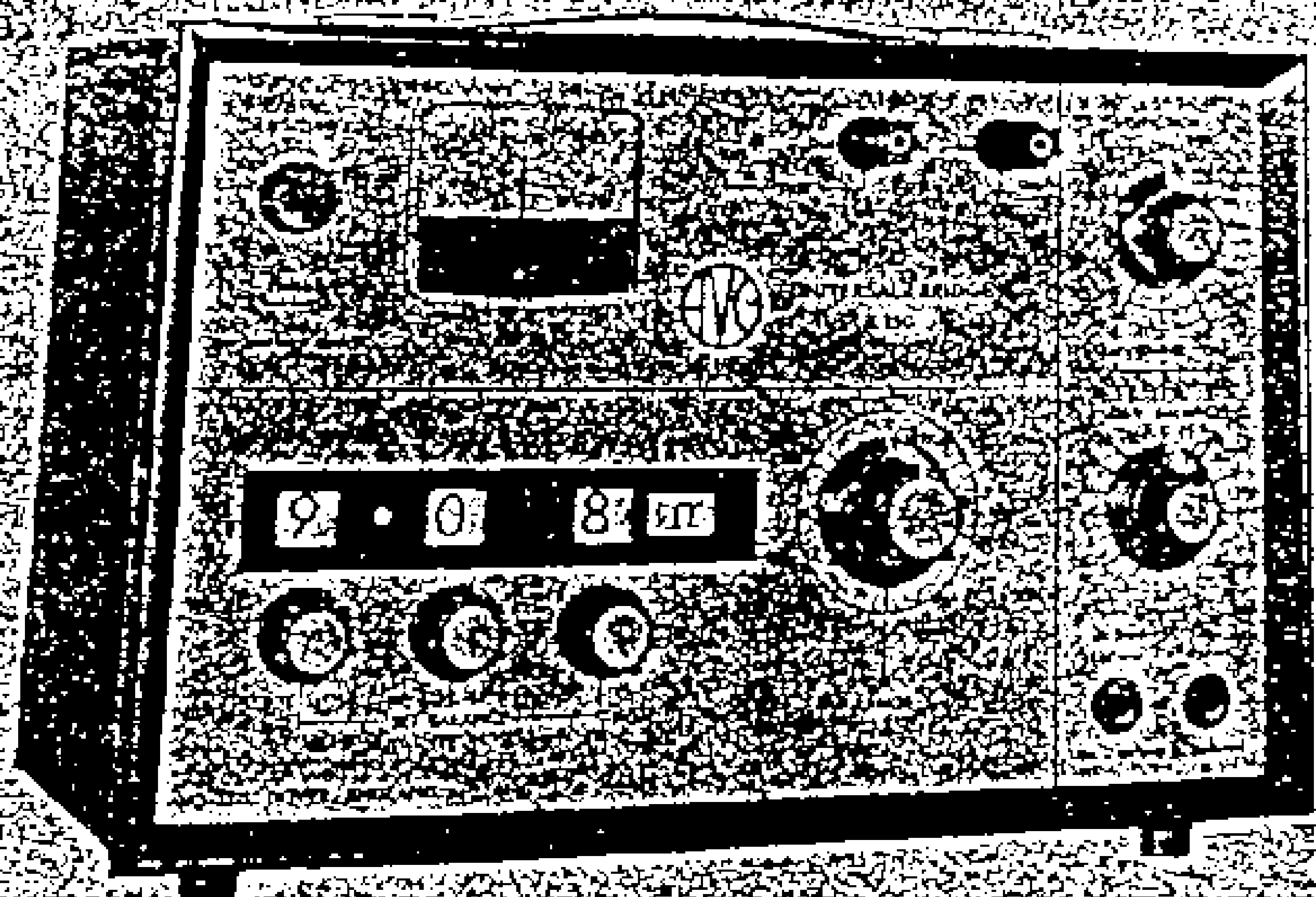
Operating Instructions

Universal Bridge Type B150 MK I



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GENERAL INFORMATION

The Avo Universal Bridge Type B150 is a transistorised, self-contained instrument, developed for the rapid measurement of a wide range of inductance, capacitance and resistance values. When the bridge is balanced, as indicated by the 'NULL' meter, the value of the component under test is automatically presented in digital form for unambiguous read-out. This is accomplished by means of a unique in-line display which shows not only the relevant figures but gives the units of measurement and the decimal position also. This eliminates mistakes due to errors of interpretation of dial settings and multiplying factors.

The bridge is energised by an internal 1 kHz oscillator for the a.c. measurement of Capacitance, Inductance and Resistance. Provision is made for the connection of an external source of between 20 Hz and 30 kHz for use where an alternative frequency may be used to advantage. An internal 9V battery power supply is provided for d.c. resistance measurements but a higher external voltage may be applied to improve d.c. sensitivity at range extremes. Facilities are also provided for the connection of an external polarising voltage of up to 500V. Non-linear elements may be tested by applying a variable d.c. bias upon which the a.f. signal is superimposed.

