EB 2702
C1 - 7/67

MANUAL CHANGE

for

INDUCTOR ANALYSER

TF 2702

p. 57:

CURRENT RATIO-ARM:

On extreme right hand switches, remove the right hand link between the x100 and x10 switches.

VOLTAGE RATIO-ARM:

On the 10 H switch, remove the link connecting the closed terminals; connect the 10 H right hand closed terminal to the 1 H right hand closed terminal.

p. 61:

SJ2Fb should go to HT1, not HT as shown.

p. 65:

Change R19 to 160 Ω.

p. 54:

Change 6R19 to 160 Ω ±7% TE, M.I. code 24552-055.

p. 48:

Add 1R13, carb 1 kΩ ±10% 1 W, M.I. code 24342-080.

TF 2702

TF 2702

Inductor Analyser

INSTRUCTION MANUAL

mi
MARCONI INSTRUMENTS

INSTRUCTION MANUAL

No. EB 2702

for

Inductor Analyser TF 2702

(Including A.C.+ D.C. Mixer Unit, TM 8339)

M.I. Technical Publications

MARCONI INSTRUMENTS LIMITED

ST. ALBANS HERTFORDSHIRE ENGLAND

Contents

Chapter 1

General information

1.1 INTRODUCTION

Inductor Analyser TF 2702 is a bridge for the testing of inductors over a wide range of current and voltage. Where the ordinary universal bridge is severely limited in respect of the low dissipation of the ratio arms, $\frac{1}{2}$ W to 1 W being usual, the TF 2702 has a maximum dissipation of 100 W which allows test currents of up to 10 A r.m.s. to be used.

The measuring bridge used in this instrument follows Maxwell configuration for series L and R, and Hay for parallel L and R. The balancing arm comprises a variable resistor for loss balance and a variable capacitor for inductance balance. The two adjustments are independent, a feature particularly valuable in the testing of low Q inductors.

The detector is across the ratio arms of the bridge, and its output is taken to either a cathode ray tube display or a conventional, high sensitivity tuned amplifier. The c.r.t. enables the saturation level of iron cored inductors to be readily determined, the distortion component being seen on an otherwise straight line. This display is also used for preliminary balancing. The tuned amplifier feeds a meter which is used as a final balance null detector, and which also indicates the test voltage or current when the instrument is in the preliminary mode.

For low voltage tests at 1 kHz, 10 kHz or mains frequency, an internal source is provided, and external d.c. up to $\frac{1}{2}$ A may be superimposed on this supply. It is also possible to supplant the internal supply with external a.c., within defined limits, via a jack on the front panel. With optional accessory TM 8339, A.C. + D.C. Mixer, d.c. of up to 10 A can be applied.

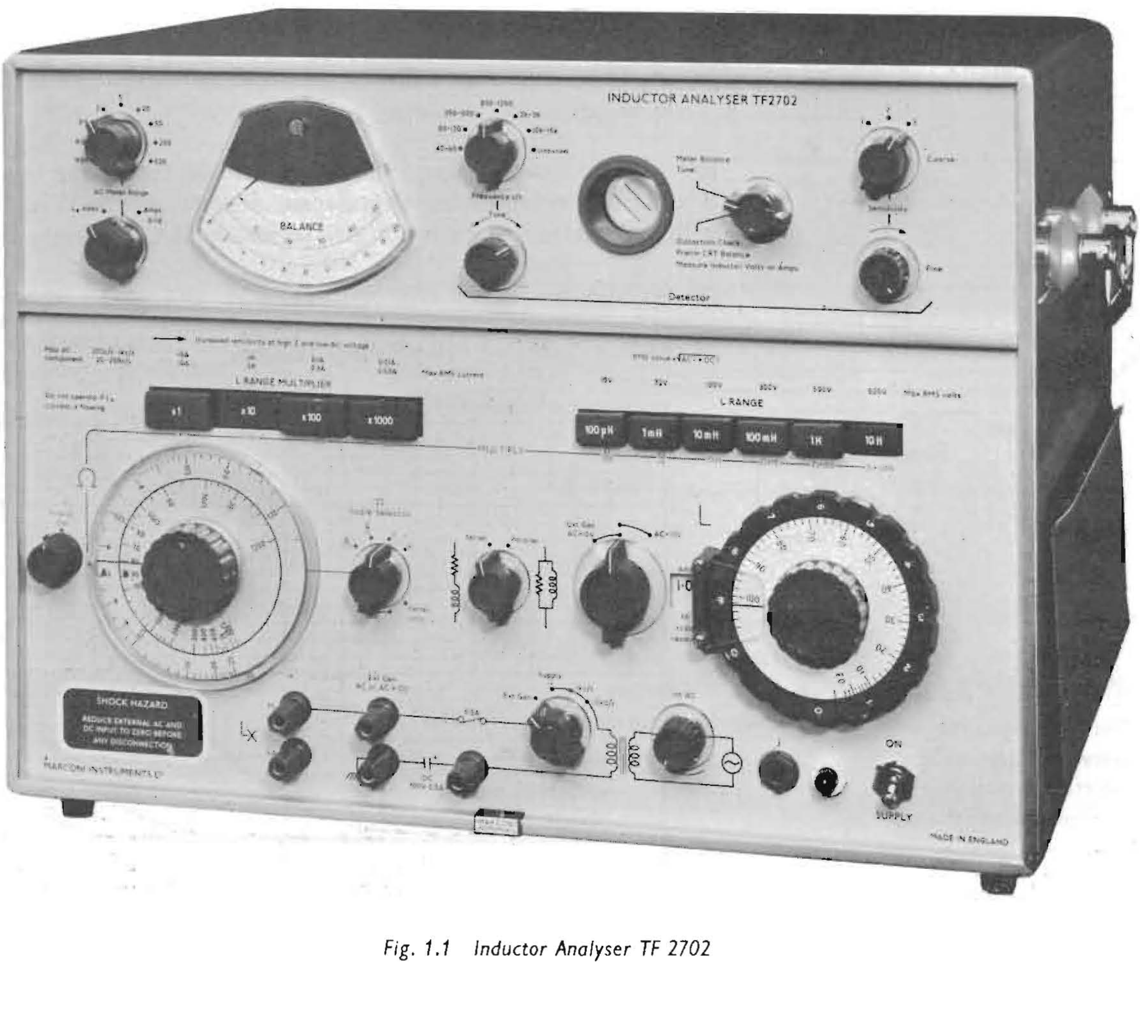


Fig. 1.1 Inductor Analyser TF 2702

1.2 DATA SUMMARY

RANGES:

Inductance: 0.3 μH to 21 000 H by means of 6 range switches and 4 multiplier switches. The scale on each range is divided into 20 equal steps and has an interpolating dial which has 100 divisions.

Resistance: Series or parallel resistance may be selected giving equivalent Q from less than 0.1 to approaching infinity. The scale is calibrated from 0.02 Ω to 2 kΩ in 4 steps for series resistance, and from 0.2 Ω to 2 kΩ in 3 steps for parallel resistance, with multiplying factors of from 10^{-2} to 10^{6} in decade steps.

CURRENT RATING: A.C. or d.c. or $\sqrt{\text{a.c.}^2 + \text{d.c.}^2}$

10 A r.m.s. up to 21 H	0.3 A r.m.s. up to 2100 H
3 A r.m.s. up to 210 H	0.03 A r.m.s. up to 21 000 H

ACCURACY: ±1% of reading ±0.05% of range full scale, subject to current limitations of:

7 A up to 21 H,	0.3 A up to 2.1 kH,
2 A up to 210 H,	0.03 A up to 21 kH.

and the following qualifications:

(a) At high current add ±0.25% of reading within the following limits:

10 A up to 21 H, 3 A up to 210 H.

(b) At low inductance subtract residual inductance of approximately 0.25 μH.

(c) At inductance above 1 kH the maximum frequency is 1 kHz and it must be derived from an external source, as the discrimination with internal supplies is too low to maintain the basic accuracy.

(d) At high frequency and/or low Q add $\pm(0.001f^2 + \frac{0.5f}{Q})\%$ of reading, where f = frequency in kHz.

