can't be supported should be laid on the insulated component platform. Note the following precautions :-

(a) Impedance between the HI side of the component and earth, shunts the 'balance' arm of the bridge, and may result in an inaccurate reading.

(b) Stray pick-up on the lead to the DET terminal is applied to the input of the bridge detector and may cause difficulty in obtaining a clear balance indication. Using a screened lead, with the screen connected to the E terminal, helps to avoid this effect.

(c) The presence of an earth on either side of the component will short-circuit the bridge and make measurement impossible.

(d) The bridge energizing voltages appearing at the test terminals (see Data Summary) are too small to cause damage to the component or shock to the operator.

(e) When measuring screened inductors, the screen may be left disconnected, or connected to the E terminal.

2.5 RESISTANCE MEASUREMENT

Resistance can be measured at d. c. only. The 1 kc/s-10 kc/s switch and the loss balance controls are inoperative.

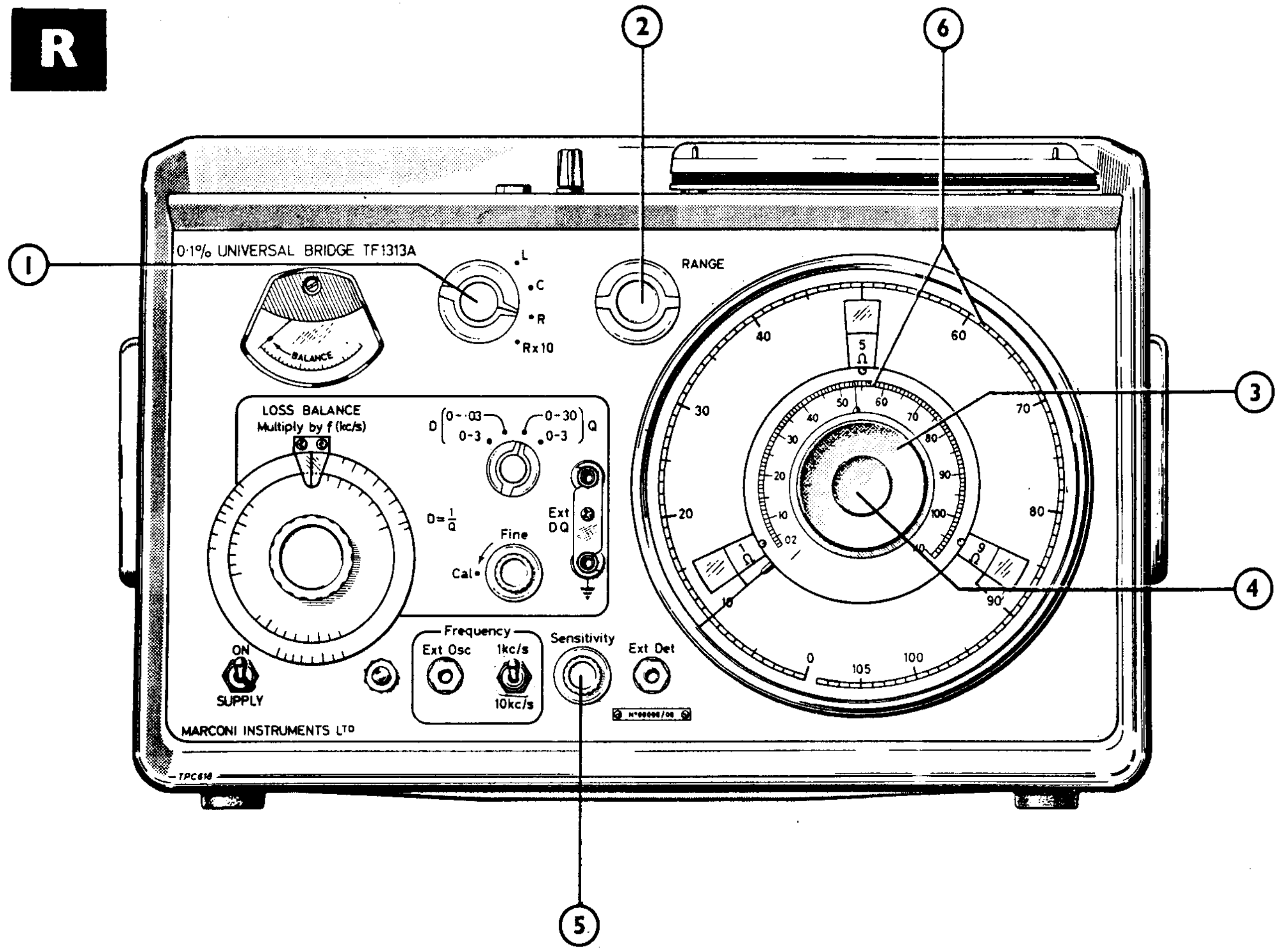
1. Set the LCR switch to R (or Rx10 if the anticipated value is above 11 MΩ).

2. If the resistance value is completely unknown, set the RANGE switch to its highest setting.

3. 4. Set the COARSE and FINE BALANCE pointers to mid scale.

5. Adjust the SENSITIVITY control to give a meter deflection of no more than half scale.

R



(2) Adjust the RANGE switch to give the lowest meter reading. If the resistance value is approximately known select the appropriate range.

(3) (4) (5) Balance the bridge by adjusting first the COARSE and finally the FINE BALANCE controls, to give a minimum meter deflection, progressively advancing the SENSITIVITY control as required.

(6) Read the resistance value from the BALANCE scales as described in Section 2.3.

Note : It may be observed that many composition resistors show a continuous drift in value.

Measuring low-wattage resistors

On the lower ranges, the effect of the 4 V source e.m.f. may have to be considered when measuring low wattage resistors. The general circuit used for resistance measurement is shown in Fig. 2.3. The bridge source resistance is 30 Ω and the first two range resistors are 1 Ω and 10 Ω. Using this circuit to calculate the power dissipation in resistors under test it will be found that the maximum is 100 mW for resistors between 10-50 Ω.

If a resistor of less than 100 mW rating is to be measured the power dissipation can be reduced by adding a resistor of known value in series with the test resistor. The value of such a res-

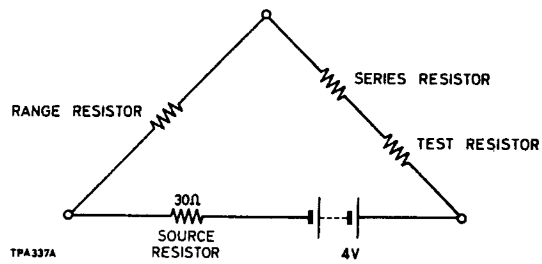


Fig. 2.3 Circuit used in measuring low-wattage resistors

istor should be no larger than is sufficient to reduce the dissipation to an acceptable level otherwise measurement discrimination will suffer. Alternatively, at the expense of accuracy, selecting a higher range than usual will have the desired effect.

Detector zero

The detector circuit used for resistance measurements is extremely sensitive and is susceptible to thermal e. m. f. 's especially on the 10 Ω, 10 MΩ and 100 MΩ ranges. Such an e. m. f. will produce a residual meter deflection and an internal preset control is provided to enable this to be offset. If the control requires resetting allow at least 20 minutes from switching on the Bridge for internal thermal stabilization and then remove the top plate as described in Section 4. 3.

The control is located behind the Balance switch assembly and is labelled RV11 SET ZERO. Set the RANGE switch and BALANCE controls to 10 MΩ, short circuit the DET and E terminals with copper wire and adjust RV11 for minimum meter reading with maximum SENSITIVITY.

Residual and connection resistance

When measuring resistors near the lower limit of the range, the residual resistance (Ro) should be deducted from the value obtained. Also note that the component connections can have a significant resistance.

An approximate value of Ro is given in the Data Summary, but the actual value for a particular bridge may be found as follows :-

> Short circuit the HI and DET terminals with a thick copper strap (of 'zero' resistance). Set the LCR switch to R, and the RANGE switch to its lowest setting.
>
> Balance the bridge with the FINE BALANCE control to as near zero on the meter as possible. Read the residual resistance from the FINE BALANCE scale; the 'O2' calibration is equivalent to 0. 002 Ω.

Typical component connections have a resistance of about 1 mΩ per inch (0. 4 mΩ per cm). This amounts of 0. 1% per inch at 1 Ω. Therefore where this is considered to be significant the connections should be measured separately and allowed for in the result.

Further extraneous errors can be avoided by not handling the resistor under test and making sure that it is isolated from earth or any external supplies.

2.6 INDUCTANCE MEASUREMENT

When measuring inductance, the loss balance controls are used to balance out the resistive component of the inductor. The loss balance dial is direct-reading at 1 kc/s only; readings on either scale must be multiplied by 10 when measuring at 10 kc/s - further details are given in Section 2. 7. The main balance dial is direct reading at all frequencies.

Most audio and power-frequency inductors may be measured at 1kc/s using the 0-30 Q range. For small low-Q inductors such as r. f. coils it is better to use 10 kc/s and the 0-3 Q range. Large inductors with a low self-resonant frequency, or small inductors with a saturable core need special precautions and these are described later in the section.

General measurement procedure

(1) Set the LCR switch to L.

(2) Set the D-Q switch to Q = 0-30.

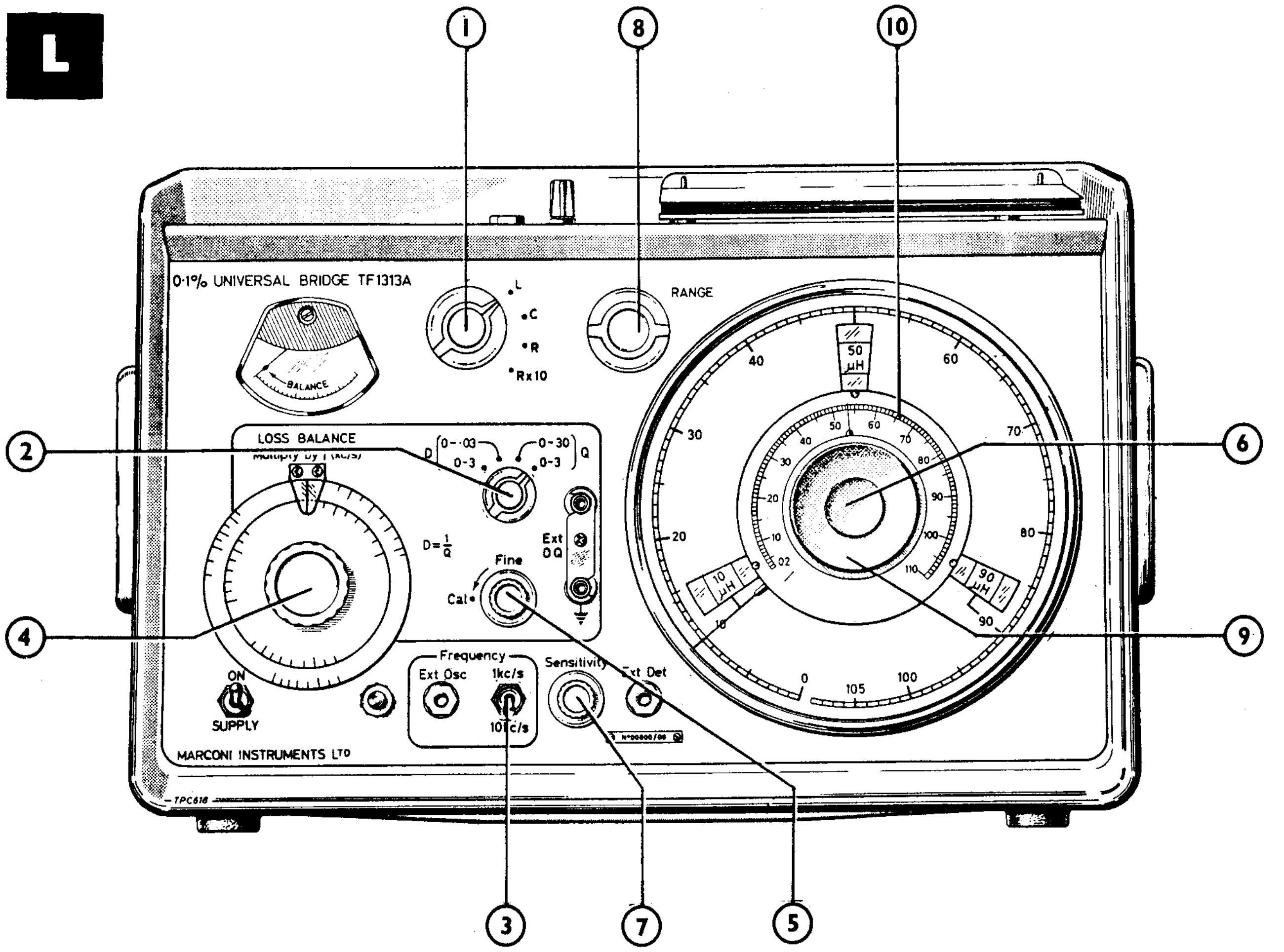
(3) Set the 1 kc/s- 10 kc/s switch to 1 kc/s.

(4) Set the LOSS BALANCE control to about 10.

(5) (6) (7) Set the FINE Q and the FINE and COARSE BALANCE controls to about mid-way.

(8) Set the SENSITIVITY control to give a meter deflection of no more than half scale.

L



(1) Set the LCR switch to L.

(2) Set the D-Q switch to Q = 0-3.

(3) Set the 1 kc/s-10 kc/s switch to 10 kc/s.

(4) Turn the LOSS BALANCE control fully clockwise.

(5) Set the FINE Q control mid-way.

(8) Set the RANGE switch to its highest setting.

(9) Set the COARSE BALANCE control to 0.

First measure the approximate inductance as follows :-

(7) Set the SENSITIVITY control to give a meter deflection of no more than half scale.

(6) Using the FINE BALANCE control only search for a null. If the best null is below

(8) 05 reduce the RANGE by one step. Once an apparent null has been obtained on

(4) scale adjust the LOSS BALANCE and FINE

(6) BALANCE controls successively to obtain a minimum meter reading.

Note : If the inductor Q is extremely low, the balance indication will be rather flat.

(10) Read the inductance value from the FINE BALANCE scale noting that its range is 1/10th of that indicated in the lower left hand window. This will only be an approximate value, although the sharper the balance indication the more accurate the value obtained.

To measure the coil accurately, proceed as follows :-

(8) Select the RANGE suitable for the approximate value obtained above, usually two

(9) lower. Set the COARSE BALANCE pointer to the value and re-balance the bridge with

(4) slight adjustment of the LOSS BALANCE control to obtain the lowest meter reading.

(9) Offset the COARSE BALANCE control a
step at a time (usually counter clockwise)
(4) re-balancing with the LOSS BALANCE
(7) control and advancing the SENSITIVITY
control as necessary. Use the FINE Q
(5) control if the loss adjustment becomes
critical.

It is important to progress to the lowest
(6) possible reading, ultimately using the
FINE BALANCE and FINE Q controls to
(5) obtain a zero reading - or at least within
one or two divisions - on the meter scale,
(7) with the SENSITIVITY control fully clock-
wise.

Measuring iron-cored inductors

To avoid errors 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 even at 1 kc/s will be in error - inductance will appear high, and magnification low. It will be found that 1 henry is the practical upper limit for measurements at 10 kc/s.

These errors will increase rapidly as the self-resonant frequency of the inductor approaches the test frequency, and it is impossible to measure an inductor which resonates below 1 kc/s, since it will exhibit capacitive reactance. This effective capacitance may be measured on the bridge, but it will appear to have a poor dissipation factor. The inherent capacitance of the bridge at the test terminals is low - approximately 0.05 pF - and will contribute little to lowering the self-resonant frequency of the component.

Shunt capacitance however, due to the positioning of the components and arrangement of the test leads, may lead to appreciable errors in measurement. Such errors, which will increase with frequency, can be minimized by careful positioning of the component, using short well-spaced leads and, whenever possible, supporting it on the insulated component platform.

Core saturation

If the inductor is of such a type that its core is easily saturated, it is advisable to use 10 kc/s and to switch to the highest range that still covers the component value (for example by measuring a 10 mH inductor on the 10- to 100 mH range instead of the 0- to 10 mH range) thereby reducing the current through the inductor windings.

Note : Iron- or ferrite-cored inductors are particularly liable to pick up stray radiation which, applied to the bridge via the DET terminal, will tend to mask the balance point indication. To check for this effect, insert an unconnected telephone plug into the EXT OSC jack in order to switch off the internal oscillator. Any reading on the meter is now due to stray pick-up, and the inductor should be turned or repositioned to minimize the effect.

Residual inductance

When measuring inductance near the lower limit of the range, the residual inductance (Lo) should be deducted from the value obtained.

An approximate value of Lo is given in the Data Summary, but the actual value for a particular bridge may be found as follows :-

Short-circuit the HI and DET terminals with a thick copper strap.

Set the LCR switch to L, and the RANGE switch to its lowest setting.

Switch to 10 kc/s; Q = 0-3; set the coarse BALANCE control to zero, and the fine control to '10!

Balance the bridge in the normal manner to obtain a balance as near zero, on the meter, as possible.

Read the residual inductance from the FINE BALANCE scale; the '10' calibration is equivalent to 0.1 μH.

Screening cans on h. f. coils

These are usually best connected to the E terminal but if already connected to the inductor then join to the DET terminal. 10 kc/s test frequency should be used as the shorted turn effect of an aluminium or copper can rapidly reduces at lower frequencies.