The instrument is small and compact with a carrying handle for portability. A fold-away stand mounted on the base enables the instrument to be inclined at a convenient angle if required, and a retainer is provided on the back of the case to hold the Instruction Manual.

SPECIFICATION

Ranges:

CAPACITANCE: From 0 (allowing 0.2 pF residual capacitance and 0.1 pF resolution) to 1199 μF in 8 ranges.

INDUCTANCE: From 0 (allowing 0.15 μH residual inductance and 0.01 μH resolution) to 119.9 H in 8 ranges.

RESISTANCE: From 0 (allowing 2 mΩ residual resistance and 1 mΩ resolution) to 11.99 MΩ in 8 ranges.

Q Indication: 0 to 10 at 1 kHz.

D Indication: 0 to 0.1, or 0 to 10 at 1 kHz.

Accuracy: ± 1 digit ± 1% of reading except lowest inductance range 0 to 11.99μH: Lowest inductance range ± 1% — 5% of reading, + 0 — 0 5μH dependent upon Q.

Bridge Power Source:

INTERNAL: 1 kHz oscillator for a.c. measurement of C, L and R. (9V battery for d.c. measurement of R).

EXTERNAL: External a.f. between 20 Hz and 30 kHz may be connected for C, L and R measurements where an alternative frequency is more appropriate.
External d.c. may be used for R measurements in place of the internal battery to improve d.c. sensitivity at range extremes.
A polarising voltage of up to 500V may be applied to the component under test. Non-linear elements may be tested by applying a variable d.c. bias upon which the a.f. signal is superimposed.

INTERNAL POWER SUPPLY: Internationally available 9V battery, usual current drain approx. 4 mA. Recommended Type Ever-Ready PP9

Dimensions: 8¾ × 13¾ × 6½ in. (222 × 350 × 165 mm).

Weight: 11 lb. approx.

All main controls are front panel mounted and to assist in the operation of these controls their functions are detailed below:—

SET BALANCE. The SET BALANCE controls provide digital readout of the value of a component under test. They comprise one twelve position and one ten position switch together with a potentiometer indexed by a conventional 10-way switch mechanism. This indexed potentiometer provides last digit adjustment and also additional fine adjustment between the click positions of the switch to ensure a true balance null.

RANGE SWITCH. A 24 position switch which selects the type and range of component measurement required, i.e. either inductance, capacitance or resistance measurements. With the selection of the appropriate range the decimal point is set and the units of measurement displayed automatically.

FUNCTION. A seven position switch includes the OFF position for the instrument. The conditions of resistance measurement can also be selected at one of three positions, either using the internal battery, an external d.c. voltage or the internal oscillator. Three additional positions are used in conjunction with the LOSS BALANCE adjustment.

LOSS BALANCE. This control is used in addition to the SET BALANCE control when measuring inductance or capacitance to set the meter to the null position. The setting of this control will depend upon the power factor of the component under test.

D.C. BIAS. An external polarising supply of up to 500V may be connected via this jack.

EXT. A.C. When an external a.f. source is being used, it should be connected to this jack. The internal oscillator is then automatically disconnected.

SENSITIVITY. A two-gang potentiometer, one section of which operates as a gain control for the amplifier and thus allows the overall sensitivity to be adjusted to a value which will ensure maximum measurement accuracy. The other section of this control shunts the meter in order that the sensitivity may be adjusted during d.c. resistance measurements.

TEST TERMINALS. The component under test should be connected to these terminals using the shortest possible connections.

DET +ve TERMINAL. An external d.c. supply or detector which may be used to improve sensitivity at range extremes is connected to this terminal. (See appropriate operating instructions.)

—ve (chassis) TERMINAL The earthy or negative side of an external supply should be connected to this terminal.

METER. Indication of balance is given on the panel mounted centre zero meter. When the meter is set to the null position by means of the SET BALANCE controls the value of the component under test will be given by the digital in-line display. Minimum battery limit is indicated on the meter.

PUSH BUTTON (Battery Check). Depressing this button with the Bridge switched OFF or under any conditions of operation, enables the battery voltage to be checked to ensure that it is above the minimum level for satisfactory operation of the bridge circuit.

TECHNICAL INFORMATION

Brief Circuit Description

A Wheatstone Bridge provides facilities for resistance measurements whilst inductance and capacitance are measured by comparison with a standard capacitor in R.C. ratio arm circuits. The circuit is arranged such that the standard capacitor C13 is connected in series or parallel with the ganged LOSS BALANCE potentiometers RV3 and RV4, dependent upon the D, Q setting of the FUNCTION switch, SE. When the range switch SD is set to a resistance range the RC ratio arm is replaced by a 100Ω resistor R38 and the RANGE control resistors R21 to R28 provide the eight ranges of resistance measurement.