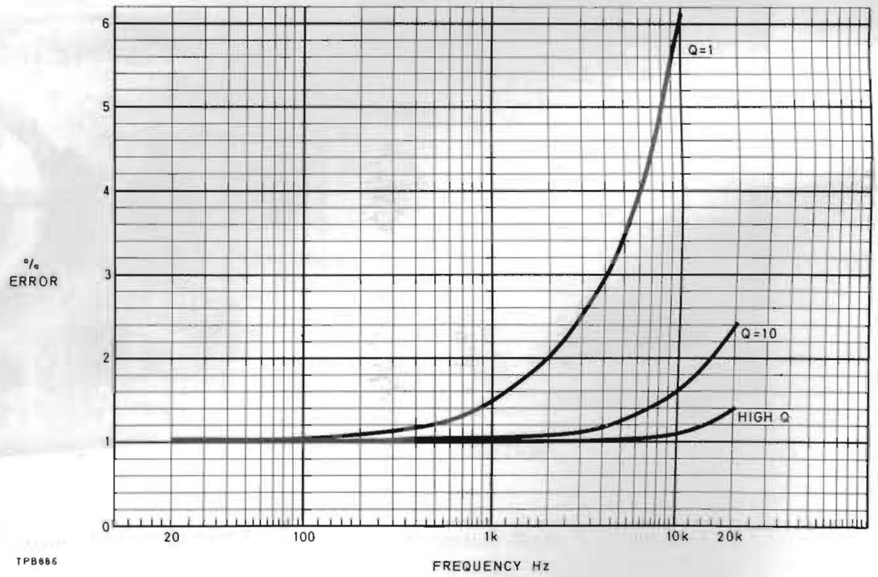


Fig. 1.2 Inductance accuracy

This graph shows the percentage error of the inductance measurement at representative values of Q

EQUIVALENT RESISTANCE MEASUREMENT ACCURACY:

On A scale: $\pm 5\% \ \pm(\frac{A}{4})\% + \frac{f^2}{10^7}\ \Omega$

On $\frac{A}{10}$ scale: $\pm 10\% \ \pm 0.02 + \frac{f^2}{10^7}\ \Omega$

On $\frac{A}{100}$ scale: $\pm 10\% \ \pm 0.02 + \frac{f^2}{10^7}\ \Omega$

On B scale: $\pm 5\% + \frac{100B}{2k\Omega + B}\% + \frac{f^2}{10^7}\Omega$

Where f is frequency in Hz, and A and B are scale readings:

A scale is 2 Ω to 25 Ω.

B scale is 20 Ω to infinity.

The above accuracy applies after the residual resistance (< 30 mΩ) has been deducted from the reading. Fig. 1.3 shows a graph of typical scale accuracy at representative frequencies.

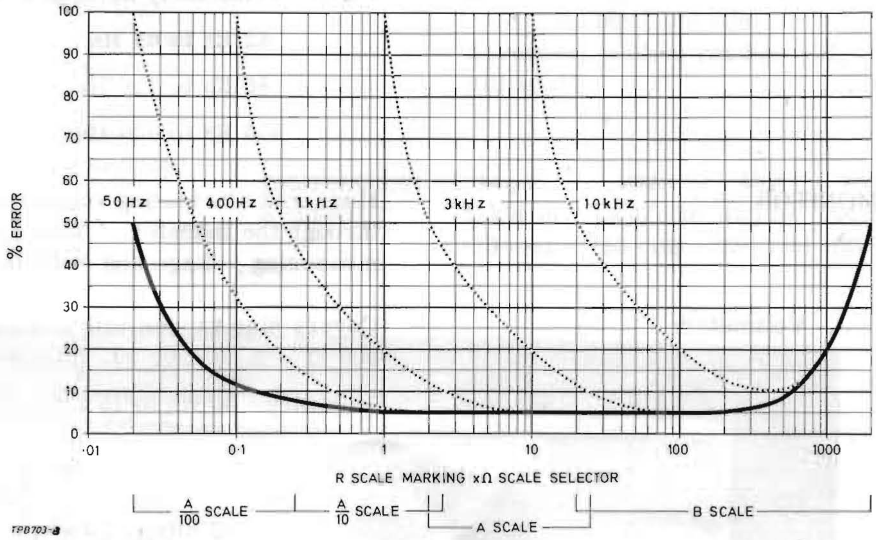


Fig. 1.3 Typical resistance scale accuracy at representative frequencies

BRIDGE EXCITATION

Internal a. c. :

An e. m. f. of at least 10 V r. m. s. is available at supply frequency, at a source resistance of typically 25 Ω.

An internal oscillator provides frequencies of 1 kHz and 10 kHz at an e. m. f. of at least 2.0 V r. m. s.; the source resistance is typically 70 Ω.

External a. c. :

External supplies from 20 Hz to 20 kHz may be used within the following limitations provided that the current ratings given earlier are not exceeded:

Max. level	*Range*
500 V	0.11 H to 21 000 H
300 V	11 mH to 21 000 H
100 V	1.1 mH to 21 000 H
30 V	110 μH to 21 000 H
10 V	11 μH to 21 000 H

External supplies are required above about 1000 H, at supply frequency this should be > 10 V per 1000 H.

External d.c.: The internal a.c./d.c. mixing transformer may be used with external d.c. of up to 0.5 A provided that the rated current maxima are not exceeded. Internal a.c. as specified above or external a.c. via the front panel jack may be applied; this external a.c. must not exceed f/5 V (where f is the frequency in Hz) up to a maximum of 100 V r.m.s. Above 0.5 A d.c. an external mixing unit is required; A.C. + D.C. Mixer, type TM 8339 is such a unit.

DETECTOR: This uses a 1 in c.r.t. for preliminary balance and search, and a meter for final balance. The c.r.t. also indicates any core non-linearity of the inductor under test.

Frequency range: Untuned and search: 20 Hz to 20 kHz.

Tuned: continually adjustable over the ranges,

42 Hz to 60 Hz	800 Hz to 1200 Hz
80 Hz to 120 Hz	2 kHz to 3 kHz
350 Hz to 500 Hz	10 kHz to 16 kHz

MONITOR: Measures alternating voltage across and alternating current through the inductor. This meter may be used independently for measuring voltage and current.

Voltmeter: Covers nine ranges with full scale deflections of 50, 200 and 500 mV, 2, 5, 20, 50, 200 and 500 V over the range 20 Hz to 20 kHz.

Accuracy: 50 Hz to 10 kHz, ±3% of reading ±2% of full scale.

20 Hz to 50 Hz, 10 kHz to 20 kHz: ±6% of reading ±2% of full scale.

Ammeter: Covers six ranges with full scale deflections of 50, 200 and 500 mA and 2, 5 and 20 A.

Accuracy: 50 Hz to 10 kHz, ±3% of reading ±2% of full scale.

20 Hz to 50 Hz, 10 kHz to 20 kHz: ±6% of reading ±2% of full scale.

POWER REQUIREMENTS: 100 V to 130 V or 200 V to 250 V, 45 to 65 Hz. 60 VA.

DIMENSIONS AND WEIGHT:

Height	*Width*	*Depth*	*Weight*
13 in	18 in	14 in	30 lb
(33 cm)	(46 cm)	(36 cm)	(13.6 kg)

1.3 ACCESSORIES

Supplied: One telephone plug, type P40, to connect with the external - a. c. jack.

Available: A. C. + D. C. Mixer, type TM 8339. This unit is used when the testing of an inductor requires d. c. > $\frac{1}{2}$ A, and an alternating voltage > 10 V at 50 Hz to > 100 V at 500 Hz.

A. C. + D. C. OUTPUT:
30 V a. c. max. with 10 A d. c. max.
100 V a. c. max. with 3 A d. c. max.
300 V a. c. max. with 1 A d. c. max.
500 V a. c. max. with 0. 3 A d. c. max.

The above outputs are obtained by varying the input voltage over the range 0 - 100 V r. m. s. and the input current up to 10 A d. c.
A 10 A fuse protects the output circuit.

A. C. INPUT: Input terminals are isolated from chassis and earth. A 5 A fuse provides protection.

Max. alternating voltage: 100 V r. m. s. , 40 Hz to 5 kHz, linearly derated from 100 V at 40 Hz to 50 V at 20 Hz, and from 100 V at 5 kHz to 50 V at 20 kHz.

D. C. INPUT: Negative terminal is earthed. A 10 A fuse provides protection.

Max. direct voltage: ±300 V.

D. C. input load: Parallel combination of output terminal load (e. g. , TF 2702 and test inductor), 3000 μF smoothing capacitor, voltmeter and 100 kΩ discharge resistor.

A. C. input load: Transformer winding (80 VA at 50 Hz on no load).

MONITORING FACILITIES:

Meter ranges (direct current):
10 A full scale (associated with 30 V a. c. max.)
3 A full scale (associated with 100 V a. c. max.)
1 A full scale (associated with 500 V a. c. max.)
Accuracy: ±3% of reading ±2% of full scale.

Meter ranges (direct voltage): 300 V, 100 V, 30 V and 10 V full scale.
A 'press to read voltage' switch, biased to 'current' enables the current range meter to be used to read d. c. input voltage.
Accuracy: ±3% of reading ±2% of full scale.