Higher voltage testing

Using the internal bridge source the voltage applied to the test inductor varies from 20 mV to 500 mV depending upon range and frequency. Using an External Oscillator drive via the jack socket provided on the front panel this limit may be increased approximately 5 times; see Section 2.11.

For higher voltages the following method may be useful :-

With the bridge supply switched OFF, apply the oscillator signal between the DET and E terminals. An external detector of 1-100 mV sensitivity, preferably selective, must be used, connected via the EXT OSC jack socket.

The Balance control of 1.1 kΩ max. is in series with the test inductor and below about 1 H at 1 kc/s it will noticeably effect the inductor voltage. The effect can be reduced by using one range higher than usual, between 0 and 10 on the main Balance scale.

A. C. input voltage must be limited according to the following :

Lx	*Range*	*50 c/s*	*1 kc/s*	*10 kc/s*
> 1 H	100 H	10. Lx*	100	100
> 0.1 H	10 H	10. Lx	100	100
> 0.02 H	1 H	10. Lx	30. Lx	30

*100 V r.m.s. max.

Also current into the HI terminal must never exceed 33 mA or a permanent change in accuracy may occur.

Errors due to strays AYS

Stray capacitance from HI to earth causes maximum errors as follows :-

Q (0.0006% Q) . (f kc/s) . (C pF)

L $\frac{(0.0006\%)}{(Q)}$. (f kc/s) . (C pF)

Shunt capacitance between the HI and DET terminals gives errors as follows :-

+ (Lx H) . (C pF) . (0.004%) at 1 kc/s, or
+ (Lx H) . (C pF) . (0.4%) at 10 kc/s.

For example 1 H with 40 pF stray shunt capacitance will measure 0.16% high at 1 kc/s and 16% high at 10 kc/s.

2.7 NOTES ON INDUCTIVE LOSS BALANCING

(1) Definitions

$$Q = \text{magnification factor} = \frac{\omega L}{R} = \frac{X}{R}$$

$$D = \text{dissipation factor (or tan } \delta \text{ or loss tangent)} = \frac{1}{Q} = \frac{R}{X}$$

$$\cos\phi = \text{power factor} = \frac{R}{\sqrt{X^2 + X^2}} = \frac{R}{Z}$$

($\cos\phi \simeq D$ for values less than 0.1)

(2) Fine D-Q control

This has a range of 0.006 D and 0.06 Q at 1 kc/s and 0.006 D and 0.6 Q at 10 kc/s and is therefore only effective towards the lower end of the LOSS BALANCE range. For optimum loss measurement accuracy in this region it should be set to the CAL mark and the bridge balanced with the main control only.

(3) *LOSS BALANCE* dial reading

The LOSS BALANCE dial indicates either Q or D depending on the range selected. This is shown in the following tables together with the scale multiplying factors appropriate to the bridge operating frequency.

Note that an additional Q or D error, varying with the range in use, should also be taken into account when computing the loss value. A table of these corrections, together with examples of their use is included in the Abridged Instructions on the top panel of the Bridge.

Readings may be converted by : $D = \frac{1}{Q}$ and $Q = \frac{1}{D}$.

(a) Measurement at 1 kc/s

D-Q switch position	*LOSS BALANCE dial reading*	*Q range*	*D range*
Q = 0-3	Divide Q scale by 10	0-3	
Q = 0-30	Q scale is direct reading	0-30	
D = 0-.03	D scale is direct reading	30-∞	0-.03
D = 0-3	Multiply D scale by 100		0-3

(b) Measurement at 10 kc/s

D-Q switch position	*LOSS BALANCE dial reading*	*Q range*	*D range*
Q = 0-3	Q scale is direct reading	0-30	
Q = 0-30	Multiply Q scale by 10	0-300	
D = 0-.03	Multiply D scale by 10	30-∞	limited to 0-.031
D = 0-3	Not normally used		

(c) Measurements at other frequencies
(using external oscillator and detector, where f = oscillator frequency in kc/s.)

D-Q switch position	*LOSS BALANCE dial reading*
Q = 0-3	Multiply Q scale by f/10
Q = 0-30	Multiply Q scale by f
D = 0-.03	Multiply D scale by f (limited to D < .031)
D = 0-3	Multiply D scale by 100f (only for f ≤ 1)

(4) Series or parallel values

The Bridge measures the inductive and resistive components of an inductance as a series network when the D-Q switch is set to Q, and as a parallel network when switched to D.

The equivalent series (Ls) and parallel (Lp) inductance are related by the expression

$$Ls = Lp \left(\frac{1}{1 + D^2}\right)$$

Therefore, when switched to D the indicated parallel inductance can be converted to the more familiar series form by multiplying $1/(1 + D^2)$. The difference is normally very small : about 1% for D = 0.1 (Q = 10) and 0.1% for D = 0.03 (Q = 33).

2.8 USING THE D.C. CHOKE ADAPTOR TYPE TM 6113

This Adaptor is designed to operate at 1 kc/s but, in order to accommodate frequency variations between individual Bridges, one of the 'isolating' tuned circuits within the Adaptor is variable. It is left to the user to adjust the Q TRIMMERS (switch and variable capacitor) to match the frequency of the Bridge in use. Once set, there is no need to make any further adjustments to these controls unless the Adaptor is used on a different Bridge.

The Q TRIMMERS are so called because their correct adjustment is essential if accurate Q readings are to be obtained.

When using the Adaptor, d.c. up to 200 mA from an external source may be passed through the windings of the inductor under test while the measurement is being made.

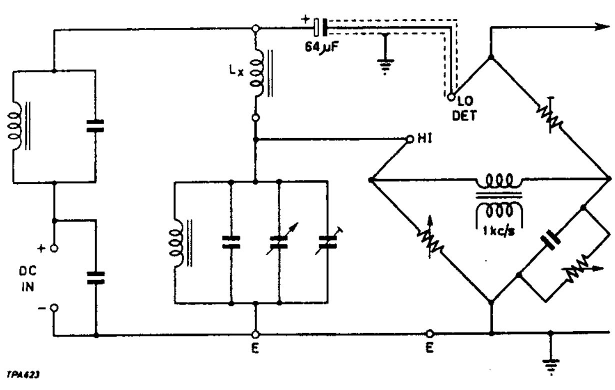


Fig. 2.4 Choke adaptor connected to bridge

Fig. 2.4 shows the circuit diagram of the Adaptor connected to the Bridge.

To measure an inductor in this way, (in the range 100 mH to 100 henrys), proceed as follows:-

(1) With the Adaptor disconnected, measure an inductor on the Bridge at 1 kc/s, note the control settings, and leave the inductor in place. If the balance indication is vague, this may be due to interference picked up by the inductor - see note under Core Saturation in Section 2.6.

(2) Join the E terminal on the Adaptor to the E terminal on the Bridge, or a convenient place on the case.

(3) Join the brown (Hi) Adaptor lead to the HI terminal on the Bridge. This will usually cause a change in balance as indicated on the meter. Minimize this change by operating the Q TRIMMERS. A small adjustment to the FINE BALANCE will also be necessary; if this is insufficient, move the COARSE BALANCE by one step and readjust the FINE BALANCE.

If the Bridge frequency is further off tune than can be compensated for by the Q TRIMMERS, then readjustment of the Q control on the Bridge will be necessary. In such circumstances the inductance measurement accuracy will not be seriously affected unless Q control is grossly offset.

(4) Finally, disconnect the inductor and connect the screened Lo lead from the Adaptor to the DET terminal on the Bridge.

Chokes may now be measured, with appropriate d.c. polarization, by connecting them across the Hi and Lo terminals on the Adaptor. The normal Bridge controls should be used without further readjustment of the Q TRIMMERS.

Accuracy

The accurate measurement of the inductance of transformers and chokes with laminated cores requires very careful precautions. The inductance reading will often vary with changes in position of the inductor relative to earthed objects, mains power leads, etc. Movement of the leads can often change the answer. These effects are due to the imperfections of ordinary alloys as a core material, and to stray capacitance between leads. The errors are, in general, proportional to inductance.

When measuring chokes in excess of about 20 henrys, slight residual coupling between the tuned circuits in the Adaptor may give rise to false balance. Careful arrangement and screening have reduced the largest error at 100 henrys to about 10%. This error reduces with reduced inductance to an error which normally does not exceed 3% at 20 henrys and below. Q accuracy, however, degenerates progressively above about 10 henrys - but this is a requirement that is seldom encountered.

2.9 CAPACITANCE MEASUREMENT

All capacitors may be measured at 1 kc/s and most with the D-Q switch at D = 0-.03. Electrolytic capacitors can be measured provided they are formed;it may then be necessary to use the 0-3 D range.

Do not overlook stray capacitances and the fact that lead inductance may introduce errors.

General measurement procedure

(1) Set the LCR switch to C

(2) Set the D-Q switch to D = 0-.03 (or 0-3 for electrolytics).

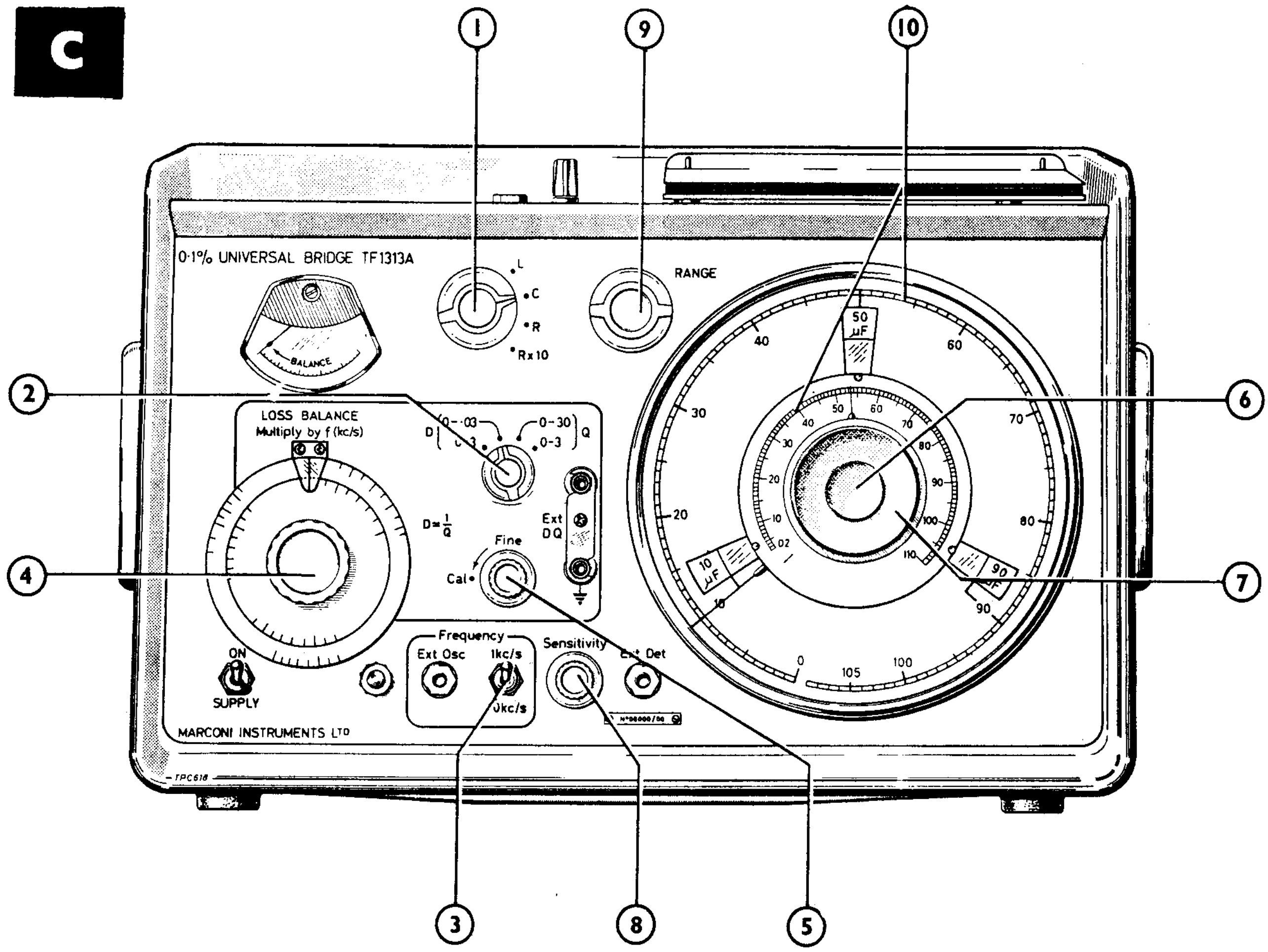
(3) Set the 1 kc/s-10 kc/s switch to 1 kc/s.

(4) (5) (6) Set the LOSS BALANCE, FINE D and the FINE and COARSE BALANCE controls mid-way.

(7) (8) Set the SENSITIVITY control to give a meter deflection of no more than half scale.

(9) Adjust the RANGE switch to give the lowest meter reading. If the capacitance value is approximately known select the appropriate range.

C



(7) Adjust the COARSE BALANCE control to obtain a minimum meter reading. When the approximate balance position has been
(4) found adjust the LOSS BALANCE control to
(8) give a sharp null, advancing the SENSITIVITY control as required.

Finally obtain as near as possible a zero
(6) meter reading by adjustment of the FINE
(4) BALANCE control together with the LOSS BALANCE control (use the FINE D control
(5) if the loss adjustment is critical).

(10) Read the inductance value from the BALANCE scales as described in Section 2.3. Read the D value from the inner scale of the LOSS BALANCE dial (for optimum accuracy the FINE D control should be at the CAL mark).

Connections

Care should be taken in connecting the capacitor under test to the Bridge terminals. Lead inductance and stray impedance to earth can give rise to additional measurement errors and interference pick up can obscure the balance indication.

By observing the following precautions such effects may be minimized.

(1) Neither the HI nor the DET terminal of the Bridge must be earthed. If one side of the capacitor under test is connected to a chassis, the chassis itself must be isolated from earth.

(2) Impedance connected between the HI terminal and earth (E terminal) shunts the internal standard. Each 100 pF of stray capacitance will give a -0.1% error; 1.6 MΩ will give -0.001 D error at 1 kc/s.

(3) Connecting-lead inductance gives an error of +(LμH) . (CμF) . (0.004%) at 1 kc/s, or +(LμH) . (CμF) . (0.4%) at 10 kc/s.
A typical value for L is 0.5 μH for 2-3 inch leads.

(4) When measuring a low capacitance value remote from the Bridge, the capacitance between the connecting leads should be measured and subtracted from the result.

(5) The 'LO' or 'outside foil' terminal of the test capacitor should be connected to the DET terminal of the Bridge. If it has an outer screen connection this should be joined to the E terminal.

(6) Interference pick up on the lead to the DET terminal may mask the balanace point. In order to reduce the interference a screened lead should be used with the screen joined to the E terminal. Check the interference level by plugging an open circuit jack into the EXT OSC socket. The meter reading should be nearly zero.

In-situ capacitance measurement

Capacitors may be measured in situ, that is without disconnecting them from their associated circuit, provided the precautions described above are observed.

If interference pick up is not sufficiently reduced by screening the lead to the DET terminal, screen the connection to the HI terminal in a similar manner. This will add to the effect of (2) above and if the error incurred is likely to be significant it can be determined by the following substitution method :-

After balance has been reached, note the capacitance reading; then, without disturbing the test arrangement, disconnect - without moving - the leads from the test capacitor, and substitute a capacitor of similar known value to the capacitor under test. This should be of small physical size. Measure the new value accurately, the percentage error should then be used to correct the original measurement.

For example:

Value obtained by in-situ measurement	= 120 pF
Value of substitution capacitor	= 110 pF
Value of substitution capacitor with lead reconnected	= 99 pF

Percentage change

$$= \frac{-(110-99)}{110} \times 100\% \qquad = -10\%$$

Corrected value for in-situ measurement	= 120 pF +10%
	= 132 pF

Avoiding the effects of (2) and (6) often leads to conflicting requirements, since the large mass of the capacitor (e.g., the chassis) increases the stray capacitance effect if connected to the HI terminal and may introduce pick-up if connected to the DET terminal. It is generally better to connect it to the HI terminal and correct for the error rather than try to eliminate the pick-up.

Residual capacitance

When measuring capacitance near the lower limit of the range, the residual capacitance (Co) should be deducted from the value obtained.

An approximate value of Co is given in the Data Summary, but the actual value for a particular bridge may be found as follows :-

Open-circuit the HI and DET terminals.

Set the LCR switch to C, and the RANGE switch to its lowest setting.

Switch to 10 kc/s; D = 0-.03; set the COARSE BALANCE control to zero, and the FINE control to '10'.

Balance the bridge in the normal manner to obtain a balance as near zero on the meter as possible.

Read the residual capacitance from the FINE BALANCE scale, the '10' calibration is equivalent to 0.1 pF.

D.C. bias

A facility for applying a d.c. bias to the capacitor under test is included, a jack socket being provided adjacent to the test terminals.

Up to 350 V d.c. may be applied. In order to protect the bridge resistors from damage a limiting resistor must be included in series with the supply, this should be :-

10 Ω per volt for the 1 μF to 100 μF ranges,

and 100 Ω per volt for the 100 pF to 1 μF ranges.

The positive side of the test capacitor should be connected to the DET terminal and the positive side of the bias supply to the tip of the jack plug. In order to provide an a.c. path for the bridge energizing source a by-pass capacitor must also be connected across the jack plug. This should be at least 1 μF or twice the value of the test capacitor.