The twelve position switch SA and the ten position switch SB together with a potentiometer RV5, which is indexed by a conventional 10 way switch mechanism, comprise the SET BALANCE controls. These controls together provide digital read-out of the balance position, the indexed potentiometer providing last digit adjustment and also fine adjustment to ensure a true null.

Potentiometers RV1 and RV2 are ganged potentiometers which form a SENSITIVITY control. Potentiometer RV1 shunts the meter in order that the control may function during d.c. resistance measurements and RV2 provides a gain control for the amplifier.

Two germanium diodes D2 and D3 connected across the indicating meter as limiters provide protection under overload conditions. The push-button switch, SF, also associated with the meter enables the condition of the internal 9V battery to be checked either with the instrument FUNCTION switch SE at the OFF position or under any operating condition.

With the FUNCTION switch SE set to R d.c. Int., the internal battery energises the bridge for resistance measurements. When set to the R.d.c. Ext. position the bridge may be energised by an external source of higher voltage. At the R.a.c. position of the FUNCTION switch or when the RANGE switch is set to L or C an alternative a.f. signal may be connected for the a.c. measurement of resistance, capacitance or inductance.

Amplifier

The amplifier, which comprises VT1, VT2 and VT3 and associated circuitry, is designed such that the frequency response is flat between 20 Hz and 30 kHz in order that the bridge may be energised by an external source of any frequency within this frequency band.

The circuit is arranged to provide the high input resistance essential to maintain the sensitivity on the high impedance ranges whilst the value of the input capacitor C2 is low enough to provide protection for the transistors under the surge conditions which can arise when external polarising voltages are applied to the components under test. Negative feedback is applied from the emitter of VT3 via potentiometer RV2, a section of the ganged SENSITIVITY control. RV2 operates therefore, as a gain control for the amplifier, enabling overall sensitivity to be set. The output is taken from the collector of VT3, rectified by shunt diode D1 and fed to the indicating meter.

1 kHz Oscillator

A single transistor VT4 with a tuned collector circuit, formed by capacitor C11 and the primary of transformer TR1, comprises the 1 kHz oscillator. Feedback is applied to the base of VT4 from the transformer via the capacitor C10. Two outputs are taken from the secondary of transformer TR1, one, the full output of 1.5V is used for the high impedance ranges, and the second, 170 mV is taken from a tapping on the transformer for use on the lower impedance ranges.

Power for the 1 kHz oscillator is provided by the 9V battery. When an external source is connected at the Ext.a.c. jack the a.f. signal is fed to the bridge via the secondary of transformer TR1. The 9V battery supply is disconnected and capacitor C12 is discharged to earth rapidly via resistor R19, ensuring that the internal oscillations will cease immediately.

Battery Check

The measurement accuracy of the bridge will be dependent upon the battery voltage. It is essential therefore to ensure that the battery voltage is maintained at a level which provides satisfactory operation of the bridge circuit. The battery voltage may be checked either with the FUNCTION switch at the OFF position or under any operating condition by depressing the Press for Battery Check button. If the battery voltage is below a satisfactory level, as indicated by the position of the meter pointer in the 'Replace Battery' section, the battery should be replaced (See Maintenance). To economise on battery power consumption the instrument should be switched off when not in use.

Null Position

Before using the bridge ensure that the meter pointer is at the NULL position. If necessary, it can be set to this position using the screw adjuster below the scaleplate.

General Operating Notes

Components to be measured are connected across the TEST terminals. This will displace the meter pointer from the centre 'NULL' position. To obtain the value of the component under test the bridge must be balanced, i.e. the meter pointer must again be set to the centre NULL position using the SET BALANCE and LOSS BALANCE controls (for inductance and capacitance measurement) together with the SENSITIVITY control. Whenever the position of the SET BALANCE controls is changed, the LOSS BALANCE control must also be re-adjusted during inductance and capacitance measurement.

The first digit position of the SET BALANCE control may be adjusted through 360° to provide a digit read-out between 0 and 11. The second digit position is similar with digit read-out between 0 and 9. The last digit adjustment however is adjustable through 300° only. It provides digit read-out between 0 and 9 and also fine adjustment between each position of the click mechanism. The position of the LOSS BALANCE control is dependent upon the type of component under test and details will be found under individual measurement headings. During balancing, the SENSITIVITY control is rotated clockwise to enable a more accurate indication of the balance position to be obtained.
When the bridge is balanced the value of the component under test will be given by the digital in-line display.

CAPACITANCE MEASUREMENTS

Capacitance values may be measured at 1 kHz using the internal oscillator or at an alternative frequency of 20 Hz to 30 kHz using an external source. In addition to an external a.c. source, an external d.c. supply may be connected for the polarisation of electrolytic capacitors.

CAPACITANCE MEASUREMENTS USING THE INTERNAL OSCILLATOR

(a) The component should be connected across the TEST terminals, keeping the connecting leads as short as possible.