DIMENSIONS & WEIGHT:	*Height*	*Width*	*Depth*	*Weight*
	7 3/4 in (20 cm)	18 3/4 in (48 cm)	13½ in (34 cm)	64 lb (29 kg)

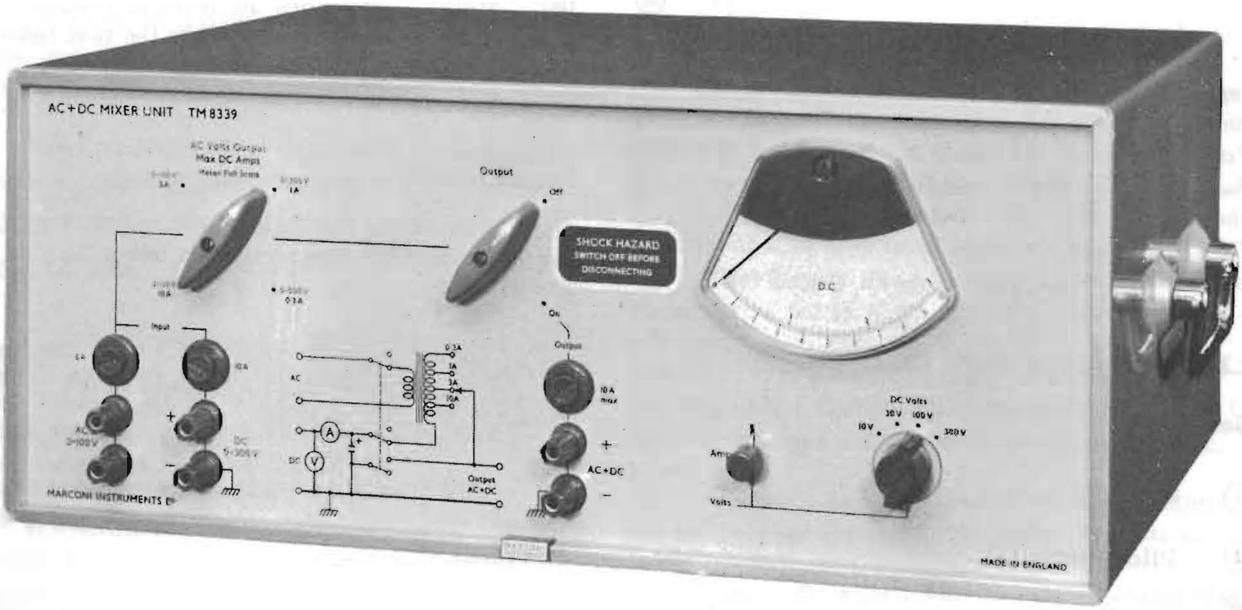


Fig. 1.4 A.C. + D.C. Mixer Unit TM 8339

Chapter 2 Operation

2.1 INSTALLATION

The mains lead is a free cable fitted at one end with a female plug which connects with the instrument. When fitting a mains plug note that the earth (or chassis) conductor has a yellow designation sleeve with a green circuit earth symbol, the neutral conductor has a black sleeve with a white 'N', and the line (or phase) conductor has no sleeve.

RACK MOUNTING: When the instrument is to be mounted in the same rack as the A. C. + D. C. Mixer Unit, TM 8339, the two should be 4 to 6 inches apart and it is preferable that the TM 8339 is mounted above the TF 2702. If a mobile rack is used, it will be necessary to provide additional support. This arrangement minimizes pick-up error which may be caused by the large stray field associated with the mixer unit.

2.2 PRELIMINARIES

Before connecting the instrument to the power supply, check that the transformer tapping and fuse rating are correct for the available supply voltage. The instrument is normally dispatched for use with 240 V supplies but may be adjusted for other voltages as described in Section 4. 2.

When testing iron or ferrite cored inductors, keep the inductor under test well clear of any field source as this may cause pick-up errors. For example, if the bench standing version of the A. C. + D. C. Mixer Unit, TM 8339, is used it should be positioned about 9 inches from the TF 2702 and on the right hand side of it looking from the front.

2.3 CONTROLS AND CONNECTORS

Generator

(1) SUPPLY switch.

(2) Pilot lamp.

(3) External A. C. socket. A. C. applied to this socket replaces the internally generated supply; the voltage applied must not exceed f/5 V (f in Hz) up to a maximum of 100 V r. m. s. at $\geqslant$ 500 Hz.

(4) INT A. C. control. Adjust level of a. c. (from the internal source) applied to the inductor under test.

(5) Generator selector. Select internal or external source of test voltage; three internally generated test frequencies are available - 10 kHz, 1 kHz or the mains supply frequency.

(6) Test Supply terminals. Alternative connections for externally generated supplies for the inductor under test. Connect a. c. or a. c. + d. c. across terminals TP3 and TP4; connect only d. c. across TP4 and TP5.

(7) Lx Test terminals. Connect the inductor under test across these terminals.

Voltmeter

(8) A. C. METER RANGE switch. Select meter full scale range, current or voltage.

(9) Meter Volts/Amps switch. Select either voltage or current indication on the meter.

(10) Meter. Monitors the level of voltage or current which is being applied to the test inductor.

Detector

(11) Frequency Range selector. Set to range which covers the test frequency being applied to the inductor.

(12) Tuning control. Adjust for peak reading on the meter when the Mode switch is in the METER BALANCE TUNE position.

(13) CRT Display. Used in preliminary balancing and also shows distortion of the inductor characteristic.

(14) Mode switch. Select the operating mode of the detector. In bottom position, set the test

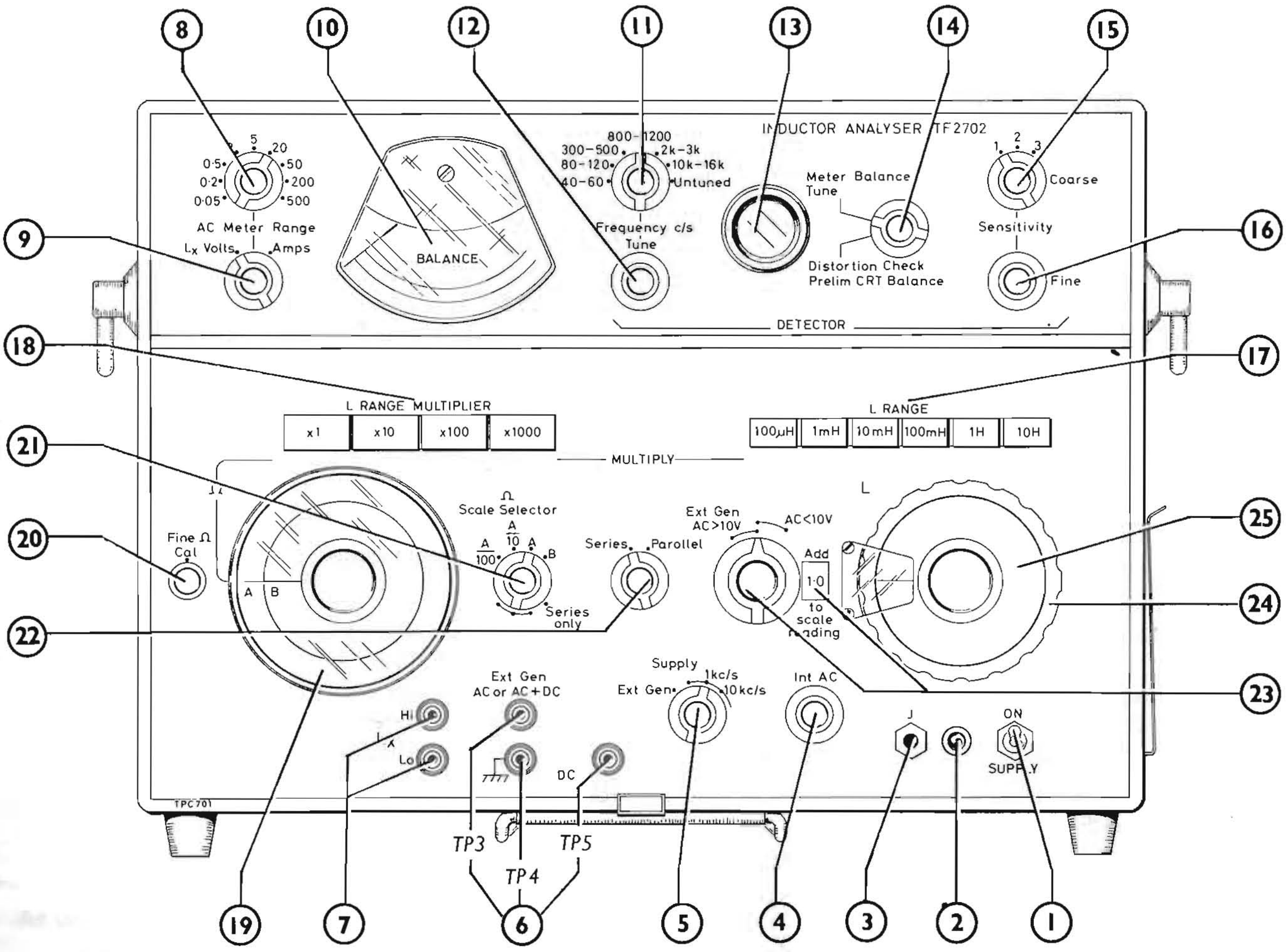


Fig. 2.1 Controls and connectors

supply, check distortion and make preliminary balance; in top position, make final balance.