CAUTION

(1) Because the jack plug connects to the HI terminal the d.c. supply must be thoroughly isolated from earth to avoid connection of any stray capacitance.

(2) Make sure that the D-Q switch is in the correct D position before connecting the d.c. bias.

(3) Because there can be up to 350 V applied to the test terminals the test capacitor should only be attached or removed when the bias supply is disconnected.

2.10 NOTES ON CAPACITIVE LOSS BALANCING

The information given for inductive loss balancing in parts (1) to (3) of Section 2.7 applies equally for capacitors. However, since most capacitors have a dissipation factor of less than 0.03, measurement will generally be made at 1 kc/s using the 0-.03 D range in which case the D scale of the LOSS BALANCE dial is direct reading. The 0-3 D range is intended for electrolytics and when using an external low frequency source.

The Bridge measures the resistive and capacitive components of a capacitor as a series network when the D-Q switch is set to D; and as a parallel network when set to Q. The equivalent parallel (Cp) and series (Cs) capacitances are related by the expressions

$$Cp = \frac{Cs}{1 + D^2}$$

$$Cs = Cp \frac{(1 + Q^2)}{Q^2}$$

It is important to note the larger difference between Cs and Cp as the Q of the test component is reduced, viz:-

Q = 5	Cs = Cp + 4%
Q = 3	Cs = Cp + 11%
Q = 2	Cs = Cp + 25%

With electrolytic capacitors in particular, it is found that provided Q is greater than 5 the results are fairly reliable, but as Q decreases, the interpretation of the measurement after applying the Cs/Cp relationship does not necessarily give results having any great degree of accuracy. They are particularly prone to be frequency dependent and, in practice, apparent error up to 50% can arise between the claimed and measured values both of which may be correct; this confusion usually arises because such capacitors are commonly tested during manufacture at 50 or 60 c/s.

When measuring high grade capacitors, especially at 10 kc/s, the LOSS BALANCE scale corrections given in the Abridged Instructions become most significant. Before applying the correction ensure that the correct scale reading is obtained. The FINE D-Q control must be set to the CAL mark; also ensure the EXT D-Q terminals are firmly tightened since extraneous contact resistance here can upset balancing and calibration of the control.

2.11 USE OF EXTERNAL OSCILLATOR AND DETECTOR

For measurements at frequencies other than 1 or 10 kc/s the bridge can be energized by an external audio oscillator at frequencies from 20 c/s to 30 kc/s. When the oscillator is plugged into the EXT OSC jack socket the internal oscillator is automatically switched off. The input voltages that should be used are as follows :-

0 to 20 V direct:	20 c/s to 30 kc/s
20 to 50 V via a series 10 kΩ resistor:	50 c/s to 30 kc/s
50 to 75 V via a series 22 kΩ resistor:	75 c/s to 30 kc/s.

The bridge e.m.f. will be one twentieth of the input voltage.

The internal detector is normally double tuned at 1 and 10 kc/s. It becomes aperiodic with reduced sensitivity when a plug is inserted into the EXT DET jack socket. If interference or supply frequency hum obscures a clear balance an external selective detector should be used.

As the impedance ratios of the bridge favour high frequencies, harmonics in the oscillator input will be accentuated in the output to the detector, and this may necessitate the use of filters in the external detector circuit. This is particularly important below 200 c/s; at higher frequencies an oscilloscope may be used to observe the balance but below 200 c/s extra selectivity and extra gain is necessary.

When an external input of 10 V is applied to the EXT OSC socket an external detector should have the following sensitivity:

a) when connected via the EXT DET jack with the bridge switched on:

unselective	-		15 mV full scale
selective	-	above 200 c/s,	5 mV full scale
	-	at 100 c/s,	2.5 mV full scale
	-	at 20 c/s,	1 mV full scale.

b) when connected direct to the DET and E terminals with the bridge switched off,

selective	-	above 200 c/s,	50 μV full scale
	-	at 100 c/s,	25 μV full scale
	-	at 20 c/s,	10 μV full scale.

In this case the detector (or the bridge) must be fully floating to avoid earth currents; and the input resistance should be approximately twice the impedance of the test component.

Although the main BALANCE dial is direct reading at any frequency, the reading of the LOSS BALANCE dial must be multiplied by f/1000, where f = external oscillator frequency in c/s. If f is less than 1 kc/s, an external loss balance control may have to be added - see below.

External D–Q terminals

These terminals, which are always linked for measurements at 1 or 10 kc/s, enable an external potentiometer to be connected in series with the LOSS BALANCE controls. This is necessary to maintain continuous Q coverage when using an external bridge-energizing oscillator at frequencies below 100 c/s.

A suitable value, Rv, for an external D-Q potentiometer is given by

$$Rv = \frac{D \text{ or } Q}{f} \times 1592 \text{ k}\Omega$$

where D or Q = maximum expected D or Q of component
f = test frequency in c/s.

The balance procedure is then normal except that the external Q potentiometer is used as well as the two internal controls. The Q value, however, cannot be obtained from the readings on the dial; if this is required, set the LOSS BALANCE control to zero and rebalance using only the external Q potentiometer, then disconnect the potentiometer and measure its value, R.

$$D \text{ or } Q = \frac{Rf}{1592}$$

where R is in kΩ and f in c/s.

CAUTION

When replacing the link ensure that the terminals are securely tightened.

Section 3 Technical description

3.1 CIRCUIT SUMMARY

Fig. 3.1 shows a functional diagram of the Bridge.

Two separate internal energizing sources are available to the measuring bridge for the evaluation of reactive and resistive components. When measuring reactive components, the measuring bridge may be energized either from an internal 1 kc/s or 10 kc/s oscillator-amplifier, or from an external source via the front panel socket. When measuring resistance, the bridge is energized by d. c. from the rectified output of an l. t. secondary winding on the mains transformer.

The correct energizing voltage, and the bridge circuit arrangement appropriate to the component under test, are automatically selected by the LCR switch. For inductance and capacitance measurement the out-of-balance voltage from the measuring bridge is applied directly to the first amplifying valve, V3. For resistance measurement, the d. c. output from the bridge is first interrupted (chopped) by means of a photo-chopper.

After amplification by V3, the signal level to a further two-stage amplifier, V4, can be varied by RV12, the SENSITIVITY control. The output of V4 is then applied to the diode detector MR5 & 6.

Tandem 1 kc/s and 10 kc/s tuned filters are normally connected across the output of the first amplifier, V3, but are automatically disconnected if an external detector (e.g., oscilloscope) is plugged in.

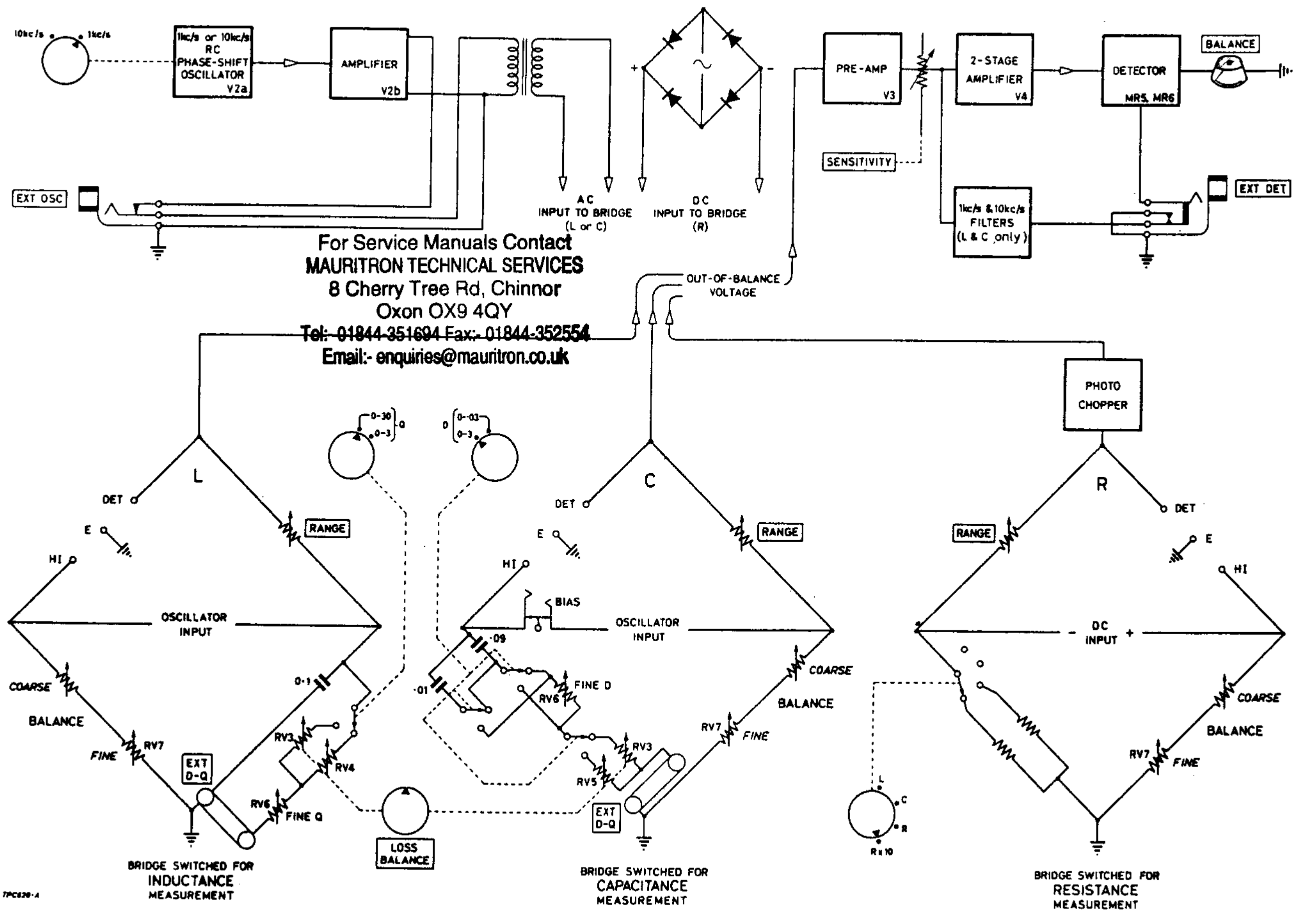


Fig. 3.1 Functional diagram

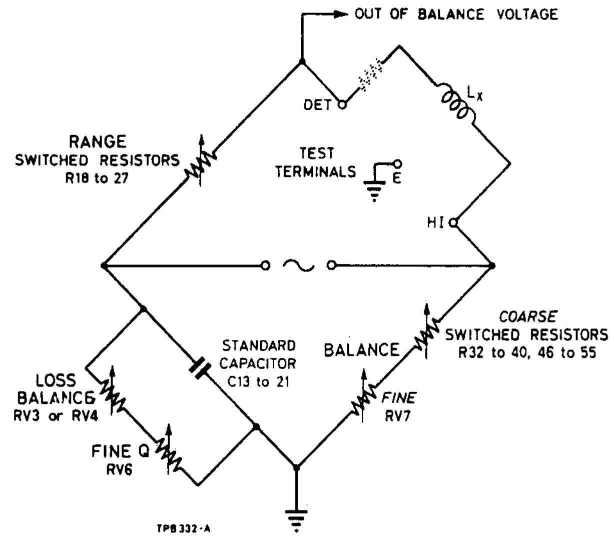


Fig. 3.3 Simplified inductance bridge (measuring inductance with series loss)

The standard capacitance consists of the parallel connected capacitors C13 to C21 (some of which may have been disconnected during the initial setting-up and calibration procedure), and the final adjustment preset capacitor C21. With the D-Q switch at Q = 0-3 and Q = 0-30, the FINE Q control, RV6, in series with either LOSS BALANCE resistor RV3 or RV4, is placed in parallel with the standard capacitance. In these switch positions, it is the series inductance value that is indicated on the main BALANCE dial (see Fig. 3.3). When the D-Q switch is at D = 0-.03, these resistors are disconnected and instead, RV5 (also ganged with RV3 and RV4) is placed in

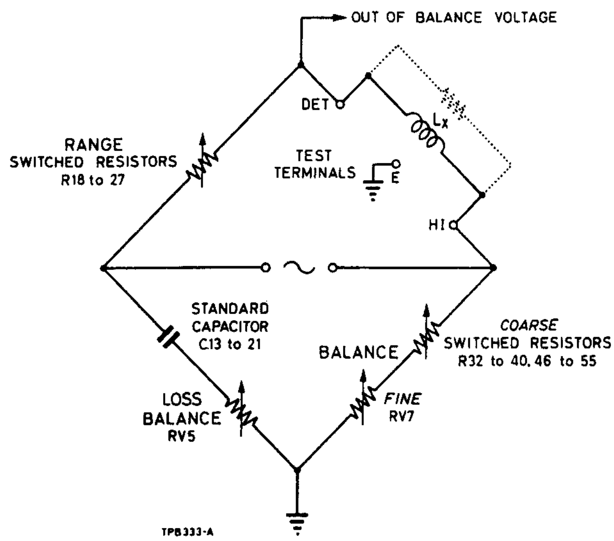


Fig. 3.4 Simplified inductance bridge (measuring inductance with parallel loss)

series with the standard capacitance. In this case, the main BALANCE dial indicates the equivalent parallel inductance (see Fig. 3.4).

CAPACITANCE BRIDGE When changing from inductance to capacitance measurement, the standard arm of the bridge is interchanged with the main balance arm, by the contacts of the LCR switch.

As for inductance measurement, the arrangement of the standard arm will depend upon the loss in the component under test. A typical arrangement for the measurement of capacitance and dissipation factor (D or tan δ) is when the standard capacitance is in series with the LOSS BALANCE variable resistors RV3 or RV5 and RV6, as shown in Fig. 3.5.

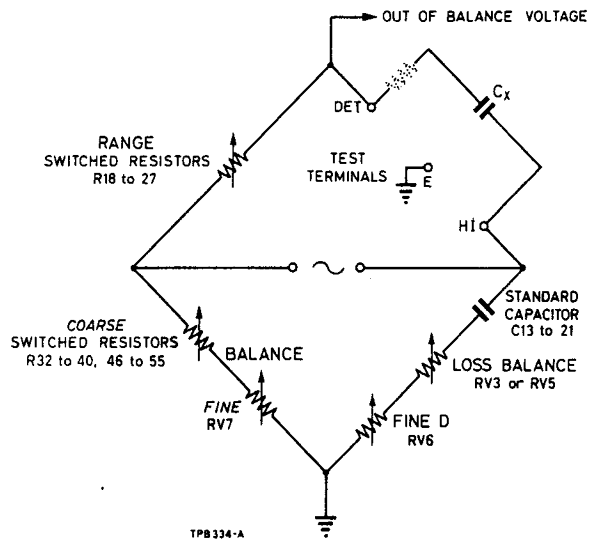


Fig. 3.5 Simplified capacitance bridge

Range switching and main balancing adjustment remains the same as for inductance measurement; in fact, if comparison is made between the two bridges, it will be seen that they offer exactly the same operational functions.

3.5 AMPLIFIER-DETECTOR

This circuit, Fig. 6.3, employs two valves, a pentode, V3, and a double triode, V4 in a circuit arrangement consisting of three stages of amplification followed by a diode detector, MR5/6, feeding the balance meter.

When resistance is measured, the out-of-balance d.c. voltage from the bridge is applied via the LCR switch (SB1B) and an R-C filter network to the photo chopper. The R-C filter network smooths the out-of-balance bridge voltage and attenuates any supply-frequency hum pick-up on the test component.

The photo chopper comprises two photo sensitive resistors R63 and R64 whose resistance changes by a factor of 1000 with illumination. By illuminating them alternately with neons N2 and N3 an effective switching action is obtained. The neons are made to strike and extinguish alternately at about 20 c/s by means of R61, R62 and C39. The subsidiary circuit of MR8, R81 and C55 is included to ensure that on switching the LCR switch (SB4B) to R, neon N3 is delayed in striking so that the two neons cycle correctly. The photo resistors and the neons are mounted in holes in a metal block such that N2 illuminates R63 and N3 illuminates R64. The amount of light falling on each photo resistor can be restricted by means of a set screw in order to adjust the system to maximum sensitivity.

When detecting very small d. c. voltages it is necessary to compensate for thermal e. m. f. 's which could obscure the balance null. For this purpose a d. c. supply is derived from the main l. t. supply and applied to the grid circuit of V3 via the SET ZERO preset RV11.

For inductance and capacitance measurements the a. c. output from the bridge is applied to the grid of V3 via LCR switch wafer SB1B. The SENSITIVITY control, RV12, in the output of V3 allows the gain of the amplifier to be varied to give a convenient meter deflection.

The filter circuits in the grid circuit of V4 are automatically brought into use by the action of the LCR switch. When the switch is set to R or Rx10, the low-pass R-C network R69 and C47 shunts the output of V3 via switch wafer SB1B; this eliminates the high frequency components in the waveform produced by the chopper. When the LCR switch is moved to either L or C, capacitor C47 is replaced by two rejector circuits connected in tandem. These circuits, which consist of coils L1 and L2 together with their associated shunt capacitors, offer maximum circuit sensitivity at the internal oscillator frequencies of 10 and 1 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.

Plugging in an external detector automatically disconnects the 1- and 10-kc/s filters at the contacts of the EXT DET socket, JKC.