(b) Using the RANGE switch select the appropriate range measurement. Where the approximate value of the cor ponent under test is unknown, the appropriate ranç may be determined by setting the SET BALANC controls for a reading of 300. Set the FUNCTION switc to D × 0.01 (for electrolytic capacitors a setting of D × is preferable). Set the LOSS BALANCE control t approximately 1. Select the range which gives the min mum deflection on the meter.

(c) The bridge may now be balanced using the SE BALANCE and LOSS BALANCE controls together wit the SENSITIVITY control. The meter deflection wi always be to the right of the NULL position. Incorrec adjustment of the LOSS BALANCE control may result ir difficulty in obtaining a perfect null. Alternatively pick-uț of interference by the component under test or its connections may obscure the balance position.

When the pointer is at the null position the capacitance of the component under test is given directly by the digital in-line display, the decimal point being automatically set when the range is selected. For values of a few picofarads the residual capacitance value must be taken into account when determining the component value. Since the calibration of the LOSS BALANCE control is purely nominal its setting for balance can only be taken as a guide to the quality of the component under test.
Electrolytic and other high value capacitors may probably be measured more accurately using an alternative frequency.

CAPACITANCE MEASUREMENTS USING AN EXTERNAL A.F. SOURCE

Although the measurement procedure is similar to that when using the internal oscillator, additional details are given to assist in obtaining an accurate balance indication.
An external a.c. supply of a frequency between 20 Hz and 30 kHz may be connected via a jack plug inserted into the Ext.a.c. jack. The maximum permissible voltage that may be applied is dependent upon the range in use and the type of component under test. It is recommended that the voltage should not exceed 35V r.m.s. open circuit from a 600Ω source, which will be found to be satisfactory for most measurements.
When using frequencies other than 1 kHz, the D and Q scales must be multiplied by a factor of f/1000, f being the frequency in Hz.
For low (i.e. mains frequency) measurements, a mains transformer may be used to supply the bridge. This should be screened and the screen connected to the −ve (chassis) terminal. It is advisable for the winding capacity to be less than 100 pF.
For other frequencies the supply should preferably be connected via an isolating transformer, otherwise a battery operated audio oscillator may be used which should be isolated from earth. The oscillator should be placed some distance from the bridge and the case of the oscillator connected to the sleeve of the jack plug. A mains operated oscillator may be used, but precautions must be taken to guard against pick-up of mains hum and the bridge must be placed clear of any earthed metalwork. The case should not be handled whilst making measurements.
If a high voltage is being used balance may be difficult to obtain due to overload of the detector. The sensitivity can be improved by connecting a 25 kΩ potentiometer between the Det +ve and −ve (chassis) terminals. If an external bias is being used the d.c. should be blocked by connecting a capacitor of approximately 5μF in series with the potentiometer.
Difficulty in obtaining a perfect balance, may be due to the presence of harmonics or mains hum and an external frequency selective detector may be necessary. This should be connected between the Det +ve and −ve (chassis) terminals.

POLARISING BIAS FOR ELECTROLYTIC CAPACITORS

Due to their construction electrolytic capacitors have relatively large series and parallel loss components. As the series loss is usually greater, the D × 1 setting of the LOSS BALANCE control should be used. The LOSS BALANCE adjustment may be found to be critical and it may be advisable to reduce the sensitivity to enable a satisfactory balance to be obtained.
A suitably limited polarising d.c. supply of up to 500V may be applied to the capacitor under test, via the d.c. Bias jack (tip positive, sleeve negative). The diagram overleaf illustrates how this supply should be connected and the protective components which are necessary.