⑮ COARSE SENSITIVITY switch. Attenuates signal into CRT and meter - highest sensitivity at position 3.

⑯ FINE SENSITIVITY CONTROL. Gives continuous adjustment between steps of the COARSE switch.

Bridge balance

⑰ L RANGE selectors. Select range appropriate to inductor under test; used in conjunction with L RANGE MULTIPLIERS. The resistance multiplying factor, for loss balance, is also shown under the selected button.

⑱ L RANGE MULTIPLIER selectors. Multiplies the inductance range by the factor shown on the front of the selected push-button. The resistance multiplying factor, for loss balance, is also shown under the selected button.

⑲ Loss Balance control and Ω selector. Adjust bridge balance. Resistive component of inductor is read from the appropriate scale.

⑳ FINE Ω control. Adjust for bridge balance in conjunction with the Loss Balance control.

㉑ Ω SCALE SELECTOR. Select scale range of item ⑲.

㉒ Series/Parallel switch. Select test mode of inductor under test.

㉓ Test Supply Range switch and 'Add 1' indicator. Set to A. C. > 10 V or AC < 10 V according to voltage being applied to the test inductor. In the centre position add 1 to the reading on the Coarse Balance switch. The A. C. > 10 V imposes a mechanical scale restriction.

㉔ Coarse L Balance decade switch. Adjust bridge balance for minimum meter deflection.

㉕ Fine L Balance control. Gives continuous cover between positions on the Coarse Balance switch.

2.4 FIRST TIME OPERATION

This section is included to help you to become familiar with the TF 2702 controls. The procedure is based on a simple application of the instrument; the measurement of an inductor using internal supplies only.

Switch on and set the controls as follows (numbers in circles refer to control designations in Fig. 2.1):

(4) INT AC control fully counter-clockwise.

(14) Mode switch to PRELIMINARY CRT BALANCE.

(9) Meter Volts/Amps switch to VOLTS.

(8) AC METER RANGE switch to the 5 V range.

(23) Test Supply Range switch to AC < 10 V.

(5) Generator selector to 1 kHz (or the supply frequency if a power choke or transformer is being used as the test inductor).

(11) Frequency Range selector to 800-1200 (or 40-60 for the supply frequency).

(15) COARSE SENSITIVITY switch to 2.

(16) FINE SENSITIVITY control to about mid-travel.

(22) Series/Parallel switch to SERIES if an air or ferrite cored inductor is being used, or PARALLEL for iron cored inductors.

(17) L RANGE selectors to range which includes inductor value.

(18) L RANGE MULTIPLIER selectors to x1.

Connect an inductor of known value (but less than 10 H) across the Lx terminals (7). The inductance value is not important but this 'first time' measurement procedure is simplified if it is kept below 10 H.

Adjust the INT AC control (4) for about half-scale meter deflection.

Adjust the SENSITIVITY controls (15) (16) until the CRT trace almost fills the screen. If the trace remains too small, select the next lower L RANGE switch (17) and the x10 L RANGE MULTIPLIER. The trace will probably be a circle, ellipse or a reversed hysterisis loop shape, and should now be changed to as near a single line as possible parallel to the two cursor lines marked on the CRT screen. To do this requires finding the correct relationship between R and L balance.

Set the Ω SCALE SELECTOR (21) and the Loss Balance control (19) to the positions where the trace is nearest a single line. This line will be straight only if there is no iron distortion (see Section 2.12 on the effects of core saturation).

Now adjust Coarse and Fine L Balance controls (24) and (25), at the same time readjusting, if necessary, the Loss Balance control (19) for a trace approximately parallel to the cursor lines marked on the CRT screen.

Note that the length of the trace, and any evidence of core distortion, varies with input level (i.e., adjustment of the INT AC control (4) Also note that greater sensitivity is gained by using a higher multiplier (18) and a lower range (17).

Switch the Mode switch (14) to METER BALANCE.

Adjust the Tuning control (12) for peak reading on the meter, adjusting the sensitivity controls (15) and (16), if necessary, to obtain an on-scale indication.

Balance for minimum meter reading with the Fine L Balance control (15) and the Loss Balance control (19). If it is difficult to tune for loss balance, change the Ω range by means of the Ω SCALE SELECTOR (21). When the meter indication is at the bottom end of the scale, increase sensitivity.

The inductance value can now be read from balance scales (24) and (25), and the resistance from (19), noting the multiplying factors on (21), (17) and (18). Further details on reading the scales are given in Section 2.6.

2.5 SELECTING THE CORRECT MULTIPLIER

At tuned frequencies

Tuned frequencies are those frequencies within the bands marked on the Frequency Range selector. The multiplier selector charts, Figs. 2.2 - 2.8, should be used to find the optimum multiplier for use with a given test frequency and alternating voltage when measuring an inductor of approximately known value.

To find the correct multiplier, simply select the chart for the relevant frequency range, and find where the test voltage and inductance intersect (e.g., at the supply frequency, select Fig. 2.2; for 1 H at 100 V the multiplier is x1). If the intersection falls towards the top of the multiplier band, use the next multiplier, unless the current rating of the lower band is essential. Figs. 2.4 - 2.8 show shaded areas at the higher voltages. If inductance and voltage intersect within these areas, that particular multiplier cannot be used; the test voltage should be reduced until the intersection is clear of the shaded area.

The maximum d.c. that can be used with each multiplier is given on the charts; in Figs. 2.2 - 2.7 the x1 band is divided into two or three sections each with a different maximum d.c. rating. If the selected multiplier shows a d.c. limit less than the level required, the next multiplier below must be selected or the d.c. reduced if over-dissipation of the bridge is to be avoided. However, the d.c. limit should give little trouble in practice as, for each multiplier, an a.c. of 1% of the permitted d.c. will give adequate sensitivity.

At untuned frequencies

When working at an untuned frequency, i.e. those between the discrete steps marked on the Frequency Range selector, the charts Fig. 2.2 - 2.8 cannot be used to select the multiplier. The multiplier must be calculated from the equations in Table 2.1.

TABLE 2.1

Multiplier	*Max. L measurable*	*Min. L measurable*
x1	$\frac{2}{F}V$	$\frac{1}{2\pi F}V$
x10	$\frac{20}{F}V$	$\frac{2}{F}V$
x100	$\frac{200}{F}V$	$\frac{20}{F}V$
x1000	$\frac{2000}{F}V$	$\frac{200}{F}V$

where F is in Hz
V is the test voltage (a.c.)
L is in henrys

The minimum inductance on the x1 multiplier (i.e. $\frac{1}{2\pi F}V$) is that for the maximum d.c. permissible, 10 A; this minimum value can be reduced if the d.c. level is reduced to maintain the r.m.s. total within the 10 A limit.

D.C. limitations at untuned frequencies are exactly the same as for tuned frequencies.