The grid circuit of V4a also includes a diode, MR4, for overload protection. Conventional R-C coupling is used between V4a and V4b. Output for the external detector is taken, via socket JKC, from the cathode of V4b, while output from the anode is full-wave rectified by diodes MR5 and MR6 before application to the BALANCE meter, M1. A further diode MR7 is connected across the meter to cramp the response near full scale deflection so as to give an on-scale indication for a greater input range.

3.6 POWER SUPPLIES

The two tapped primary windings of the mains transformer, T1, permit a series or series-parallel arrangement to cover the input ranges 100 to 130 V and 200 to 250 V. Voltage adjustments are made by means of a plug-in type mains panel as described in Section 4.4.

The h. t. supply is derived from a full-wave rectifier V1 via resistance-capacitance smoothing. The heater of V1 is supplied separately from the secondary winding LT2, while secondary winding LT1 is common to the heaters of V2, V3 and V4: LT1 is also used for d. c. zeroing of the detector. LT3/LT4 provides d. c. at two levels via rectifier MR1 for energizing the resistance bridge.

3.7 D.C. CHOKE ADAPTOR TYPE TM 6113

Referring to the Simplified Circuit Fig. 3.6, it will be seen that, basically, the Adaptor comprises :

(a) An isolating capacitor to prevent the d. c. from flowing through the measuring circuits of the Bridge. This capacitor is effectively in series with the inductor under test and its value is sufficiently large to offer a very low reactance at the 1 kc/s test frequency. It does, however, set a lower limit to the inductance which can be measured; at 100 mH its approximate effect is to produce an apparent decrease in inductance of 0. 3%, while at 10 mH this effect would be about 3%.

(b) Two tuned circuits which isolate the 1 kc/s test frequency from the shunting effects of the d. c. supply. The inductors in these tuned circuits are connected in series with the inductor under test - one in each d. c. supply lead. Their construction is such that their inductance remains relatively constant despite the d. c. polarizing current.

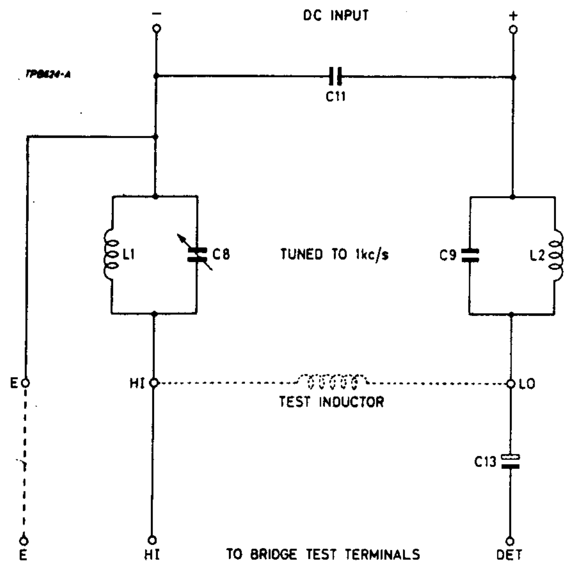


Fig. 3.6 Simplified circuit of d.c. choke adaptor

One tuned circuit, L2/C9, shunts the amplifier-detector input of the Bridge, thus only tending to reduce the sensitivity. This effect may be noticed on the higher inductance ranges, but no inaccuracy is introduced.

The other tuned circuit is connected across the main BALANCE resistor within the Bridge, and is therefore more critical with regard to measurement accuracy. When exactly at resonance the impedance presented by a tuned circuit is purely resistive, and it is under these conditions that the BALANCE circuit is intended to operate. To account for the variations in frequency between different instruments, this tuned circuit, L1/C8, is made variable by means of switched capacitors, C1 to C7 and trimmer C12. These Q Trimmers are so called because their correct adjustment is essential if accurate Q readings are to be obtained.

Section 4

Maintenance

4.1 GENERAL

This section of the manual serves as a general guide to the servicing of the instrument. It should be appreciated, however, that its high measurement accuracy can be impaired by alteration of such items as the range compensation presets or the wiring layout. Therefore, unless adequate standards and cross-checking facilities are available you are advised to return the instrument to our Service Division or Agent for recalibration; for addresses see the rear cover of this manual.

Before making any of the adjustments or checks described in the following sections you are recommended to read the preceding Technical Description and to allow the instrument a warm-up period of at least 15 minutes.

4.2 REMOVAL OF CASE

Place the instrument on its back and remove the four screws from the feet of the case. The front panel and chassis assembly can now be lifted clear of the case.

4.3 ACCESS TO COMPONENTS

For access to the SET ZERO preset or the mains input plugs, described in Section 4.4, it may be more convenient to remove only the top plate of the instrument without taking it out of its case. This plate can be lifted clear after removing five screws, two of which are accessible through holes in the component platform.

After removing the instrument from its case and taking off the top plate, the end plates and the under-chassis screening plate may be removed to gain complete access to all components for inspection or replacement. Figs. 4.2 and 4.3 show the layout of the components on the underside of the instrument.

4.4 MAINS INPUT ADJUSTMENTS

Mains input adjustments are made by four two-pin plugs which make contact with the transformer connections, through a reversible masking plate. This plate is marked on one side with voltages applicable to the 200 V to 250 V range (white figures), and on the other side with voltages applicable to the 100 V to 130 V range (black figures). All the possible combinations to suit the input ranges covered by the instrument are shown in Fig. 4.1.

The tapping panel is mounted on top of the mains transformer. To check or adjust the tapping plugs, it is only necessary to remove the five screws and then the top plate as described in Section 4.3.

4.5 WORKING VOLTAGES

The voltages given in Tables 4.1 and 4.2 are for guidance when servicing the instrument and are representative of the readings to be expected if measurements are made with a meter having a resistance of 20,000 ohms per volt.

TABLE 4.1

VALVE ELECTRODE VOLTAGES

	Anode		Cathode (k) or Grid (g)	
Valve	*Pin no.*	*Voltage*	*Pin no.*	*Voltage*
V1 (6X4)	1 & 6	260 a.c.	7 (k)	320
V2 (12AT7)	1	160	3 (k)	0.4
	6	230	8 (k)	4.7
V3 (EF86)	6	130-140*	1 (g)	40-45*
V4 (12AX7)	1	165	3 (k)	0.7
	6	170	8 (k)	0.8

All voltages shown are d. c. with respect to chassis, except for V1 anodes, measured with LCR switch set to R.

* Voltages depend upon setting of BALANCE control, otherwise BALANCE control at full scale.

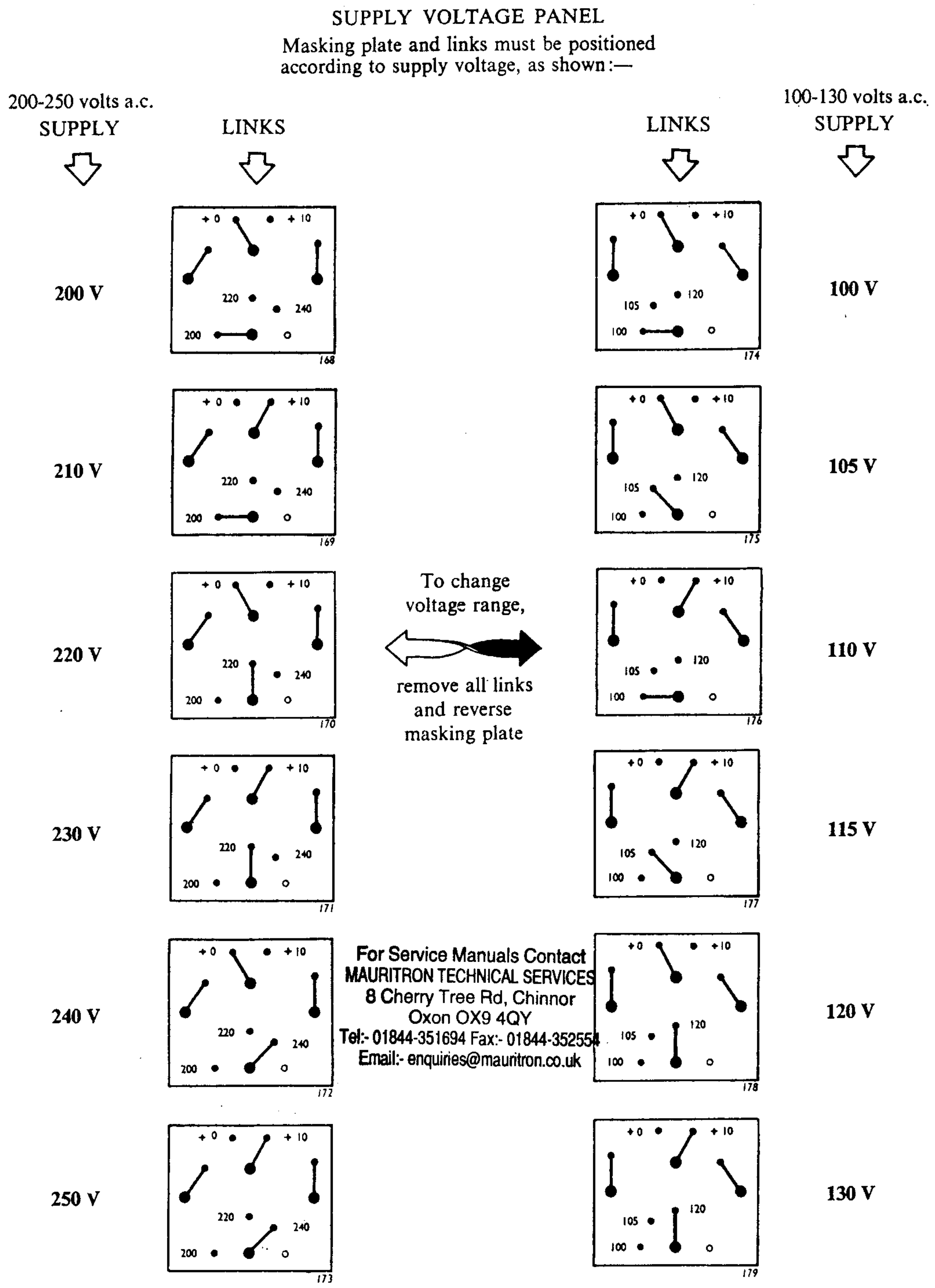


Fig. 4.1 Supply voltage plus settings

TABLE 4.2

Power Supply and Bridge Voltages

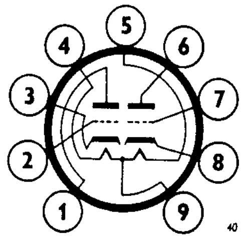
Supply	Where measured	Voltage
H. T.	Across C1	320 V d. c.
	Across C2	280 V d. c.
	Across C42	240 V d. c.
L. T. 1, 2 & 3 †	Across appropriate tags on T1	6.3 V a. c.
L. T. 4		27 V a. c.
Bridge d. c. *	Output from MR1 (LCR switch at R, test terminals open-circuited)	5.8 V d. c.
	Output from MR1 (LCR switch at R, RANGE switch set to 10 Ω, test terminals short-circuited)	0.13 V d. c.
	Output from MR1 (LCR switch at R x 10, test terminals open-circuited)	20 V d. c.
Bridge a. c. *	Secondary tags of T2 (LCR switch set at L or C, D-Q switch at D = 0-.03, test terminals open-circuited)	1 kc/s 330 mV a. c. 10 kc/s 240 mV a. c.

* All bridge voltages measured with BALANCE control at full scale.

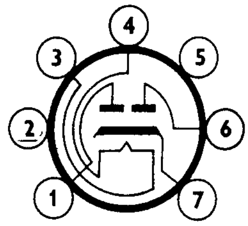
† L. T. 2 tags are at h. t. potential with respect to chassis.

4.6 REPLACEMENT OF VALVES

A list of valves fitted, together with suitable equivalent types, is shown in Table 4.3. Any valve which becomes faulty should preferably be replaced by a valve of the type originally supplied with the instrument. No special selection or aging is required.



a (B9A)



b (B7G)

TABLE 4.3

Valve	*Type*	*Base*	*Commercial equivalent*	*British services*
V1	Brimar 6X4 Full-Wave Rectifier	b	EZ90 U78	CV493 CV4005
V2	Brimar 12AT7 Double Triode	a	ECC81 B390 B152 6060*	CV455 CV4024*
V3	Mullard EF86 Pentode	a	Z729	CV2901
V4	Brimar 12AX7 Double Triode	a	ECC83 B339 6057*	CV492 CV4004*

* *High reliability type*

4.7 ADJUSTMENT OF PRESET COMPONENTS

After removing the instrument from its case, it will be seen that all the main components are clearly marked, hence no difficulty should be experienced in identifying any of the preset controls for which adjustment procedure is described below.

Oscillator preset resistors

Adjustments to the preset resistors, RV1 and RV2 in the 1 kc/s and 10 kc/s oscillator circuits are made before the instrument is despatched. It is not expected that further adjustment will normally be needed. If, however, it is found necessary to reset these resistors, then the resonant frequencies of the preset tuned circuits, including L1 and L2, in the detector-amplifier can be used as standards. The procedure is as follows :-

(1) Connect a 1000 Ω resistor between the DET terminal and the centre E terminal.

(2) Select the 100 H full-scale range.

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

(4) To check the amplitude of the 1 kc/s and 10 kc/s outputs, refer to Section 4.5, Table 4.2.