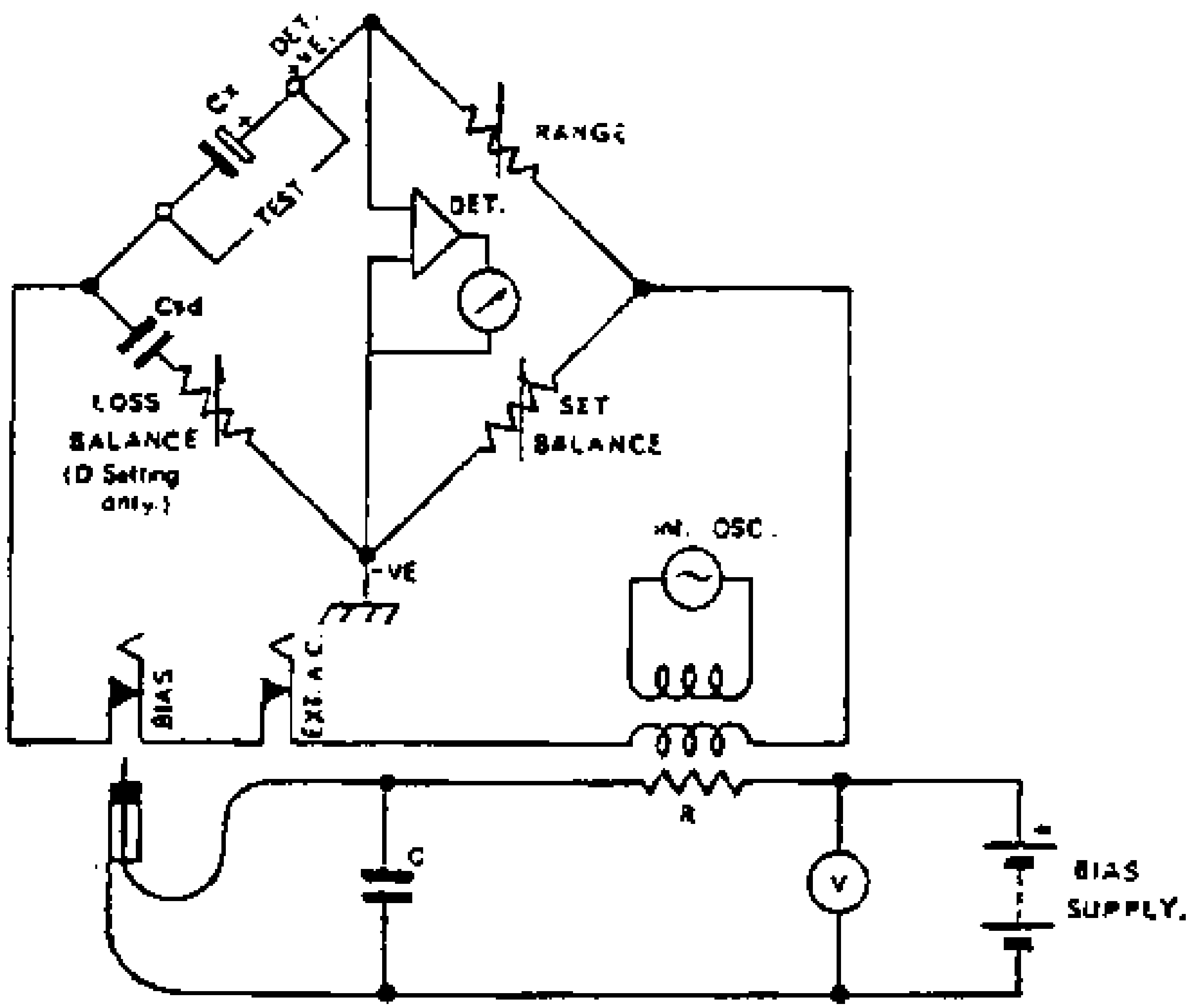


Fig. 1 Connection of external polarising bias

Resistor 'R' is a current limiting resistor to protect the range resistors should Cx become short circuited. The minimum satisfactory value for 'R' would be dependent upon the bias voltage and the range in use, bearing in mind that the range resistor rating is ½ watt. A by-pass capacitor of appropriate voltage rating is necessary in order to ensure an a.c. path for the bridge energising signal. It should be at least the full value of the range in use but not below 1 μF. The stray capacitance between the bias supply and the bridge must be kept to a minimum.

When an external a.c. source is being used it will be internally connected to the positive side of the bias supply. If, however, measurement of an earthed capacitance is to be made, it may be convenient if the two jack plugs are interchanged.

Warning 1 The positive side of the supply is connected to chassis through 'R' and the SET BALANCE resistors.
2. The bias supply must always be switched off before changing the FUNCTION switch or plug/unplugging the jack plug. The RANGE switch must not be taken beyond the capacitance ranges with the bias supply still switched on.

INDUCTANCE MEASUREMENTS

Inductance values may be measured at 1 kHz using the internal oscillator or at frequencies of 20 Hz to 30 kHz from an external source as appropriate. The application of an external d.c. bias also enables measurements such as incremental inductance of d.c. polarised chokes to be made.

INDUCTANCE MEASUREMENTS USING THE INTERNAL OSCILLATOR

(a) The component should be connected across the TEST terminals keeping the connecting leads as short as possible, and spaced apart to minimise the effect of stray capacitance. Air cored coils should be spaced clear of any metal and the case of the bridge by one or two diameters.

(b) Using the RANGE switch select the appropriate range of measurement. Where the approximate value of the component under test is unknown, the appropriate range may be determined by setting the SET BALANCE controls for a reading of 300. Set the FUNCTION switch to Q × 1 for low Q coils, D × 0.01 for high Q coils and D × 1 for laminated iron cored inductors. Set the LOSS BALANCE control to approximately 1. Select the range which gives the minimum deflection on the meter.

(c) The bridge may now be balanced using the SET BALANCE and LOSS BALANCE controls, together with the SENSITIVITY control. The meter deflection will always be to the right of the NULL position. Incorrect adjustment of the LOSS BALANCE control may result in difficulty in obtaining a perfect null. Alternatively pick-up of interference by the component under test or its connections may obscure the balance position. It may be necessary to take particular care when testing magnetic cored inductors to avoid the pick up of external magnetic fields. The amount of pick-up may be checked by inserting an open-circuited jack plug into the Ext.a.c. jack when the residual meter indication should be very low.