2.6 READING THE BALANCE SCALES

Inductance

Note the readings on the Coarse and Fine L Balance scales. Add 1 to the readings if 1.0 is shown in the yellow indicator window. Now use the L RANGE selector and the L RANGE MULTIPLIER to obtain the final answer.

e.g., Coarse L Balance reads .9

Fine L Balance reads 07 (i.e. between 03 and 10)

1.0 is indicated in the +1 window

L RANGE is 10 mH

L RANGE MULTIPLIER is x100

Following the procedure above,
.907 + 1 = 1.907 (on 10 mH scale).

i.e. 19.07 mH x 100 = 1907 mH or 1.907 H

Equivalent resistance

Read the appropriate scale in Ω and multiply by the factor on the Ω SCALE SELECTOR (A/100, A/10, A, B) and by those factors indicated under the L RANGE MULTIPLIER and L RANGE selector.

e.g. L RANGE is 1 H

L RANGE MULTIPLIER is x10

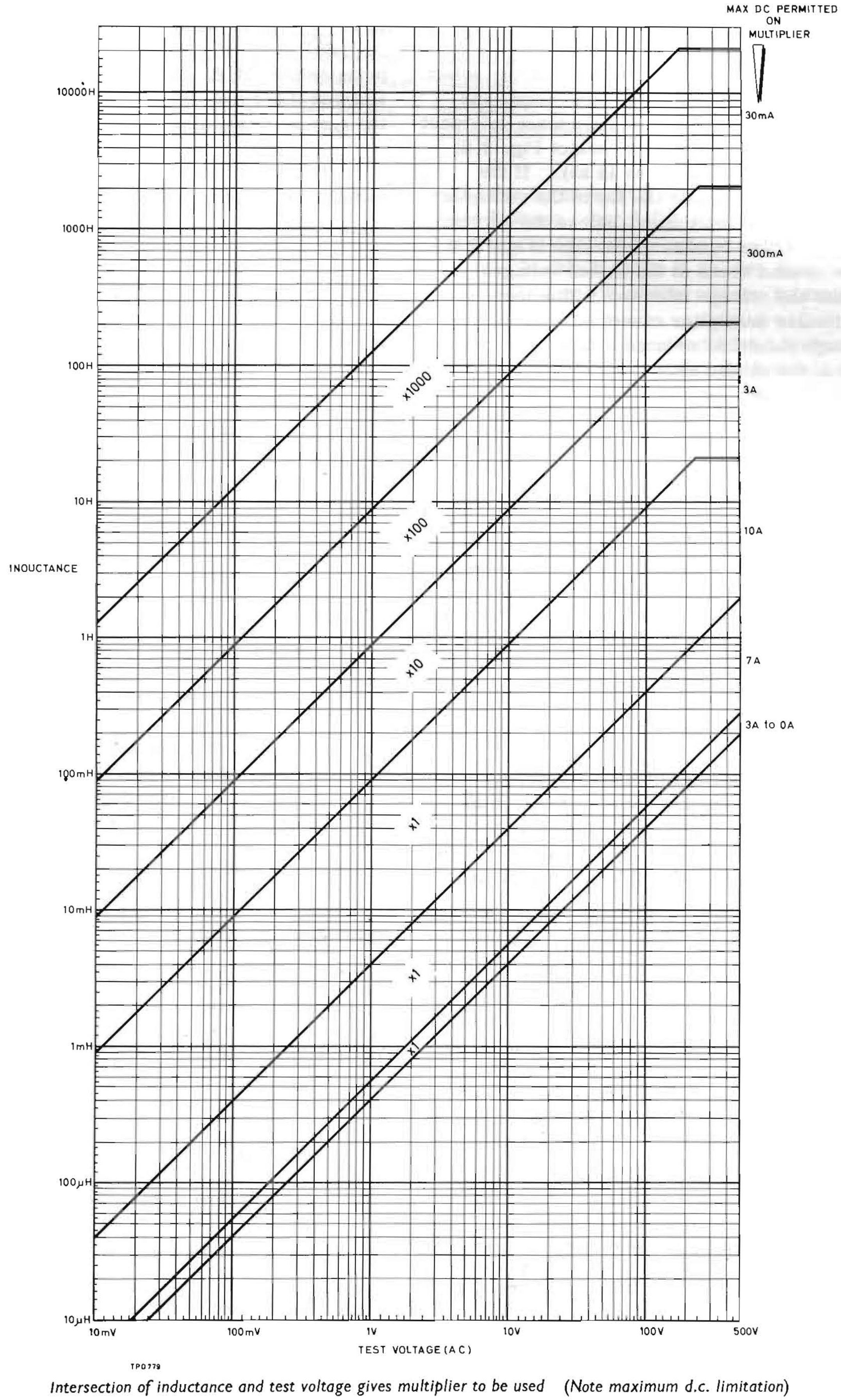
Ω SCALE SELECTOR is A/100

A scale reads 4.2 Ω

Therefore we have -

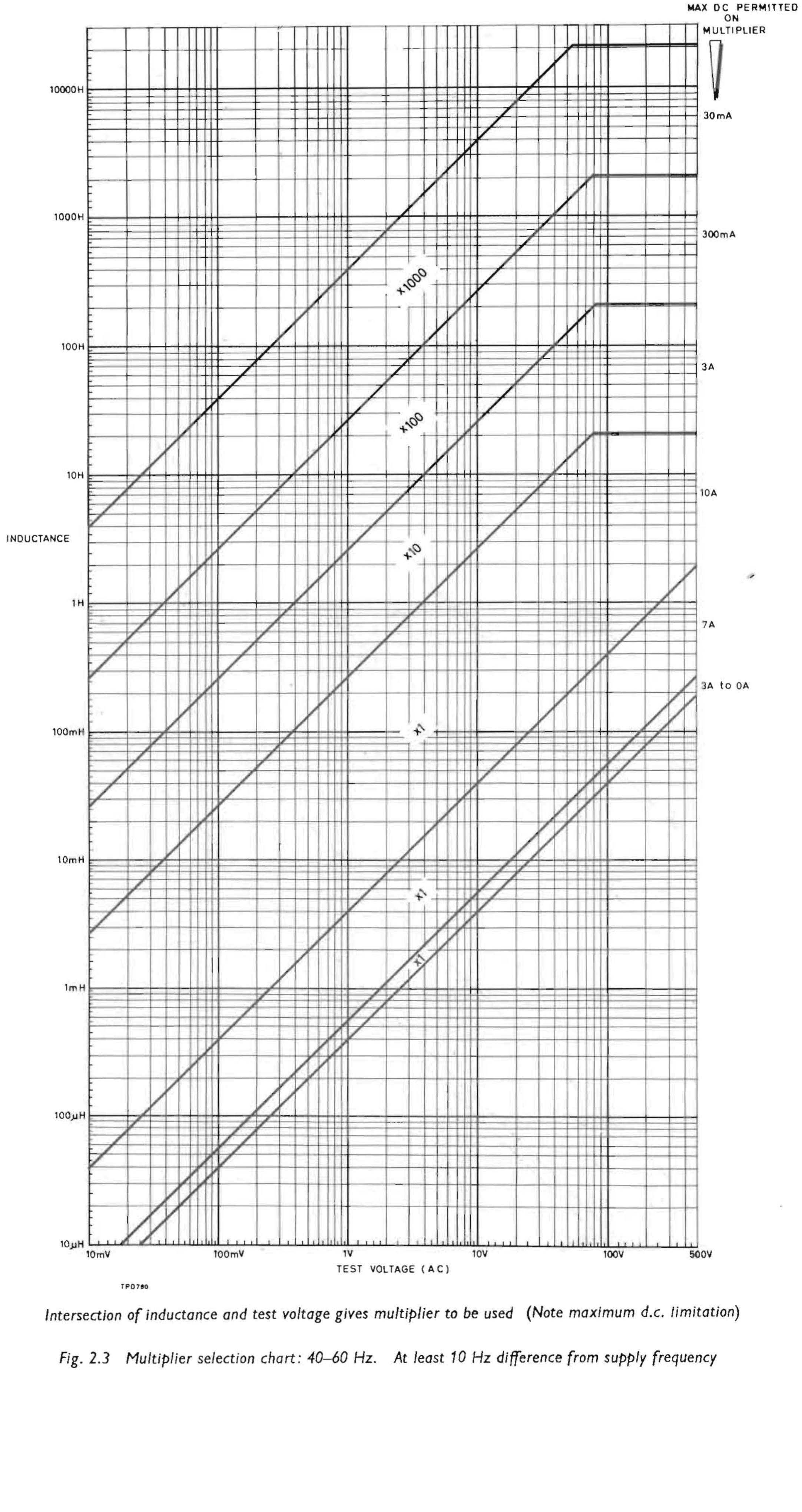
4.2 x $\frac{1}{100}$ x 100 (range) x10 (multiplier