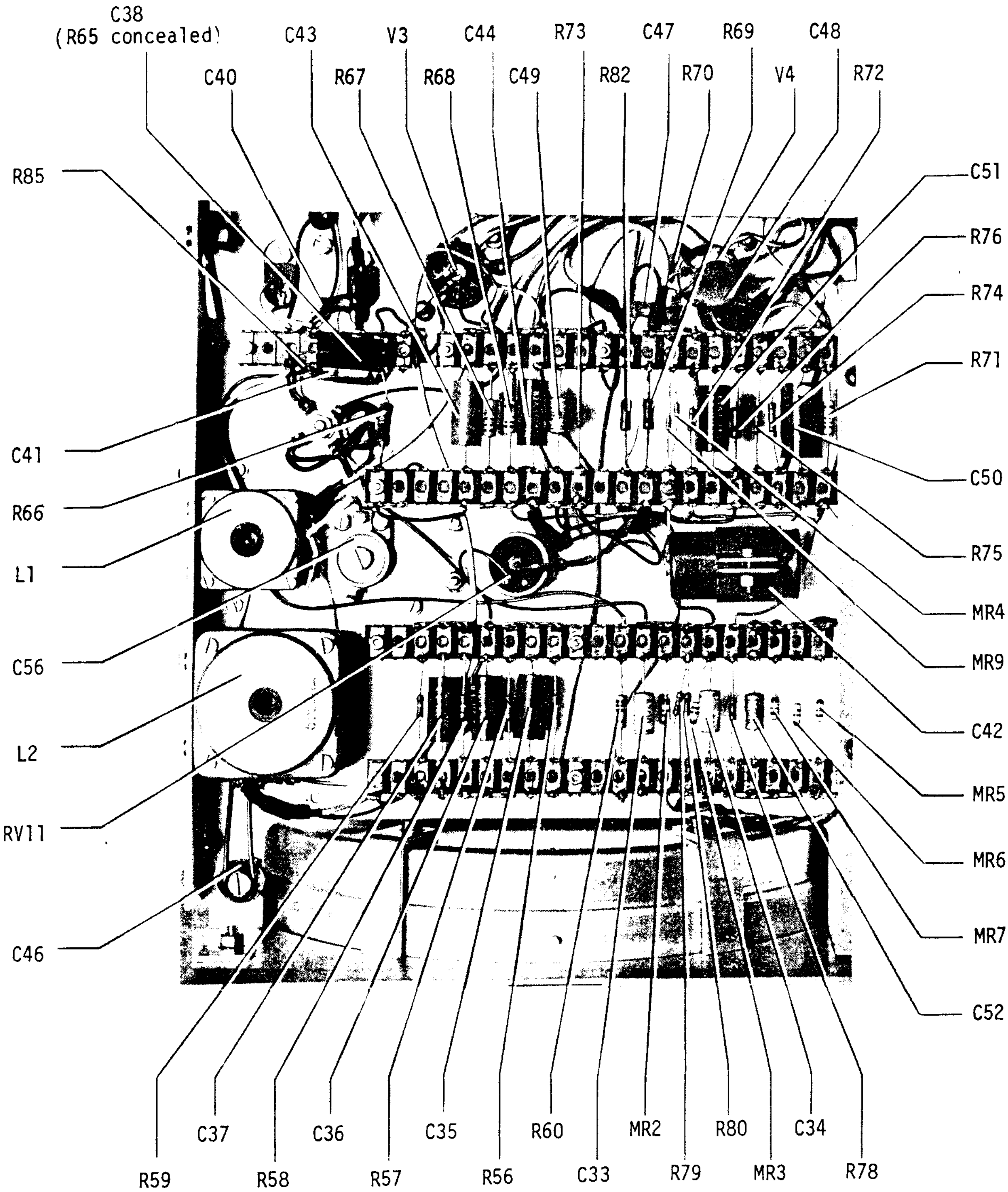


Fig. 4.2 Component layout—bottom left

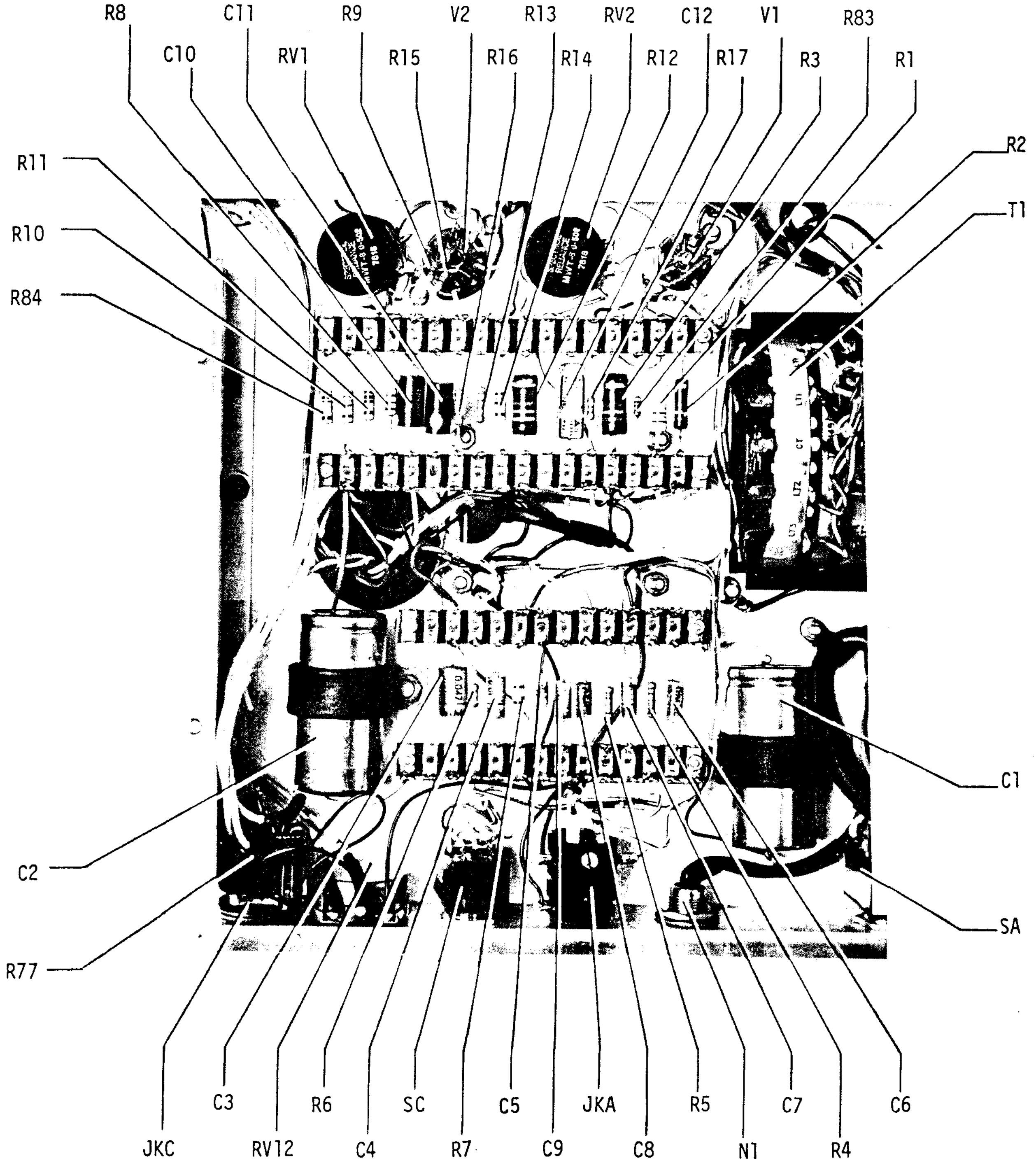


Fig. 4.3 Component layout—bottom right

Detector d.c. zero

The SET ZERO preset, RV11, located behind the main Balance control assembly, is included to allow the effect of thermal e. m. f. 's to be offset at the input of the detector. It is accessible after removing the top plate of the instrument as described in Section 4. 3.

To check the d. c. zero short circuit the DET and E terminals with copper wire, set the RANGE and BALANCE controls to 10 MΩ, and the SENSITIVITY control fully clockwise. Allow at least 20 minutes after switching on the Bridge for thermal stabilization, then adjust the SET ZERO preset for minimum meter reading.

Photo chopper sensitivity

The operation of the photo chopper can be adjusted for optimum performance by means of the two light restricting set screws. They are located in the rear face of the block which is mounted at the right rear corner of the chassis. Each one is secured by a 6BA cheese-head screw accessible through a cutout in the underside of the chassis. If any component associated with the chopper has been replaced the sensitivity may be reset as follows :-

(1) Connect a 10 Ω resistor to the test terminals and set up the Bridge as if to measure it but offset the BALANCE control by 10% (i. e. , to 9 Ω or 11 Ω).

(2) Connect an oscilloscope to the grid of V3a (pin 9).

(3) Adjust both set screws to give maximum amplitude consistent with a good square waveform without spikes. The on/off ratio of the switch should be 1:1 and the frequency approximately 20 c/s.

(4) Tighten the locking screws, taking care not to upset the adjustment of the set screws.

NOTE : A condition can occur when, due to a transient at the time of switching on the chopper, both neons strike together thus preventing the circuit from cycling correctly. The symptoms of this having happened are an unstable meter reading and inability to obtain a balance. Since the chance of this occurring is remote, switching the LCR switch to C and back to R will normally ensure correct operation.

Amplifier 1 kc/s and 10 kc/s filters

The preset tuning adjustment of the filter inductors L1 and L2, in the grid circuit of the 2nd amplifier, V4a, is made before the instrument is despatched. Accurate tape adjustment (see Section 3. 5) is made, the surplus being cut off and the remaining ends stuck down. No further adjustment should be made to the inductors, or to C56, the trimmer across L1.

Bridge preset capacitors

To maintain the accuracy of the D scale 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 the preset capacitors C28, C29, and C30. The setting of these can be checked as follows:note however that adjustment of these presets will also affect the D scale corrections given in the Abridged Instructions. These are obtained from measurements on standard capacitors of known D and will require re-establishing.

(1) Select the 100 pF full-scale range.

(2) Select D = 0-. 03 and 10 kc/s, and turn the LOSS BALANCE control to indicate zero on the D scale.

(3) Connect a 100 pF capacitor (see note below) across the DET and HI terminals; adjust the main BALANCE control to obtain minimum reading on the meter, using C30 if necessary.

(4) Switch to 1 kc/s and check that D = 0 (or nearly so) at this lower frequency. A small readjustment of the FINE BALANCE may be necessary.

The adjustment for the best balance conditions at both 1 and 10 kc/s will be a compromise. Slight re-adjustment of C30 may be necessary in order to obtain a well defined balance at both frequencies. Should a large discrepancy

onent in this part of the circuit remains undisturbed, otherwise measurement accuracy will be affected.

4.8 CHECKING THE LOSS BALANCE DIAL CALIBRATION

Q SCALE. To check the scale, rotate the control to its maximum counter-clockwise position, and ensure that the cursor hair-line coincides with the limit mark on the right of the Q-scale zero. If the cursor does not coincide with the mark, the dial should be moved relative to the spindle of the ganged potentiometers, RV3, RV4 and RV5.

Set the controls to measure capacitance at 1 kc/s, with the D-Q switch at D = 0-.03. Set the LOSS BALANCE dial to zero and the FINE D-Q control to the CAL mark. Connect a 0.1 μF ±½% high grade, polystyrene capacitor to the test terminals. Use the main BALANCE controls only to obtain C balance then add a suitable resistor across the test capacitor or between the HI and E terminals to balance for D.

Switch to Q = 0-30. Using a separate decade resistance box, shunt the capacitor with a resistance of 796 Ω (Note : the earth terminal of the box should be connected to the Bridge E terminal); a minimum meter reading should be obtained when the LOSS BALANCE dial is set to Q = 0.5. The other calibration markings can be similarly checked by shunting the capacitor with the appropriate resistance value - the scale markings and the corresponding resistances are given in Table 4.4.

TABLE 4.4

Q	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
15	23900
20	31900
25	39800
30	47800

D SCALE. The method of checking the D scale is similar to that for checking the Q scale.

As for the Q scale set up the bridge to measure a 0.1 μF capacitor, and with the D scale at zero, balance the bridge using the FINE D-Q control or a suitable resistor connected across the EXT D-Q terminals to balance for D.

Connect a decade resistance box in series with the capacitor to the DET terminal (the box earth terminal should be connected to the Bridge E terminal). The calibration marking should be balanced against the appropriate resistance as for the Q dial - the scale markings and the corresponding resistances are given in Table 4.5.

TABLE 4.5

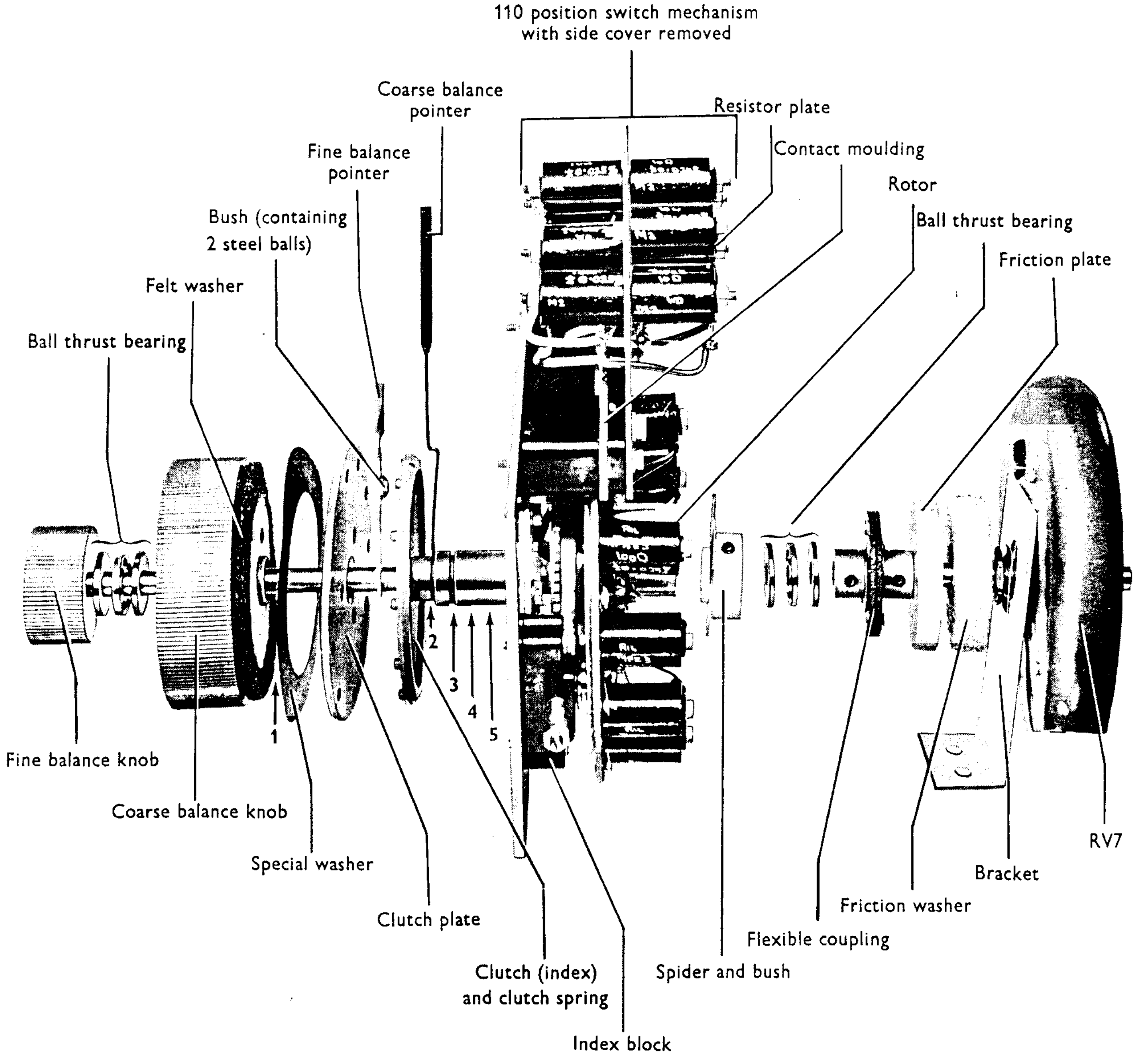
D	R; ohms
0.005	7.96
0.01	15.92
0.015	23.9
0.02	31.9
0.025	39.8
0.03	47.8

NOTE : In the event of a failure of RV3, RV4 or RV5, it should be noted that a ganged assembly, complete with calibrated LOSS BALANCE dial, must be obtained from our Service Division. Should a blank dial be obtained, or if the user prefers to reverse the existing dial, then calibration can be effected by referring to Tables 4.4 and 4.5.

4.9 ACCESS AND ADJUSTMENT TO BALANCE DIAL ASSEMBLY

Throughout the following instructions, reference is made to component parts of the switch; most of these parts are shown in the exploded view of the switch, Fig. 4.4.

Before carrying out any of the instructions below, remove the instrument from its case, take off the top plate and the right side plate.



1 Window **2** Fine balance dial **3** Coarse balance dial **4** Range indicator shutter **5** Range indicator dial

Fig. 4.4 Exploded view—balance switch assembly

Slipping Clutch : If the COARSE BALANCE control can be rotated freely, i.e., without driving the switch rotor or moving the large pointer, this indicates that the switch mechanism is at fault. If the fault is due to loose coupling between the clutch and clutch plate, this can be rectified as follows :-

(a) Set the FINE BALANCE control fully counter-clockwise.

(b) Slacken the two socket screws nearest the front panel in the flexible coupling.

(c) Push the FINE BALANCE knob while holding the flexible coupling to take up the slack in the clutch. Check that the pointer is aligned with the zero mark.

(d) Tighten the socket screws.

Should this procedure fail to cure the fault, check to see if the outer polythene ring on the clutch is worn, and needs replacing. Access to the clutch is achieved as follows :-

(1) Slacken the four socket screws in the flexible coupling and slide back the flexible coupling and ball thrust bearing onto the potentiometer spindle.

(2) Remove the FINE BALANCE pointer assembly, complete with the window and both BALANCE control knobs, by pulling on the COARSE BALANCE knob. It may be necessary to ease the window flange off the rivets with a thin blade. Care should be taken not to lose the two 3/32" steel balls which normally hold the clutch clear of the pointer, or the rivets which hold the window in place.

(3) Remove the three outer roundhead screws holding the perspex disc to which the FINE BALANCE scale is attached. Lift out the disc.

(4) Slacken the two socket screws in the spider bush, which is now at the end of the spindle. The hollow spindle, together with the clutch and large pointer, can now be removed.

(5) If the clutch needs replacing a new hollow spindle assembly must be fitted.

For notes on reassembling, see later.

Pointers : Generally, these assemblies should need no servicing, but in the event of a pointer requiring adjustment (due to its fouling a dial, for instance) the assemblies may be removed as follows.

Access is gained to the FINE BALANCE pointer by proceeding as in (1) and (2) above; then slacken the two socket screws in the FINE BALANCE knob and remove the knob and ball thrust bearing. Pull out the spindle from the rear side of the window.

The COARSE BALANCE pointer can be removed by following (1) to (5) above.

Balance Switch Contacts : It is essential that the contacts of the 110-position switch are kept lubricated in order to minimize wear. They are normally lubricated by a trace of light non-drying grease which should be replenished occasionally. Access to these contacts can be gained as follows :-

(1) Remove the cover plate round the switch assembly (see Fig. 4.5).

(2) Remove the two 6BA screws (marked 'x' in Fig. 4.5) from the resistor plate, and carefully lift off the plate complete with the stator wipers.

The spring contacts and the wipers can now be cleaned with a fine brush and a solvent, and re-lubricated.

If any spring contacts need to be replaced the rotor can now be removed as follows :-

(1) Slacken the four socket screws in the flexible coupling and slide the coupling and ball thrust bearing on to the potentiometer spindle.

(2) Slacken the socket screws in the spider bush at the end of the spindle and remove the spider. Remove the circlip from behind the rotor and slide the rotor off the spindle.

Note : When removing the rotor take care not to lose the 3/32" ball which is part of the indexing mechanism. The ball is spring loaded to press against the index gear and is released when the index gear is removed with the rotor.

Reassembling the Switch : To ensure accurate operation of the switch, after servicing, the following points should be noted :-

(a) Care must be taken to ensure that the spring contacts are not bent otherwise the contact pressure will be reduced.

(b) When refitting the COARSE BALANCE switch assembly, the pointer should indicate zero on the large dial with the switch contacts making as shown in Fig. 4.5.

(c) When replacing the window, make sure that the small rivet in the right hand side of the balance dial assembly housing, is in place.

(d) The FINE BALANCE pointer is set by turning the friction plate and washer fully counerclockwise (as viewed from the front) and setting the pointer to the limit mark before 02. Tighten the socket screws in the flexible coupling and recheck that the pointer stops at the mark when at the limit of its travel. Tension the thrust bearings as described in the adjustment for a slipping clutch.