The inductance value of the components under test is given directly by the digital in-line display, the decimal point being automatically set when the range is selected.

Note: As with all bridges of this type, with inductors of a Q less than 2 or D greater than 0.5 the LOSS BALANCE setting is very critical, and with low Q this is particularly noticeable. The SET BALANCE and LOSS BALANCE controls should be adjusted alternately until the lowest meter deflection is achieved and alternative settings should be tried. Whenever the position of the SET BALANCE control is changed the LOSS BALANCE control must also be re-adjusted.

Magnetic cored inductors also have non-linear characteristics making a true balance difficult to obtain, and for these a d.c. Bias or an alternative frequency may be used.

POLARISING BIAS FOR MAGNETIC CORED INDUCTORS

Due to the non-linear B/H characteristic of iron-cored inductors it may be desirable to measure the inductance of the component whilst a d.c. bias current is flowing through it. A d.c. supply of up to 500V with a suitable limiting resistor may be used for this purpose and the bias may be applied using one of the following methods:—

(1) Insert a jack plug (tip +ve) into the d.c. Bias jack. A suitable capacitor must be connected across the bias supply and the current limiting resistor, to provide a low impedance path to the bridge source frequency. The d.c. current will flow through the range resistor in addition to flowing through the inductor under test, therefore the value of the limiting resistor must be chosen such that the current flowing does not exceed the ½ watt rating of the range resistor. (Use D setting only.)

(2) The supply, again in series with a suitable limiting

resistor, is connected across the DET —ve and —ve (chassis) terminals. A suitably rated capacitor must be connected across a plug which is plugged into the d.c. Bias jack to prevent d.c. flowing through other arms of the bridge. However, d.c. current will flow through the SET BALANCE resistors and this current must again be limited to ensure that the $\frac{1}{4}$ watt rating is not exceeded. (Use D setting only.)

(3) The supply may also be connected directly across the TEST terminals. A capacitor must be connected to the d.c. Bias jack as in (2). In this case current only flows through the test component, but nevertheless, a resistor is required in series with the supply in order to maintain the shunt loss within the range covered by the LOSS BALANCE control. As a guide, at least 1 kΩ per 1 H of the test component value would be necessary. (Use D setting only.)

(4) An adaptor which is simple to use and more versatile will be available as an optional accessory facilitating measurements at up to 1A d.c. Full instructions for use will be supplied with the adaptor.

Caution: To avoid high transient voltages, short circuit the inductor under test before switching off the bias supply.

INDUCTANCE MEASUREMENTS USING AN EXTERNAL A.F. SOURCE

It may be desirable to measure the inductance of some components at frequencies other than 1 kHz. The measurement procedure is similar to that when using the internal oscillator, but additional details are given in the paragraph 'Capacitance Measurements using an external a.f. source'. (See Under CAPACITANCE MEASUREMENTS). When using frequencies other than 1 kHz multiply the D and Q scales by a factor of f/1000 where f is the frequency in Hz.

RESISTANCE MEASUREMENTS

Resistance may be measured at either 1 kHz using the internal oscillator or at frequencies between 20 Hz and 30 kHz using an external source. D.C. measurement of resistance may also be made using the internal battery or an external supply. Composition, metal film and metal oxide resistors are probably most conveniently measured using the 1 kHz internal oscillator. Inductive or wire wound resistors are probably best measured at a low frequency or at d.c. High value resistors may be measured with greater accuracy at lower frequencies than the internal oscillator.

MEASUREMENTS USING THE INTERNAL 1 kHz OSCILLATOR

(a) Connect the component to be measured to the TEST terminals keeping the leads as short as possible.

(b) Set the FUNCTION switch to R.a.c.

(c) Using the RANGE switch select the appropriate range of measurement. Where the approximate value of the component under test is unknown, the appropriate range may be determined by setting the SET BALANCE controls for a reading of 300 and selecting the range which gives the minimum deflection on the meter.

(d) The bridge may now be balanced using the SET BALANCE control, and the SENSITIVITY control. The meter deflection will always be to the right of the NULL position. Too much stray capacitance or inductance may cause difficulty in obtaining a perfect null.

When the pointer is at the null position the resistance of the component under test is given directly by the digital in-line display, the decimal point being automatically set when the range is selected.

RESISTANCE MEASUREMENTS USING AN EXTERNAL A.F. SOURCE

High value resistors of over 1 MΩ may be measured with greater accuracy and discrimination at low frequencies, such as 20 to 100 Hz, because the effect of stray capacitance is very much reduced and high voltages may be used to increase sensitivity. The resistance of some delicate mechanisms, such as meter movements may also be measured at low frequencies to avoid mechanical overload. The measurement procedure is similar to that when using the internal 1 kHz oscillator. Details of connections are given under 'Capacitance measurements using an external a.f. source'. See CAPACITANCE MEASUREMENTS.