i.e., 42 Ω



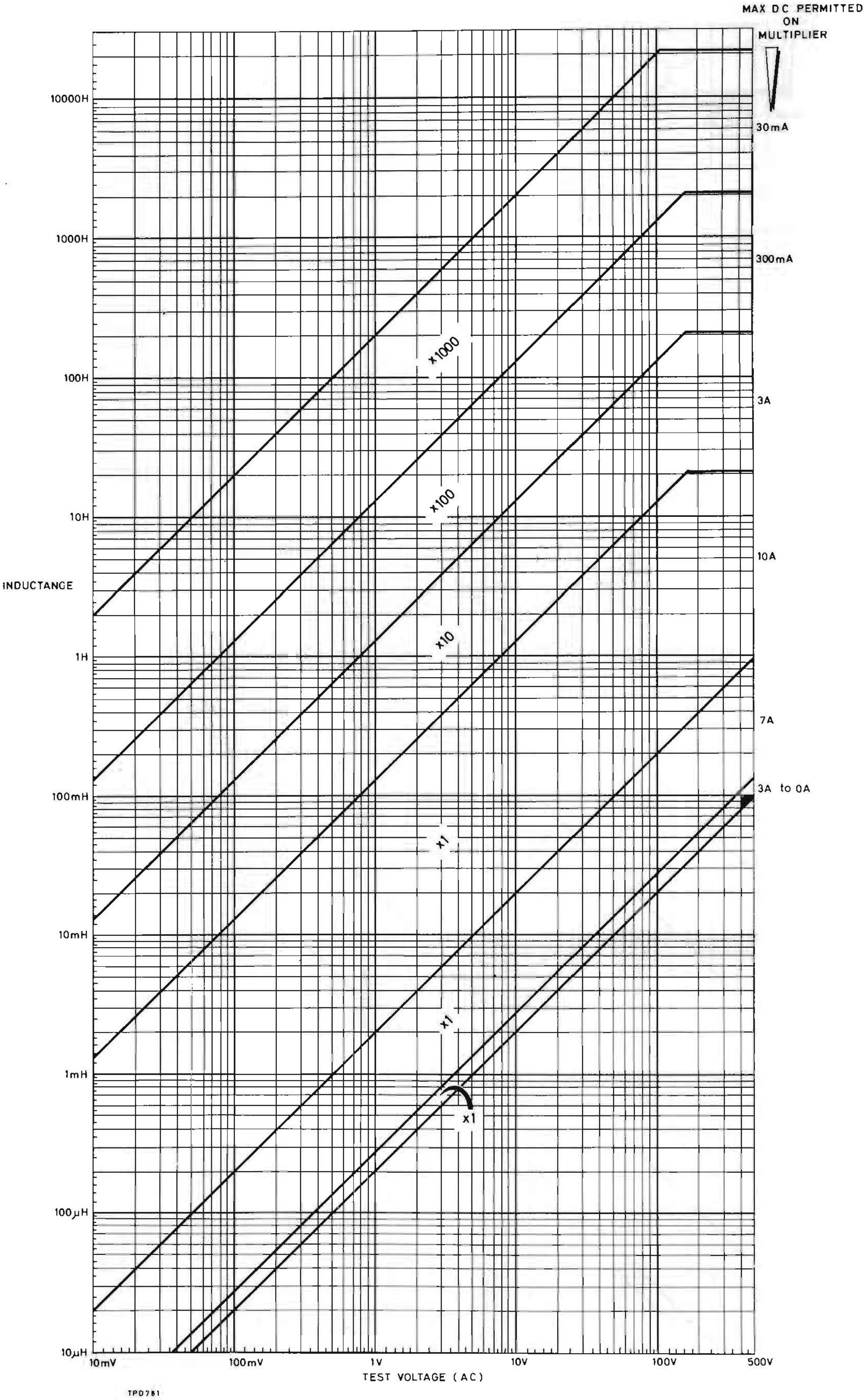
Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.2 Multiplier selection chart: 40–60 Hz. At or very near supply frequency



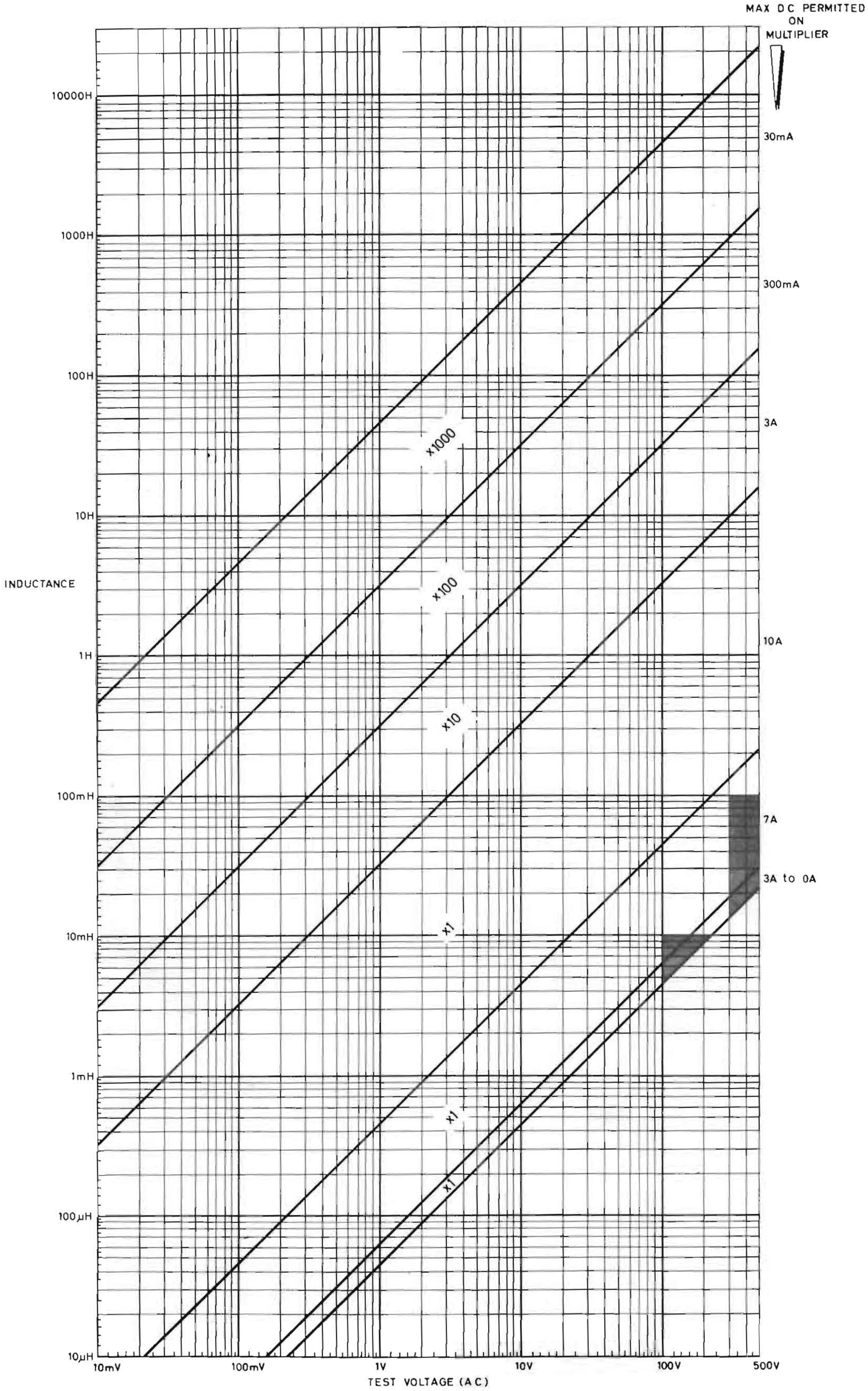
Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.3 Multiplier selection chart: 40–60 Hz. At least 10 Hz difference from supply frequency