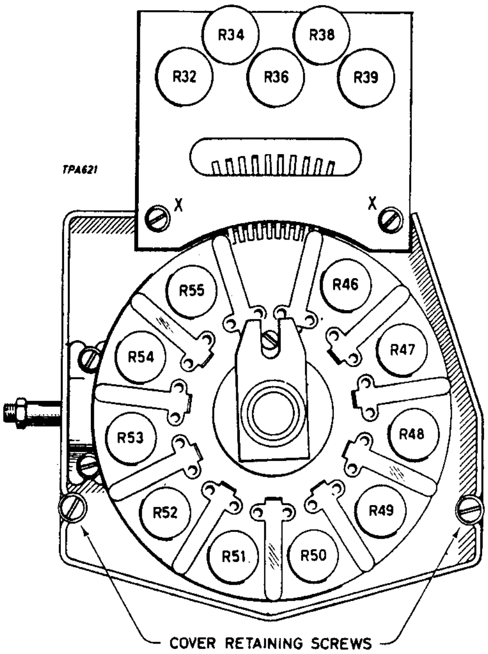


Fig. 4.5 Part of balance switch assembly

Section 5

Replaceable parts

Introduction

When ordering replaceable parts address the order to our Service Division (address on rear cover) or nearest agent and specify the following for each component required.

(1) Type* and serial number of instrument

(2) Complete circuit reference

(3) Description

(4) Marconi Instruments code

* as given on the serial number label at the rear of the instrument; if this is superseded by a model number label, quote the model number instead of the type number.

Abbreviations used are as follows :-

†	:	value selected during test, nominal value shown
C	:	capacitor
Carb	:	carbon
Cer	:	ceramic
Elec	:	electrolytic
Ger	:	germanium
JK	:	jack socket
L	:	inductor
Lin	:	linear
Log	:	logarithmic law
M	:	meter
Met	:	metal
N	:	neon
Ox	:	oxide
PL	:	plug
Plas	:	plastic
R	:	resistor
RV	:	variable resistor
S	:	switch
Sel	:	selenium
Sil	:	silicon
T	:	transformer
TE	:	total excursion
V	:	valve
Var	:	variable or preset
WW	:	wire wound
W	:	watts at 70 °C
W*	:	watts at 55 °C
W**	:	watts at 40 °C
W°	:	watts at unspecified temperature

Circuit reference	*Description*	*M.I. code*
CAPACITORS		
C1	Elec 32 µF +50-20% 450 V	26425-120
C2	Elec 68µF +50-20% 315V	26415-358
C3	Plas .047 µF ±5% 400 V	26511-340
C4	Plas .01 µF ±5% 400 V	26511-316
C5	Plas .0033 µF ±5% 400 V	26511-129
C6	Plas .0015 µF ±5% 400 V	26511-120
C7	Plas .0015 µF ±5% 400 V	26511-120
C8	Plas .0015 µF ±5% 400 V	26511-120
C9	Plas .0015 µF ±5% 400 V	26511-120
C10	Plas .01 µF ±10% 400 V	26512-204
C11	Plas .01 µF ±10% 400 V	26512-204
C12	Elec 1µF +75-20% 400V	26412-256
C13	Mica .01 µF ±1% 350 V	26257-392
C14	Mica 100 pF ±5% 350 V	26266-272
C15	Mica 200 pF ±2% 350 V	26266-433
C16	Mica 200 pF ±2% 350 V	26266-433
C17	Mica 200 pF ±2% 350 V	26266-433
C18	Mica 200 pF ±2% 350 V	26266-433
C19	Cer 400 pF ±10% 500 V	26361-926
C20	Mica .089 µF ±½% 350 V	26257-526
C21	Var Cer 12-100 pF	26847-478
C22	Cer 15 pF ±5% 750 V	26324-795
C23	Plas .033 µF ±10% 125 V	26511-331
C24	Plas 0.22µF ±10% 250V	26512-244
C25	Plas .01 µF ±10% 400 V	26512-204
C26	Plas .002 µF ±2% 125 V	26516-556
C27	Plas 110 pF ±2% 125 V	26516-254
C28	Var Air 3-30 pF	26814-409
C29	Var Cer 1 - 10 pF	26852-121
C30	Var Cer 1-10pF	26852-121

Circuit reference	*Description*	*M.I. code*
C31	Plas 390 pF ±2% 125 V	26516-387
C32	Plas 390 pF ±2% 125 V	26516-387
C33	Elec 47μF +100-20% 10V	26415-809
C34	Elec 47μF +100-20% 10V	26415-809
C35	Plas 0.22 μF ±10% 250 V	26512-244
C36	Plas 0.22 μF ±10% 250 V	26512-244
C37	Plas 0.22 μF ±10% 250 V	26512-244
C38	Plas 0.22 μF ±10% 250 V	26512-244
C39	Plas 0.15 μF ±10% 400 V	26512-240
C39A	† Plas .047 μF ±10% 400 V	26512-216
C40	Paper .002 μF ±10% 350 V	26174-129
C41	Plas .01 μF ±1% 125 V	26516-718
C42	Elec 32 μF +50-20% 300 V	26417-485
C43	Plas 0.1 μF ±10% 400 V	26512-232
C44	Plas .047 μF ±10% 400 V	26512-216
C46	Plas .01 μF ±1% 125 V	26546-285
C47	Paper .001 μF ±10% 500 V	26174-125
C48	Cer .01 μF +80-20% 350 V	26383-392
C49	Elec 22μF +100-20% 25V	26415-805
C50	Paper 0.22μF ±10% 400V	26512-248
C51	Plas .047 μF ±10% 400 V	26512-216
C52	Elec 25 μF +100-20% 6 V	26412-243
C51	Plas .047 μF ±10% 400 V	26512-216
C52	Elec 22μF +100-20% 25V	26415-805
C53	Paper .004 μF ±10% 250 V	26174-137
C54	Elec 47μF +100-20% 40V	26415-810
C55	Plas 0.1 μF ±10% 400 V	26512-232
C56	Var Cer 10-60 pF	26847-469
C57	† Plas 0.047μF ±10% 400V	26512-216
JKA	EXT OSC jack	23421-684
JKB	BIAS jack	23421-683

Circuit reference	*Description*	*M.I. code*
JKC	EXT DET jack	23421-659
L1	10 kc/s Filter choke	44265-602
L2	1 kc/s Filter choke	44265-601
M1	Meter, 100 μA	44554-412
RECTIFIERS		
MR1	Sel 430 SCF-2BI-Z	28316-386
MR2	AAZ17	28322-157
MR3	AAZ17	28322-157
MR4	1N4148	28336-676
MR5	AAZ17	28322-157
MR6	AAZ17	28322-157
MR7	AAZ17	28322-157
MR8	Sil 1S923	28356-018
MR9	1N4148	28336-676
NEONS		
N1	Pilot lamp 250 V	23733-120
N2	NE2H	23733-104
N3	NE2H	23733-104
PLA	Mains plug	43122-001

For symbols and abbreviations see introduction to this section

RESISTORS : FIXED

Circuit reference	*Description*	*M.I. code*
R1	Met ox 15Ω ±5% 1W	24585-101
R2	Met ox 560Ω ±5% 1W	24585-120
R3	Met ox 2.7kΩ ±5% 2W	24587-236
R4 †	Met ox 10kΩ ±7% TE 3/8W*	24552-110
R5 †	Met ox 10kΩ ±7% TE 3/8W*	24552-110
R6 †	Met film 18kΩ ±2% $\frac{1}{4}$W	24773-303
R7	Met ox 91kΩ ±7% TE 3/8W*	24552-134
R8	Carb 2.2MΩ ±5% 0.3W	24313-974
R9	Met film 330Ω ±2% $\frac{1}{4}$W	24773-261
R10	Met ox 33kΩ ±2% $\frac{1}{4}$W	24573-109
R11	Met ox 100Ω ±7% TE 3/8W*	24552-050
R12	Met ox 6.8kΩ ±5% 2W	24587-246
R13	Met ox 330Ω ±7% TE 3/8W*	24552-063
R14	Met ox 150Ω ±7% TE 3/8W*	24552-054
R15	Met film 330Ω ±2% $\frac{1}{4}$W	24773-261
R16	Met ox 470kΩ ±2% $\frac{1}{2}$W	24573-137
R17	Met film 5.6kΩ ±2% $\frac{1}{4}$W	24773-291
R18	WW 1.01Ω ±.025%	44361-206
R19	WW 10Ω ±.025%	44361-414
R20	Met film 39kΩ ±2% $\frac{1}{4}$W	24773-311
R21	WW 100Ω ±.025%	44362-608
R22	WW 1kΩ ±.025%	44364-605
R23	WW 10kΩ ±.025%	44366-404
R24	Met film 4.7kΩ ±2% $\frac{1}{4}$W	24638-601
R25	Met film 93.7kΩ ±1% $\frac{1}{2}$W	24657-651
R26	Met film 47kΩ ±2% $\frac{1}{4}$W	24638-776
R27	Met film 937kΩ ±1% $\frac{1}{2}$W	24657-851
R28 †	Met ox 330kΩ ±2% $\frac{1}{2}$W	24573-133
R29 †	Met ox 470kΩ ±2% $\frac{1}{2}$W	24573-137
R30 †	Met ox 1MΩ ±2% $\frac{1}{2}$W	24573-145
R31	WW 100Ω ±.025% 1W^{o}	44362-607
R32	WW 10 Ω ±.025%	44361-413
R33	WW 10 Ω ±.025%	44361-413
R34	WW 10 Ω ±.025%	44361-413
R35	WW 10 Ω ±.025%	44361-413
R36	WW 10 Ω ±.025%	44361-413
R37	WW 10 Ω ±.025%	44361-413
R38	WW 10 Ω ±.025%	44361-413
R39	WW 10 Ω ±.025%	44361-413
R40	WW 10 Ω ±.025%	44361-413
R41 †	Met film 15kΩ ±2% $\frac{1}{4}$W	24773-301
R42 †	Met film 22kΩ ±2% $\frac{1}{4}$W	24773-305
R43 †	Met film 47kΩ ±2% $\frac{1}{4}$W	24773-313
R44	WW 10Ω ±.025% 1W^{o}	44361-412
R45	Met film 5.6kΩ ±2% $\frac{1}{4}$W	24773-291
R46	WW 100 Ω ±.025%	44362-608
R47	WW 100 Ω ±.025%	44362-608
R48	WW 100 Ω ±.025%	44362-608
R49	WW 100 Ω ±.025%	44362-608
R50	WW 100 Ω ±.025%	44362-608
R51	WW 100 Ω ±.025%	44362-608
R52	WW 100 Ω ±.025%	44362-608
R53	WW 100 Ω ±.025%	44362-608
R54	WW 100 Ω ±.025%	44362-608
R55	WW 100 Ω ±.025%	44362-608
R56	Met film 150kΩ ±2% $\frac{1}{4}$W	24773-325
R57	Met film 150kΩ ±2% $\frac{1}{4}$W	24773-325
R58	Met film 150kΩ ±2% $\frac{1}{4}$W	24773-325
R59	Met film 150kΩ ±2% $\frac{1}{4}$W	24773-325
R60	Met ox 1MΩ ±2% $\frac{1}{2}$W	24573-145
R61	Met ox 110kΩ ±2% $\frac{1}{2}$W	24573-122
R62	Met ox 110kΩ ±2% $\frac{1}{2}$W	24573-122
R63	Photo Cell, NSL-364CL	25687-320
R64	Photo Cell, NSL-364CL	25687-320

For symbols and abbreviations see introduction to this section

Circuit reference	Description	M.I. code
R65	Met ox 22Ω ±10% $\frac{1}{2}$W	24511-528
R66	Carb 50MΩ ±10% 0.1W	24288-147
R67	Carb 2.2MΩ ±5% $\frac{1}{2}$W	24313-974
R68	Carb 220kΩ ±7% TE, 3/8W*	24552-143
R69	Met ox 1MΩ ±2% $\frac{1}{2}$W	24573-145
R70	Carb 4.7MΩ ±10% $\frac{1}{4}$W	24322-982
R71	Met ox 33kΩ ±2% $\frac{1}{2}$W	24573-109
R72	Met film 150kΩ ±2% $\frac{1}{4}$W	24773-325
R73	Carb 1.5kΩ ±2% $\frac{1}{4}$W	24773-277
R74	Carb 47kΩ ±2% $\frac{1}{2}$W	24573-113
R75	Met film 330Ω ±2% $\frac{1}{4}$W	24773-261
R76	Met ox 1MΩ ±2% $\frac{1}{2}$W	24573-145
R77	Met film 15kΩ ±2% $\frac{1}{4}$W	24773-301
R78	Met film 1kΩ ±2% $\frac{1}{4}$W	24773-273
R79	Met film 330Ω ±2% $\frac{1}{4}$W	24773-261
R80	Met film 330Ω ±2% $\frac{1}{4}$W	24773-261
R81	Carb 10MΩ ±10% $\frac{1}{4}$W	24322-991
R82	Met ox 1MΩ ±2% $\frac{1}{2}$W	24573-145
R83	Met film 8.2kΩ 2% $\frac{1}{4}$W	24773-295
R84	Met ox 180kΩ 2% $\frac{1}{2}$W	24573-127
R85	Carb 1MΩ 5% 1/8W	24311-945

RESISTORS : VARIABLE

Circuit reference	Description	M.I. code
RV1	WW 5 kΩ ±10% 3/4W	25815-184
RV2	WW 5 kΩ ±10% 3/4W	25815-184
RV3	WW 5.1 kΩ	44372-012
RV4	WW 51 kΩ	44372-012
RV5	WW 51 Ω	44372-012
RV6	WW 100 Ω ±10% 4 W^{O}	25824-622
RV7	WW 12 Ω ±6%	44371-022
RV8	WW 330 Ω ±10% $\frac{1}{2}$W^{O}	25815-175
RV9	WW 3.3 kΩ ±10% $\frac{1}{2}$W^{O}	25815-187
RV10	WW 33 kΩ ±10% 1 W^{O}	25815-774
RV11	Carb lin 250 kΩ ±20% $\frac{1}{4}$W^{O}	25615-163
RV12	Carb log 250 kΩ ±10% 1 W^{O}	25656-536

SWITCHES

Circuit reference	Description	M.I. code
SA	SUPPLY, D.P.C.O.	44334-003
SB	LCR 4 section 4 position	44323-705
SC	1 kc/s-10 kc/s, D.P.C.O.	44334-003
SD	D-Q, 2 section 4 position	44323-317
SE	RANGE, 2 section 8 position	44325-110
SF	BALANCE, 110 position	44331-306
T1	Mains transformer	43464-017
T2	Bridge drive transformer	43590-071

VALVES and VALVE HOLDERS

Circuit reference	Description	M.I. code
V1	Full wave rectifier, 6X4	28112-802
	Holder. for V1, B7G	28237-125
V2	Double Triode. 12AT7	28124-602
	Holder for V2, B9A	28237-272
	Screening Can	28237-548
V3	Pentode. EF86	28154-207
	Holder for V3, B9A	28237-272
	Screening Can	28237-548
V4	Double triode, 12AX7	28124-302
	Holder for V4, B9A	28237-170

For symbols and abbreviations see introduction to this section

Circuit reference	Description	M.I. code
	KNOBS	
	COARSE BALANCE	31149-019
	FINE BALANCE	31141-101
	LOSS BALANCE	41141-204
	FINE D-Q	41142-210
	LCR	41145-206
	RANGE	41145-225
	D-Q	41145-208
	SENSITIVITY	41142-210
	MISCELLANEOUS	
	BALANCE switch assembly includes :	
	Rotor assembly	44332-701
	Spring contact	44315-020
	Contact moulding (inc. 10 wipers)	37587-418
	Index gear	31361-106

Circuit reference	Description	M.I. code
	Index block	44332-806
	Spring	31111-716
	Ball, 3/32" dia.	22658-503
	Flexible coupling	41315-005
	Clutch & coarse balance pointer assembly	41171-006
	Pointer (fine balance with spindle)	41171-005
	Ball thrust bearing	22631-301
	Friction washer	37114-109
	Window moulding	37567-123
	LOSS BALANCE dial and potentiometers	44372-013
	Cursor (for loss balance dial)	31185-704
	Jack plug (to fit JKA, JKB and JKC)	23421-612
	Terminal (HI, DET, E or EXT D-Q)	23235-176