D.C. MEASUREMENTS USING THE INTERNAL BATTERY

The internal d.c. 9V battery is current limited on short circuit to 60 mA. This enables resistance values of between 0.5 Ω and 100 kΩ to be measured satisfactorily. Values outside this range may be more accurately measured using the internal 1 kHz oscillator or external a.c. or d.c. supplies.

(a) Connect the component to be measured to the TEST terminals keeping the leads as short as possible.

(b) Set the FUNCTION switch to R.d.c. int.

(c) Using the RANGE switch select the appropriate range of measurement. Where the approximate value of the component under test is unknown, the appropriate range may be determined by setting the SET BALANCE controls for a reading of 300 and selecting the range which gives the minimum deflection on the meter.

(d) The bridge may now be balanced using the SET BALANCE and SENSITIVITY controls. The pointer will swing through the null position as the balance point is passed.

When the pointer is at the NULL position the resistance of the component under test is given directly by the digital in-line display, the decimal point being automatically set when the range is selected.

MEASUREMENTS USING AN EXTERNAL D.C. SOURCE

Greater discrimination may be obtained for values above 12 kΩ using an external d.c. source of higher voltage than the 9V internal battery. No advantage will be gained however, by using an external d.c. source on the lower ranges except for very low values in conjunction with a sensitive galvanometer. For high value resistance measurements the procedure is similar to that when using the internal battery except that the FUNCTION switch should be set to R.d.c. external, and the external supply should be connected in series with a limiting resistor 'R' between the DET +ve terminal and the −ve (chassis) terminal. The table below gives the minimum value of limiting resistor and maximum permissible voltage for the range selected.

RANGE	$V_{max.}$	$R_{min.}$
11.99 kΩ	20	360 Ω
119.9 kΩ	70	2.2 kΩ
1.199 MΩ	200	24 kΩ
11.99 MΩ	500	51 kΩ

For very low resistance values, the FUNCTION switch should be set to R.a.c. and a 3V battery connected in series with a 15Ω limiting resistor at the Ext. a.c. jack. A sensitive galvanometer should be connected across the DET −ve and −ve (chassis) terminals.

INCREMENTAL RESISTANCE

Measurements on non-linear, resistive components, such as thermistors, diodes etc. may be made using a d.c. bias. The basic measurement is made using the internal 1 kHz oscillator or an external source. The d.c. is applied via a jack plug inserted at the d.c. Bias jack, tip positive, sleeve negative. A suitable capacitor must be connected across the bias supply and the current limiting resistor, to provide a low impedance path to the bridge source frequency.

To Replace the Battery

If a replacement battery is required the instrument must be removed from the case as follows:—

(a) Remove the screw from the top of the case and the two screws and washers from the back of the case. Withdraw the instrument from the case.

(b) Remove the two snap connections from the battery also the nuts and washers from the studs holding the battery supporting plate. Lift out the battery.

(c) Insert a new battery (Recommended battery Ever-Ready PP9), fit the supporting plate and replace nuts and washers.

(d) Replace the battery connections ensuring that polarity is correct, black wire to negative, and red wire to positive.