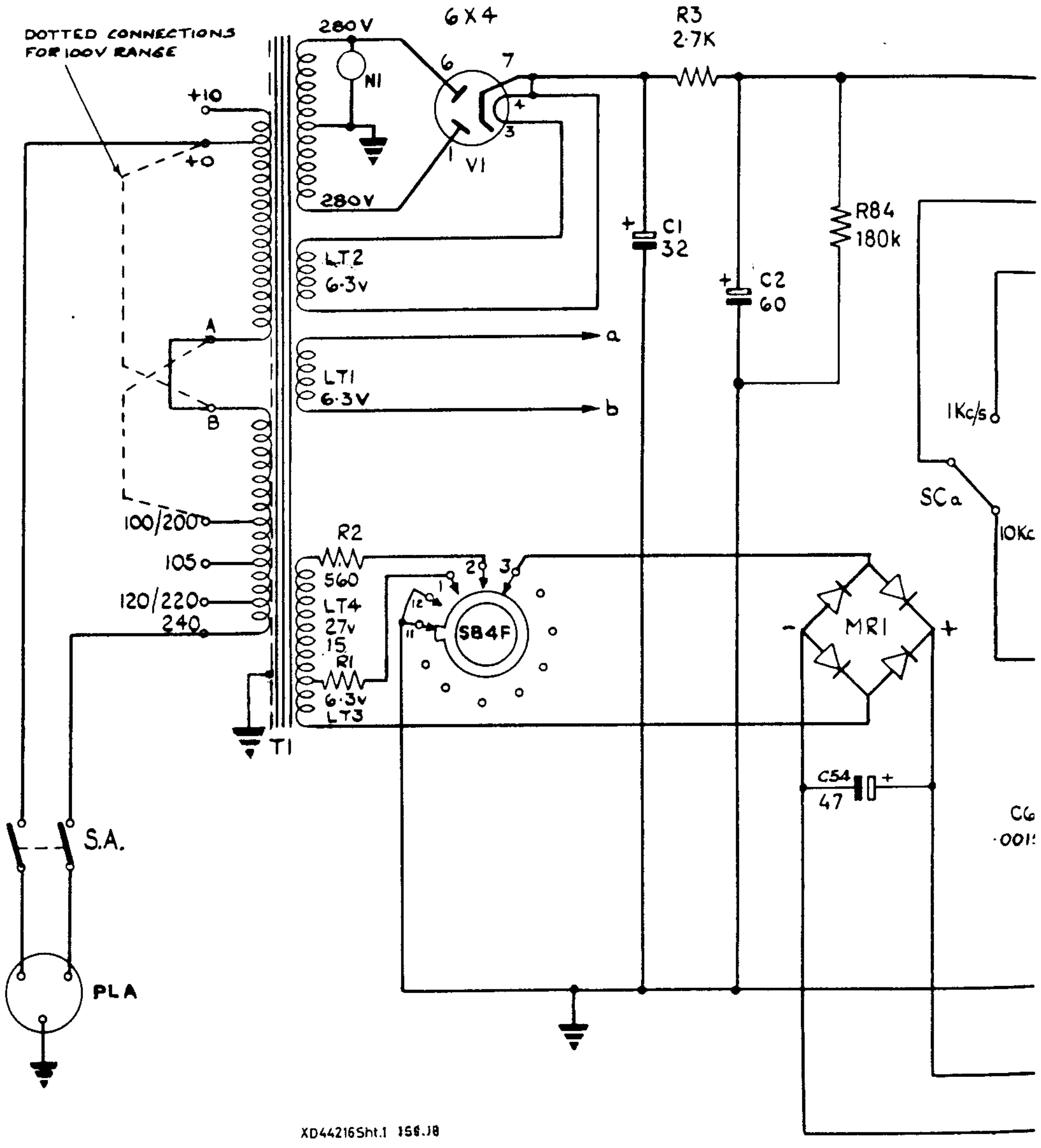
Section 6

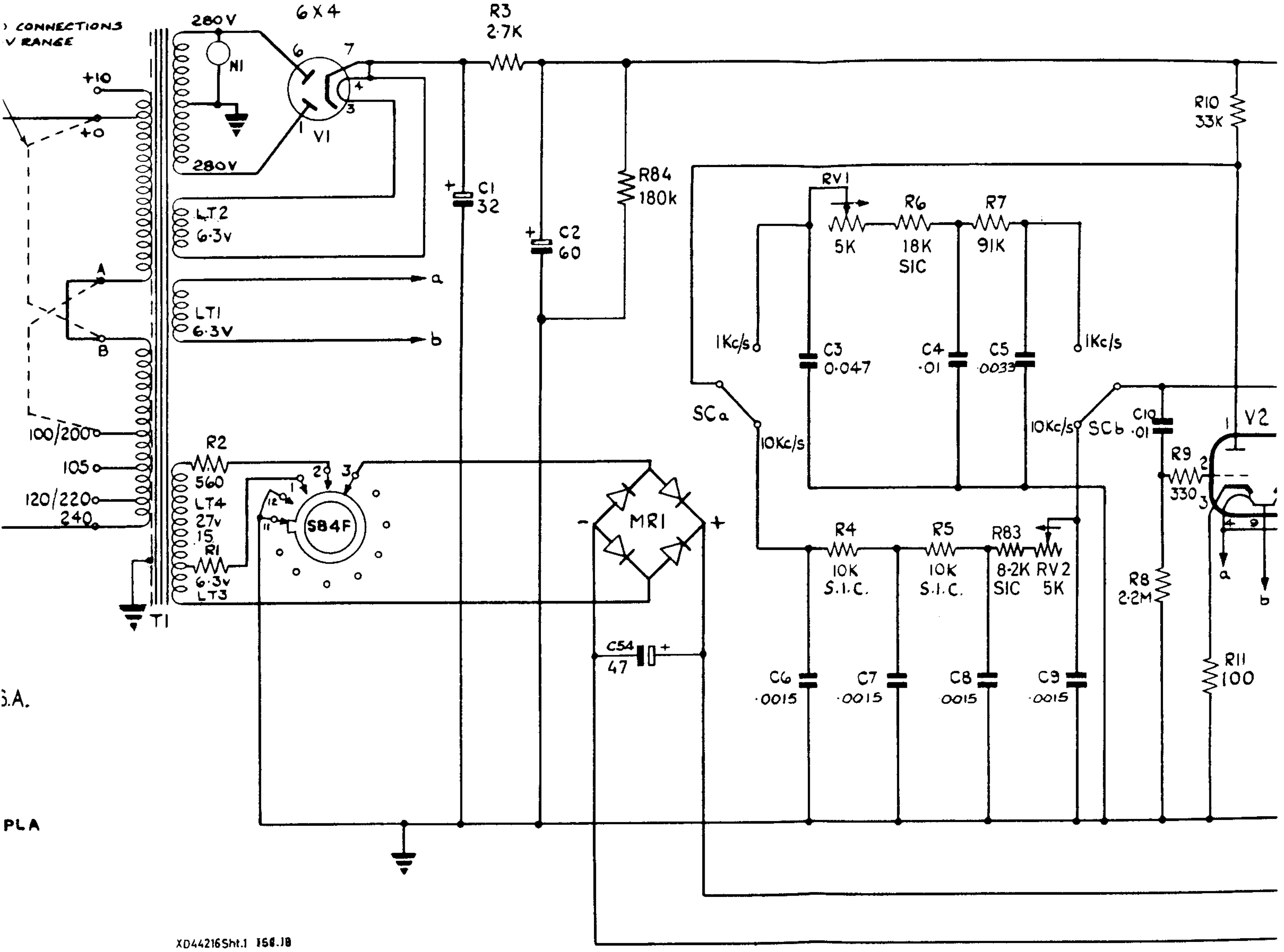
Circuit diagrams

Circuit notes

1. COMPONENT VALUES
   Resistors : No suffix = ohms, k = kilohms, M = megohms.
   Capacitors : No suffix = microfarads, p = picofarads.
   S. I. C. : Values selected or components added or omitted during test.

2. SYMBOLS
   +► arrow indicates clockwise rotation of knob.


DOTTED CONNECTIONS
FOR 100V RANGE
+10
+0
A
B
100/200
105
120/220
240
T1
280V
N1
280V
6X4
6
7
1
3
V1
LT2
6·3v
LT1
6·3V
a
b
R2
560
LT4
27v
15
R1
6·3v
LT3
SB4F
R3
2·7K
C1
32
C2
60
R84
180k
MR1
C54
47
1Kc/s
SCa
10Kc
C6
·001!
S.A.
PLA
XD44216Sht.1


CONNECTIONS
V RANGE
+10
+0
A
B
100/200
105
120/220
240
T1
280V
N1
280V
6X4
V1
LT2
6·3v
LT1
6·3V
a
b
R2
560
LT4
27v
15
R1
6·3v
LT3
S84F
R3
2·7K
C1
32
C2
60
R84
180k
MR1
C54
47
RV1
5K
R6
18K
SIC
R7
91K
1Kc/s
C3
0·047
C4
·01
C5
·0033
SCa
10Kc/s
SCb
C10
·01
R4
10K
S.I.C.
R5
10K
S.I.C.
R83
8·2K
SIC
RV2
5K
C6
·0015
C7
·0015
C8
·0015
C9
·0015
R10
33K
V2
R9
330
R8
2·2M
R11
100
XD44216Sht.1 158.18

.A.

PLA

A (1d)

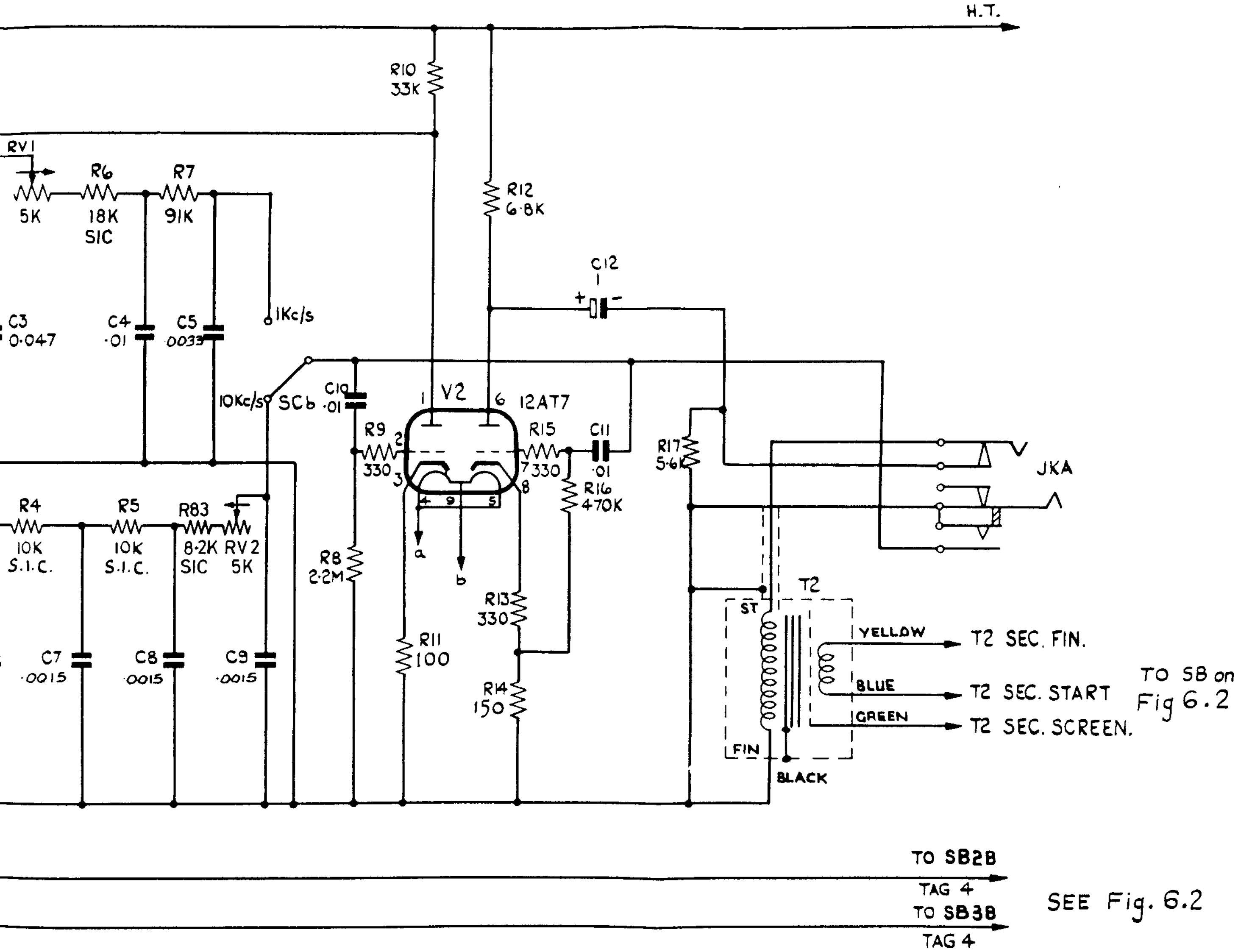
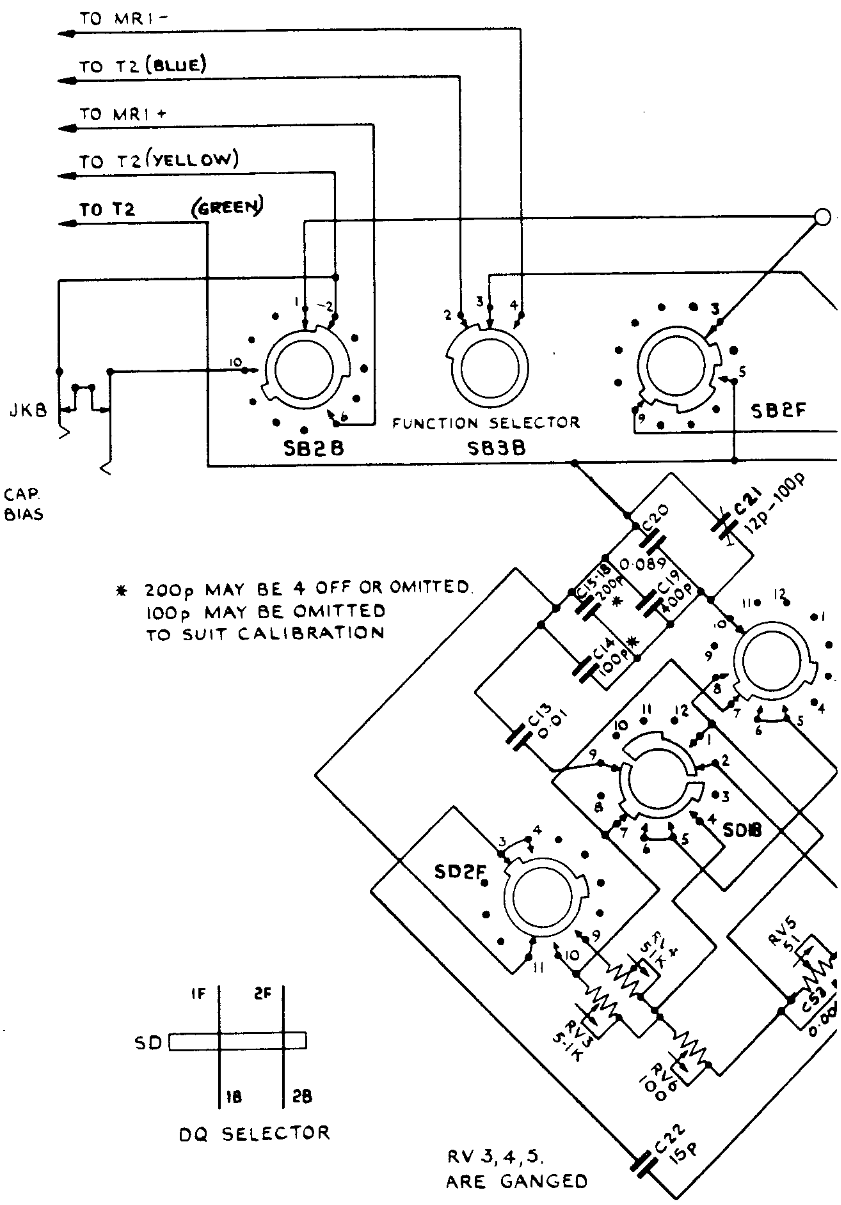
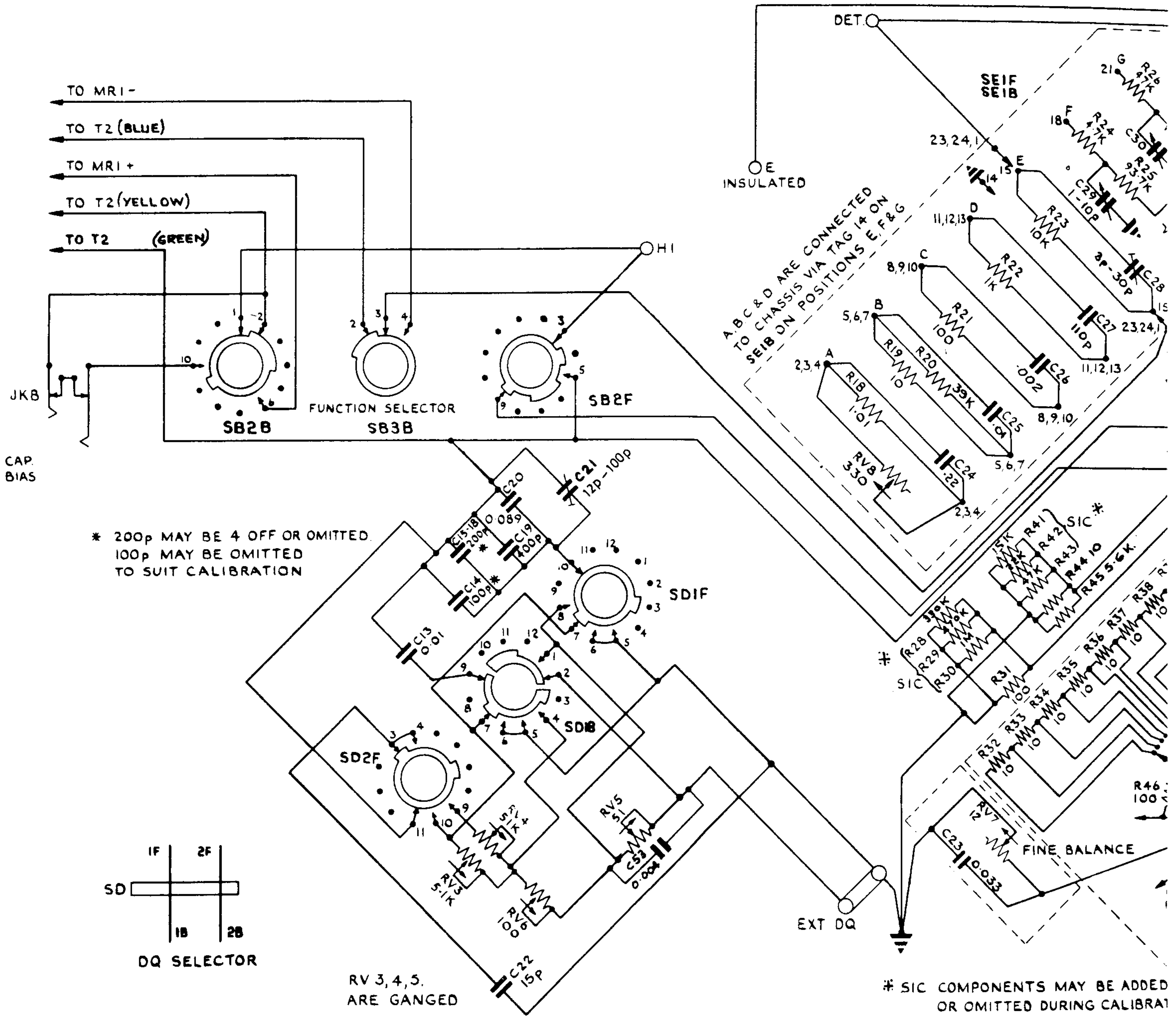


Fig. 6.1 Power supply and oscillator


TO MR1 -
TO T2 (BLUE)
TO MR1 +
TO T2 (YELLOW)
TO T2 (GREEN)
JKB
CAP.
BIAS
SB2B
FUNCTION SELECTOR
SB3B
SB2F
C20
C21 12p-100p
C15-18 200p
0.089
C19 400p
C14 100p
C13 0.01
* 200p MAY BE 4 OFF OR OMITTED
100p MAY BE OMITTED
TO SUIT CALIBRATION
SD1B
SD2F
RV4 5.1K
RV3 5.1K
RV6 10
RV5 5.1
C52
C22 15p
RV 3, 4, 5.
ARE GANGED
1F
2F
SD
1B
2B
DQ SELECTOR


TO MR1 -
TO T2 (BLUE)
TO MR1 +
TO T2 (YELLOW)
TO T2 (GREEN)
HI
DET.
E
INSULATED
SE1F
SE1B
A, B, C & D ARE CONNECTED TO CHASSIS VIA TAG 14 ON SE1B ON POSITIONS E, F & G
JKB
CAP. BIAS
SB2B
FUNCTION SELECTOR
SB3B
SB2F
* 200p MAY BE 4 OFF OR OMITTED
100p MAY BE OMITTED
TO SUIT CALIBRATION
SD1F
SD1B
SD2F
SIC
FINE BALANCE
EXT DQ
DQ SELECTOR
RV 3, 4, 5. ARE GANGED
* SIC COMPONENTS MAY BE ADDED OR OMITTED DURING CALIBRAT

(1c)

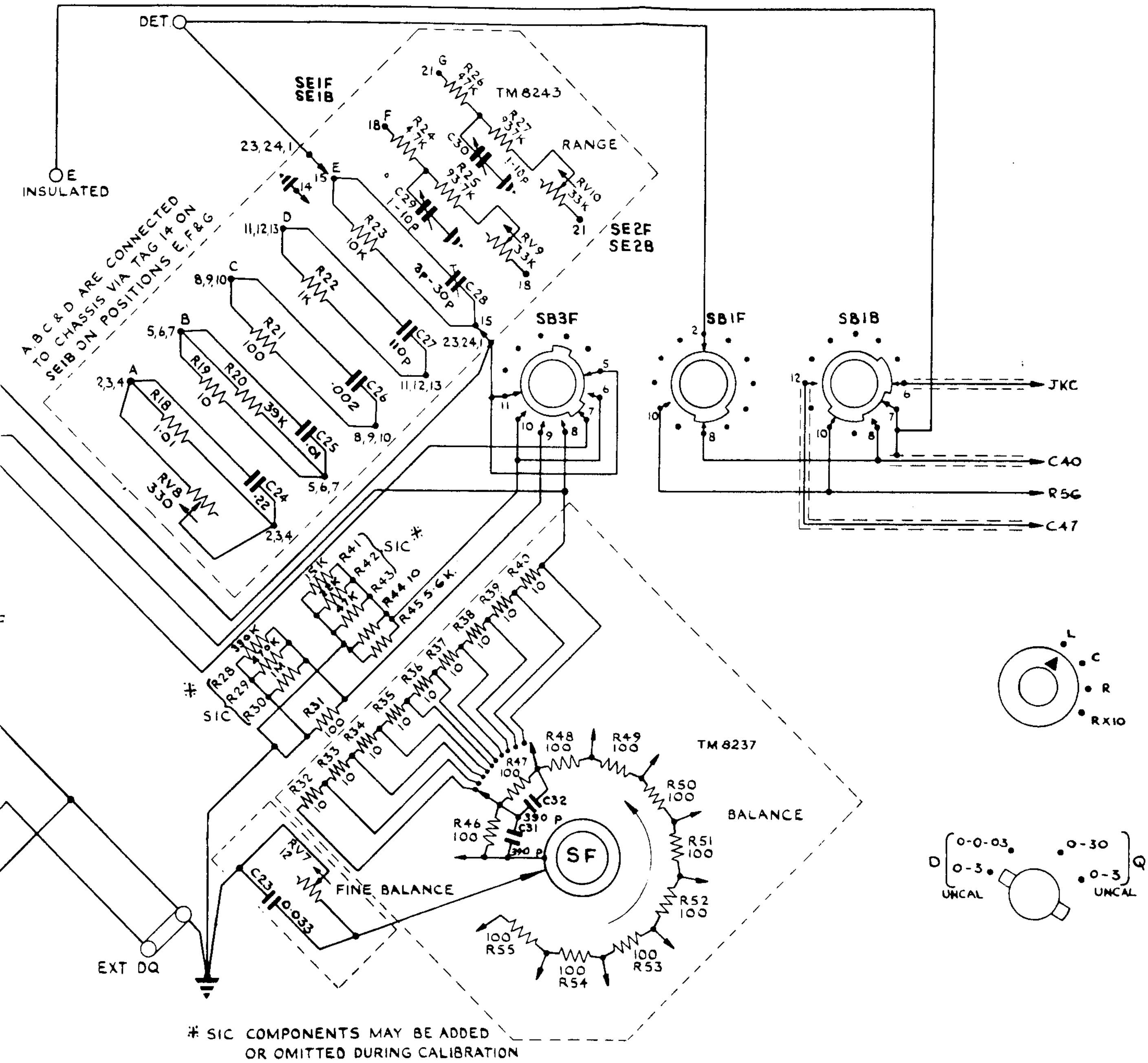
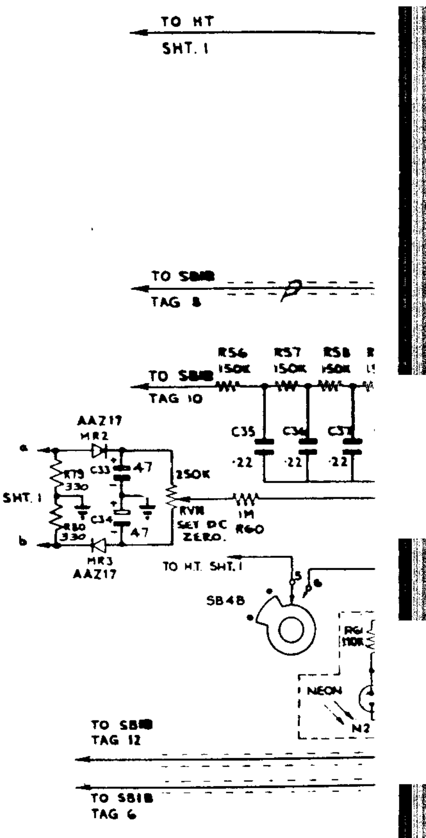
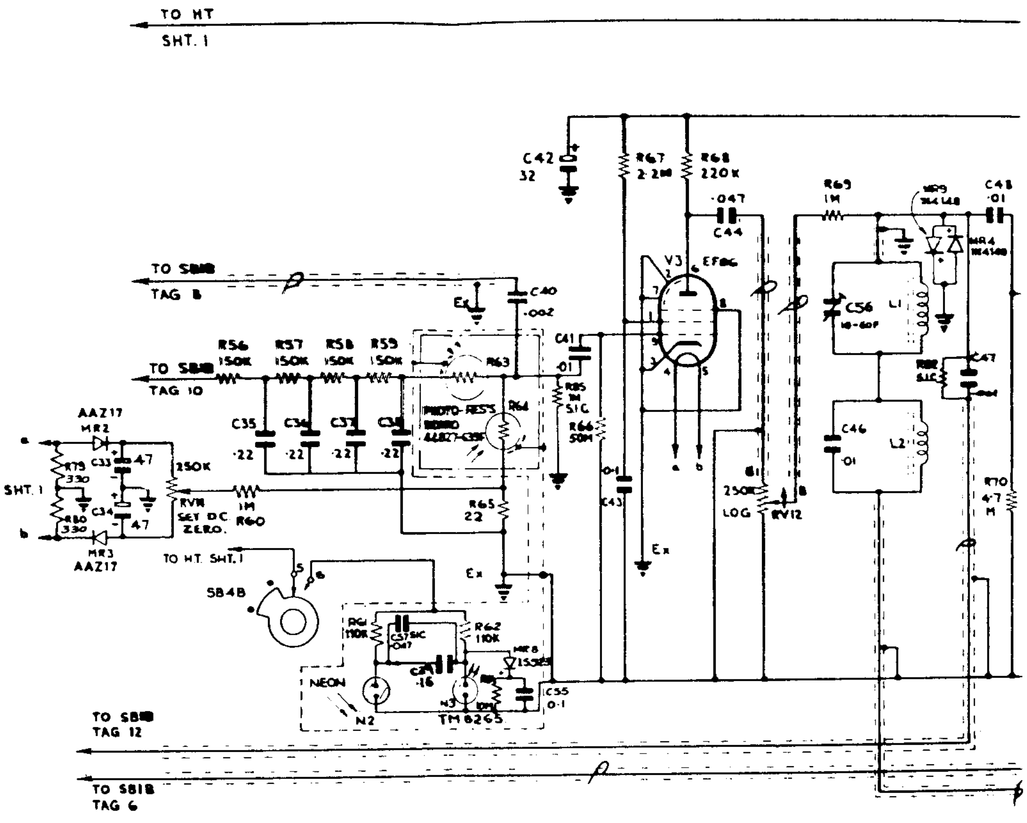
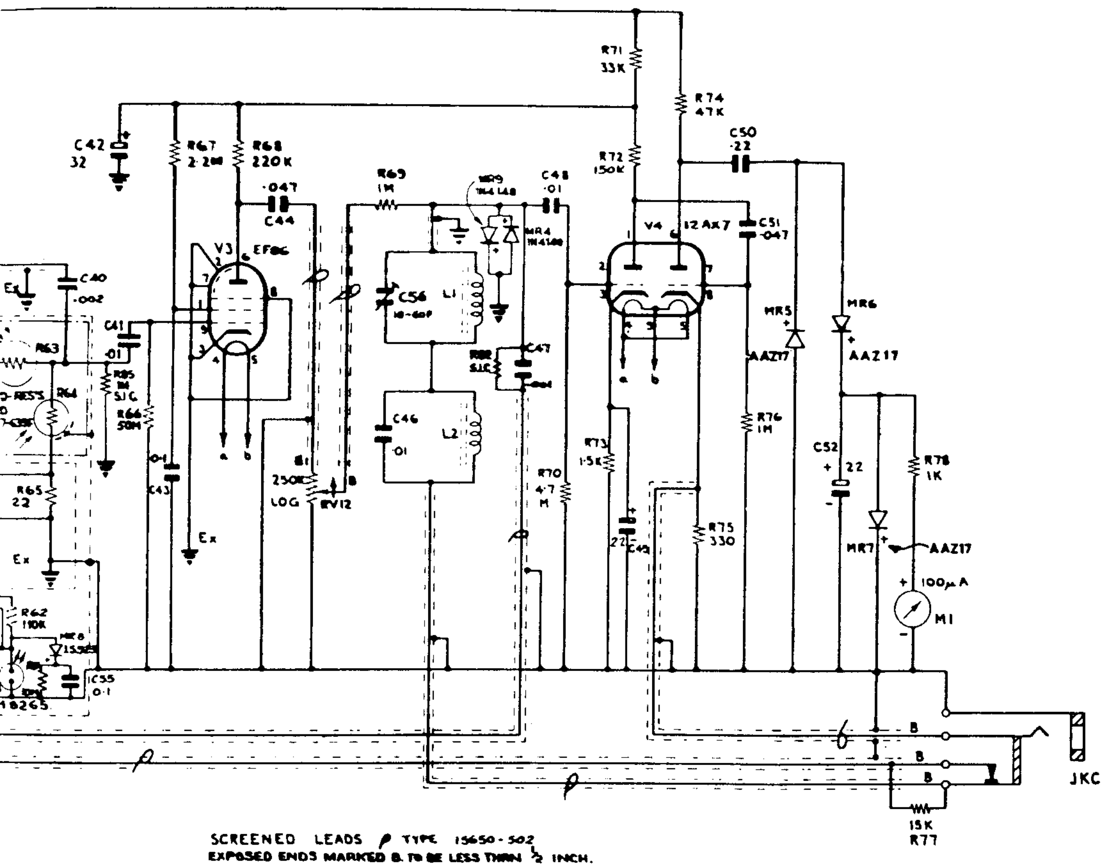


Fig. 6.2 Bridge


TO HT
SHT. 1
TAG 8
TO SB1B
TAG 10
C35
·22
AAZ17
MR2
C33
47
250K
SHT. 1
R79
330
R80
330
C34
47
RV11
SET DC
ZERO.
1M
R60
MR3
AAZ17
TO H.T. SHT.1
SB4B
NEON
N2
TAG 12
TO SB1B
TAG 6



SCREENED LEADS ρ TYPE 15650-502
EXPOSED ENDS MARKED B TO BE LESS THAN 1/2 IN



SCREENED LEADS TYPE 15650-502
EXPOSED ENDS MARKED B TO BE LESS THAN ½ INCH.

Fig. 6.3 Detector

D.C. CHOKE ADAPTOR TYPE TM 61.3

CAPACITORS

C1	Cer 2000 pF 20% 500 V	26364-210
C2	Cer 2000 pF 20% 500 V	26364-210
C3	Cer 2000 pF 20% 500 V	26364-210
C4	Cer 2000 pF 20% 500 V	26364-210
C5	Cer 2000 pF 20% 500 V	26364-210
C6	Cer 2000 pF 20% 500 V	26364-210
C7	Cer 2000 pF 20% 500 V	26364-210
C8	0.047μF (S.I.C.)*	
C9	0.047μF (S.I.C.)*	
C10	15-33 pF (S.I.C.)	
C11	Elec 1 μF 275 V	26452-101
C12	Var 500-5500 pF	26857-329
C13	Elec 68μF +20%-50% 315V	26415-358

INDUCTORS

L1	360 mH coil assembly	TB 31309
L2	360 mH coil assembly	TB 31309

SWITCH

SA	Rotary	TC 4428/545

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

KNOBS

Knob for C12	TB 28666
Knob for SA	TC 17848/4

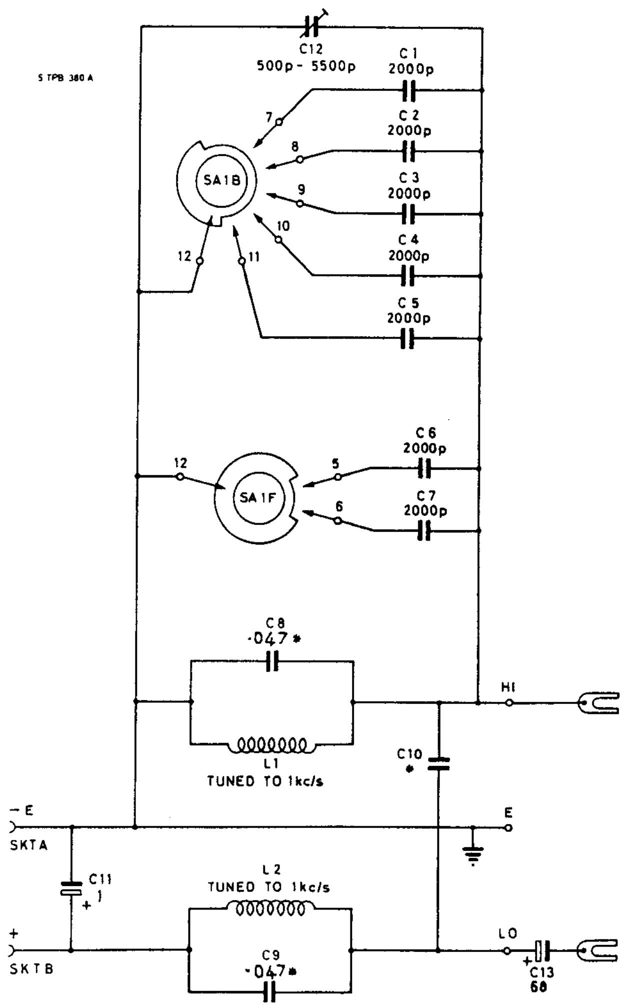


Fig. 6.4 D.C. choke adaptor