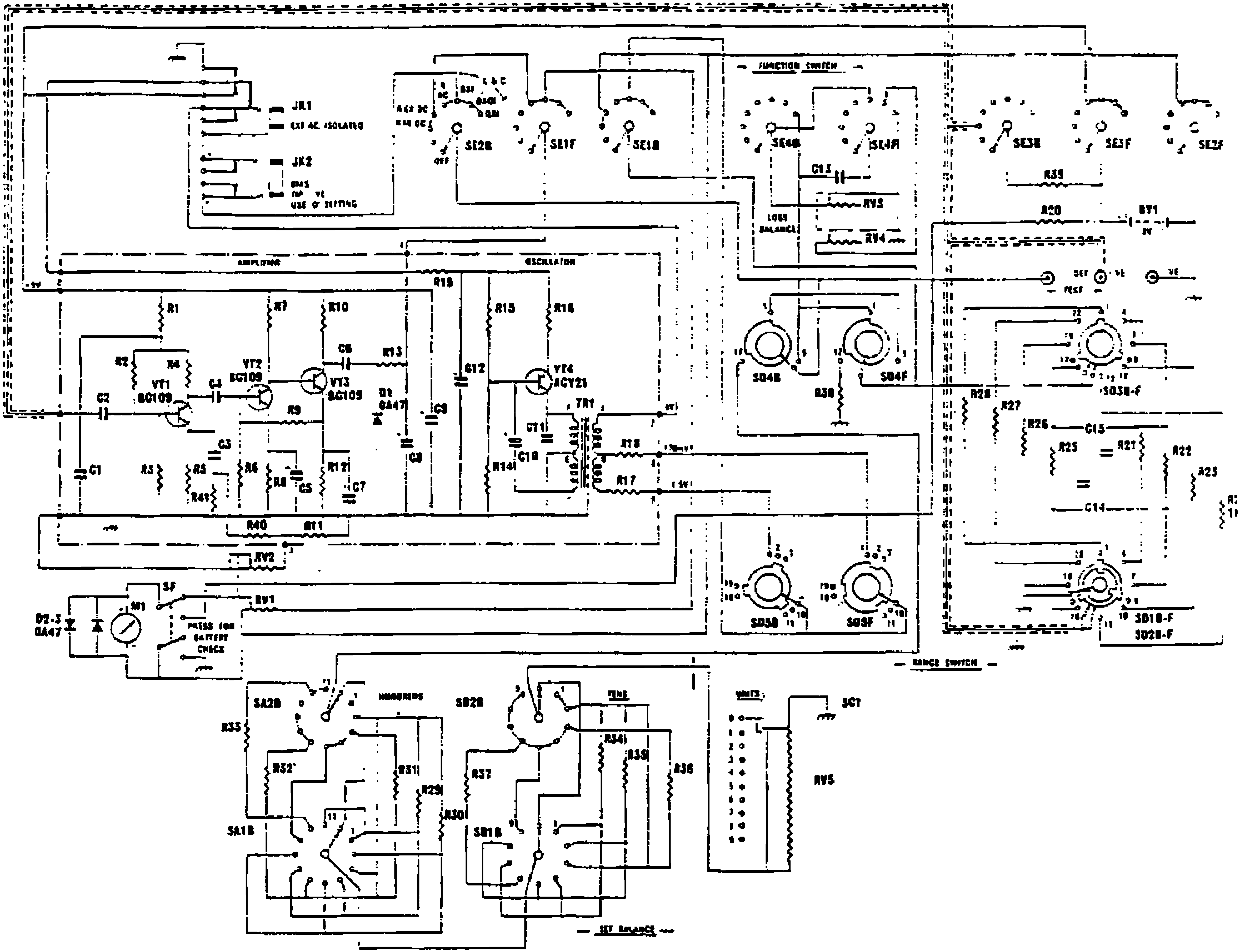
(e) Return the instrument to the case and replace the fixing screws and washers.

Adjustment of Oscillator Frequencies

The oscillator frequency may require adjustment if any oscillator components are replaced. Minor adjustment may be made by varying the value of capacitor C11. This component is located on the printed circuit board and mounted adjacent to Transformer TR1. The oscillator should be adjusted to a frequency of 1 kHz ± 5%.

COMPONENTS LIST

R1	100 kΩ
R2	1.2 MΩ
R3	430 kΩ
R4	47 kΩ
R5	130 kΩ
R6	390 kΩ
R7	51 kΩ
R8	15 kΩ
R9	240 kΩ
R10	10 kΩ
R11	10 Ω
R12	11 kΩ
R13	3.9 kΩ
R14	120 kΩ
R15	8.2 kΩ
R16	33 Ω
R17	150 Ω
R18	2.4 Ω
R19	68 Ω
R20	180 kΩ
R21	100 Ω ± 0.5%
R22	100 k ± 0.5%
R23	0.996 Ω ± 0.5%
R24	1 kΩ ± 0.5%
R25	1 MΩ ± 0.5%
R26	10 Ω ± 0.5%
R27	10 kΩ ± 0.5%
R28	0.1 Ω ADJUST ON TEST
R29	100 Ω ± 0.1%
R30	200 Ω ± 0.1%
R31	300 Ω ± 0.1%
R32	600 Ω ± 0.1%
R33	1 kΩ ± 0.1%
R34	10 Ω ± 0.5%
R35	20 Ω ± 1%
R36	30 Ω ± 1%
R37	60 Ω ± 1%
R38	100 Ω ± 0.1%
R39	150 Ω
R40	10 kΩ
R41	2 kΩ
C1	1 µF 250V
C2	0.047 µF 630V
C3	0.47 µF 160V
C4	0.47 µF 160V
C5	10 µF 70V ELECT.
C6	1 µF 250V
C7	100 µF 15V ELECT.
C8	10 µF 70V ELECT.
C9	100 µF 15V ELECT.
C10	1 µF 150V ELECT.
C11	1 µF 250V
C12	1000 µF 12V ELECT.
C13	0.1 µF ± 0.1% 350V
C14	1.5 pF ± 0.5 pF 750V
C15	1.5 pF ± 0.5 pF 750V
RV1	10 kΩ LIN.
RV2	470 Ω REV. LOG.
RV3	17 kΩ ± 5% I.G.
RV4	170 Ω ± 5% I.G.
RV5	10 Ω $^{+10\%}_{-0\%}$ 300° ± 5% LIN.
D1	OA 47
D2	OA 47
D3	OA 47
VT1	BC 109
VT2	BC 109
VT3	BC 109
VT4	ACY 21
TR1	Drg. B.45368
M1	50-0-50 µA 800 Ω



CIRCUIT DIAGRAM: UNIVERSAL BRIDGE TYPE B150