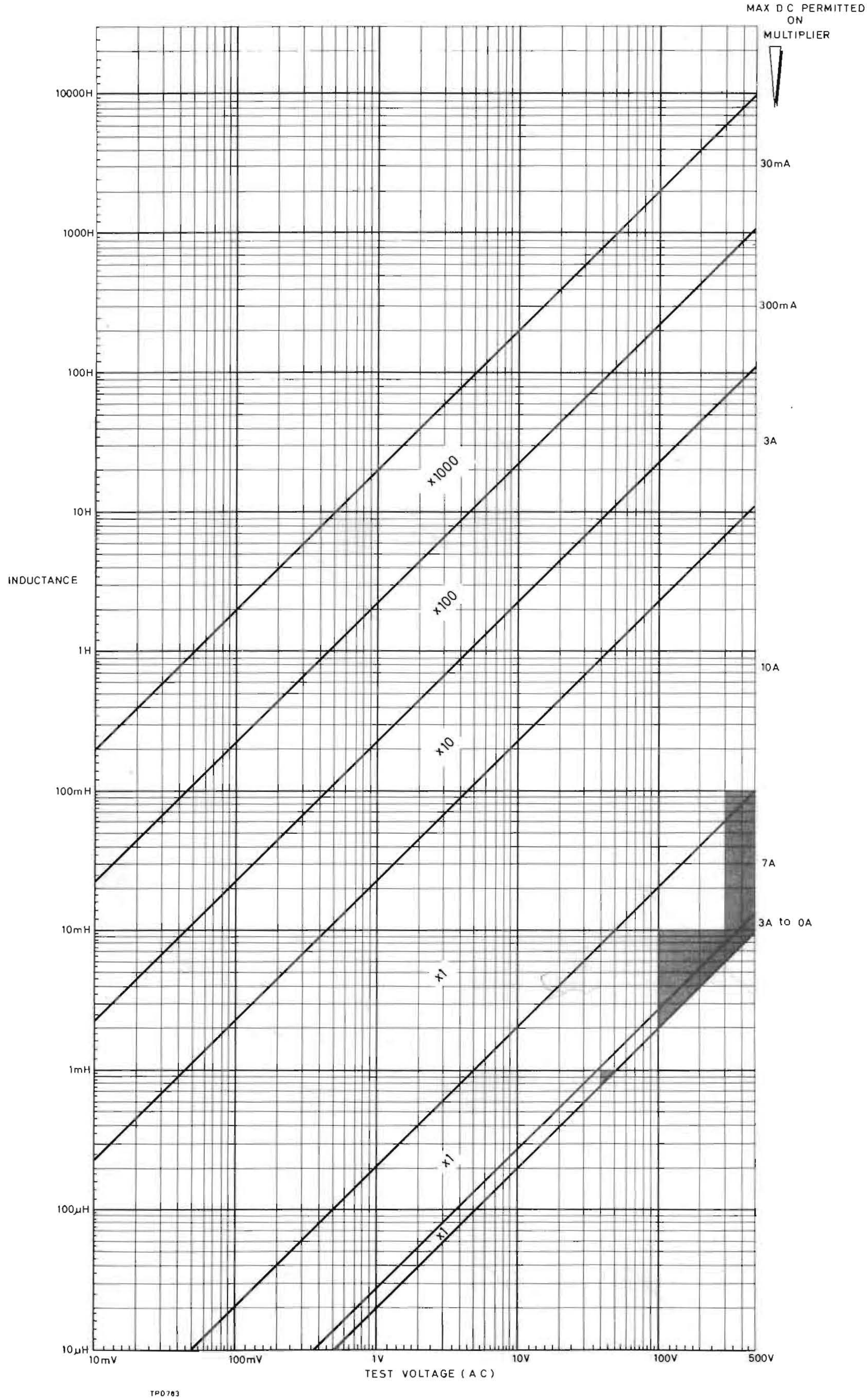
Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.4 Multiplier selection chart: 80–120 Hz.



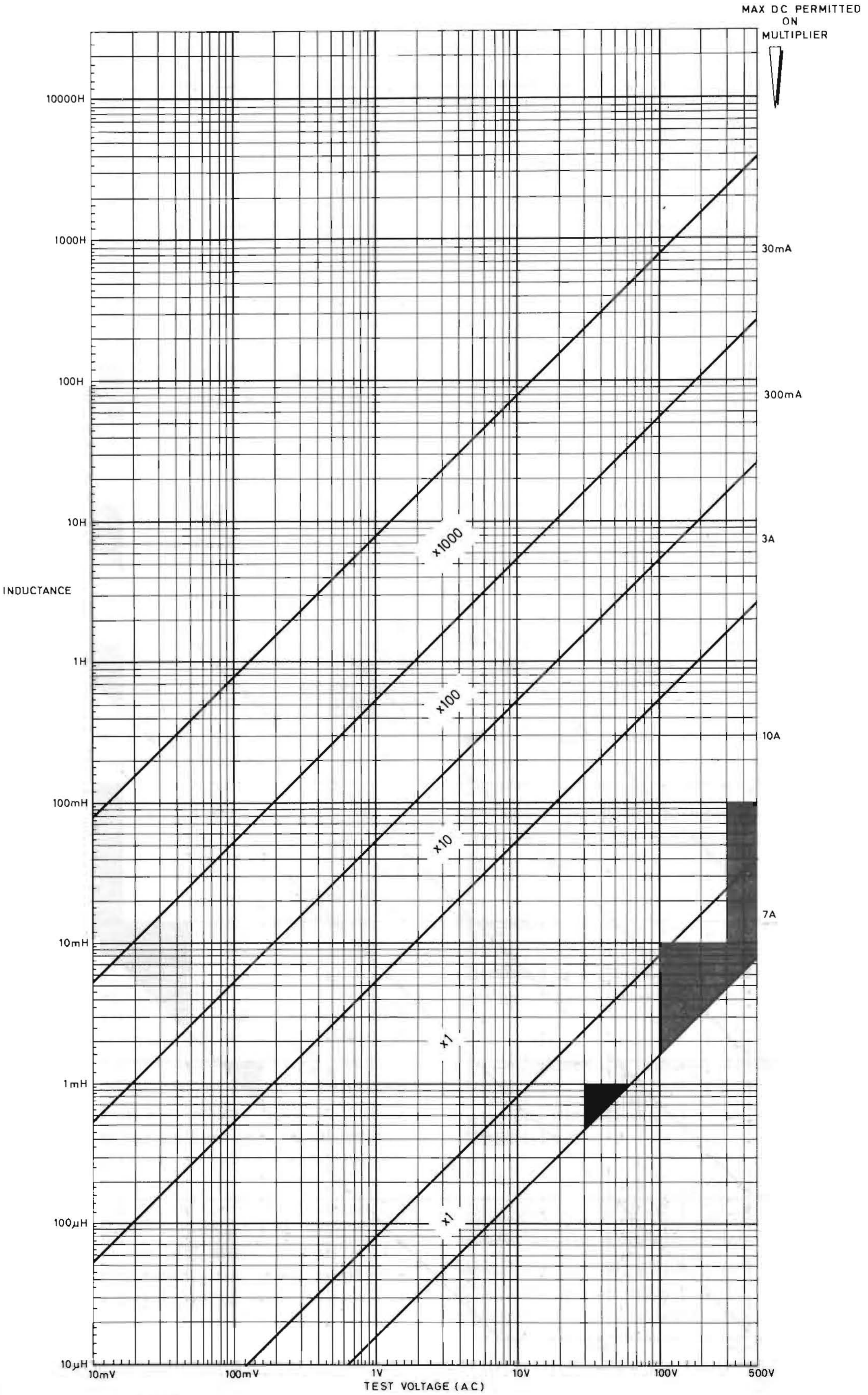
Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.5 Multiplier selection chart: 350–500 Hz. (Useful upper limit is approximately 200 H.)



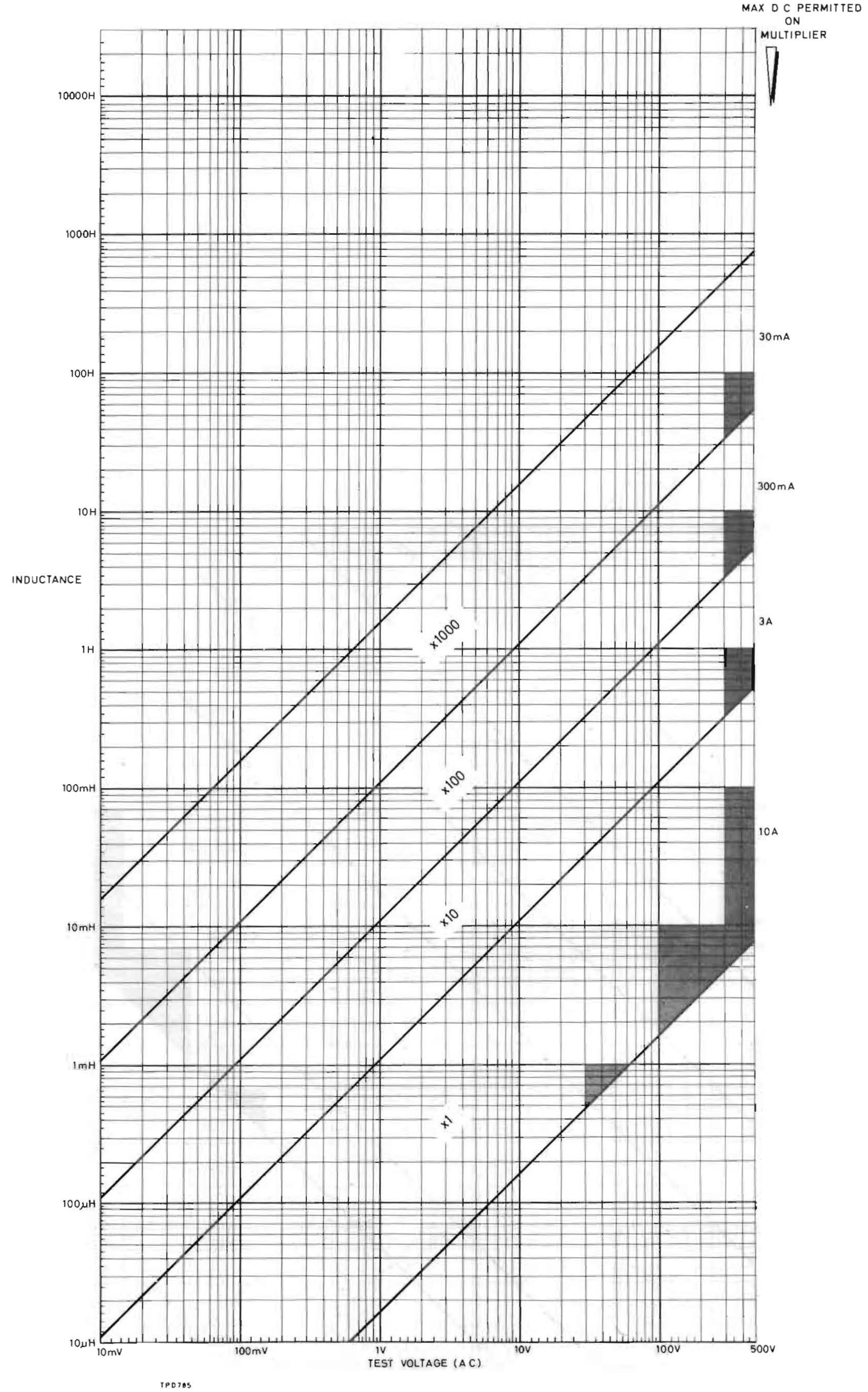
Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.6 Multiplier selection chart: 800–1200 Hz. (Useful upper limit is approximately 50 H.)



Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.7 Multiplier selection chart: 2000–3000 Hz. (Useful upper limit is approximately 5 H.)



Intersection of inductance and test voltage gives multiplier to be used (Note maximum d.c. limitation)

Fig. 2.8 Multiplier selection chart: 10–15 kHz. (Useful upper limit is approximately 0.5 H.)

2.7 ARRANGEMENT OF TEST SUPPLIES

The inductor being measured may be tested with a. c. from an internal or external source upon which d. c. can be superimposed; this d. c. must be obtained externally.

If internal a. c. is used (see Section 1. 2 for limits) up to $\frac{1}{2}$ A d. c. can be mixed with it in the internal isolating transformer. This transformer can also be used to mix up to $\frac{1}{2}$ A d. c. with a. c. applied to the front panel socket J. The a. c. must be within the limits 4 V max. at 20 Hz rising to 100 V max. at 500 Hz and above; the maximum applied voltage for a given frequency is found from the equation:

V max = f/5 V r. m. s. where f is in Hz.

The test voltage is approximately equal to this applied voltage, but there is a degree of transmission loss in the internal transformer.

A. C. greater than 10 V requires the Generator Selector to be set to A. C. > 10 V or to 'Add 1 to scale reading'. This latter position mechanically restricts the L scale to 0. 1, thus preventing overload of the internal amplifier.

For d. c. greater than $\frac{1}{2}$ A or for a. c. in excess of the limits given above, an external mixing system must be used; A. C. + D. C. Mixer Unit, TM 8339, has been specially designed for this purpose and details of its use are given in Section 2. 18.

If no d. c. test supply is required, a. c. may be obtained from a source such as an oscillator or power amplifier or from the mains supply via a transformer. Should mains be used do not connect it to the TF 2702 via an auto transformer; these are not isolated from mains and dangerous power voltages may be caused on the instrument case.

In any arrangement not using the internal isolating transformer the test supplies are connected to the instrument by the front panel terminals and the generator selector set to EXT GEN.

When superimposing d. c. on internally generated a. c. the d. c. must be connected to the appropriate terminals in the correct polarity; the negative input terminal is earthed.

2.8 SELECTING THE WORKING MODE (series or parallel)

When testing an inductor to a given specification the working mode will generally be given as part of that specification. However, where it isn't and when testing completely unknown inductors, the working mode must be decided from the construction of the inductor.

If the inductor has a laminated core or if d. c. is quoted as a test condition, use the parallel mode; this gives a higher equivalent inductance and corresponds to the Hay bridge commonly used by component manufacturers. Exceptions to this general rule may be found in some audio inductors which are wound with very thin wire (e. g. electromagnetic hearing aids and tape recorder heads). In these the wire resistance may so predominate that it is better to use the series mode.

R. F. coils and those with iron dust cores should be tested in the series mode as there is usually negligible parallel core loss.

2.9 TESTING INDUCTORS TO SPECIFICATION

Generally, the test specification of an inductor will include the following information: nominal inductance (sometimes expressed as a minimum inductance), mode of use (series or parallel), frequency at which test should be made, alternating voltage and direct current to be applied for the test.

Procedure

(numbers in circles refer to control designations in Fig. 2. 1):

Connect the inductor to the test terminals (7).

Set the INT AC control (4) fully counter-clockwise.

Select the optimum L RANGE MULTIPLIER (18) appropriate to the test voltage and frequency; details will be found in Section 2. 5. Remember that if d. c. is used and is at a sufficient level then it will dictate selection of the multiplier if over-dissipation of the bridge is to be avoided.

Having selected the multiplier, select the L RANGE (17) to suit the nominal value of the test inductor and set the L Balance control (24) and (25) to approximately the expected value, or to mid-travel.

Set the Ω RANGE SELECTOR (21) to the A scale for the series mode or the B scale for the parallel mode, and set the Loss Balance control (19) midway.

Set the Mode switch (14) to the PRELIM CRT BALANCE position.

Connect the test voltages (alternating and direct) to the instrument, setting the levels and frequency as required - see Section 2.7 for full details.

Set the Frequency Range Selector (11) to the correct range or to the UNTUNED position if the test frequency lies outside the ranges given.

Adjust the SENSITIVITY controls (15) and (16) for a clear CRT trace.

If the series mode is being used switch through the three A scale ranges on the Ω SCALE SELECTOR and set the control to the position where the CRT trace is nearest a single line.

If the inductor value is near the L Balance settings this line will normally be almost parallel to the two lines marked on the CRT screen. If, however, the line is horizontal, successively select the L RANGE buttons above the one being used; if the trace remains horizontal it means that the inductor being tested is open circuit.

If the trace is vertical, selection of a lower L RANGE should tilt it to the left. If it does not tilt the trace sufficiently for it to lie parallel to the lines on the screen, and subsequent procedure indicates a very low inductance (1 or 2 μH) then the inductor is a short circuit.

CAUTION Multiplier settings must not be changed with d.c. present, as damage may result to the instrument. The r.m.s. voltage limits are shown above each L RANGE selector.

Switch the Mode switch (14) to METER BALANCE and adjust the sensitivity controls (15) and (16) for an on-scale meter reading.

Adjust the Tuning control (12) for peak reading on the meter.

Balance for minimum meter reading with the L Balance (24) (25) and Loss Balance (19) controls. If it is difficult to tune for loss balance, switch the Ω SCALE SELECTOR (21) to another range. When the meter indication is at the bottom end of the scale, increase sensitivity and adjust for minimum reading again.

When the minimum reading is obtained read off the inductance and resistance values - see Section 2.6.

CAUTION Reduce the test supply to a safe level before disconnecting the inductor, as interrupted d.c. can result in high surge voltages in the inductor.

For repetitive measurements (e.g. testing that a number of inductors are within limits) it is necessary only to check the test voltages and go direct to the METER BALANCE position of the Mode switch.

2.10 MEASURING AN UNKNOWN INDUCTANCE

If the inductance to be measured is completely unknown two things must be decided before starting the test; the frequency at which to test the inductor and the test voltage to be used.

As the internal supplies provide up to 4 V e.m.f. at 1 kHz and 10 kHz and up to 10 V e.m.f. at mains frequency, it is best to measure small coils with about 1 V e.m.f. at 1 kHz and power chokes and transformers with about 2 V at mains frequency.

Procedure

(numbers in circles refer to control designations in Fig. 2.1):

Connect the inductor to the test terminals and set the controls as follows:

Frequency Range selector (11) to range which includes test frequency.

Mode switch (14) to PRELIMINARY CRT BALANCE.

Series/Parallel switch (22) to SERIES for h.f. coils or other coils with little iron or wound with thin wire, and to PARALLEL for iron cored devices; (see Section 2.8 for further details).

Ω SCALE SELECTOR to A scale for series mode or B scale for parallel.

Generator selector (5) to the internal frequency being used for the test.

INT AC control (4) to give the appropriate voltage on the meter (see the beginning of this section).

Select the 10 H L RANGE selector (17) and the x1 L RANGE MULTIPLIER (18).

Coarse L Balance decade switch (24) to about mid-range.

Adjust the sensitivity controls (15) and (16) for an adequate CRT trace.

Should the trace be too small, select the x10, x100 or x1000 MULTIPLIER to obtain adequate sensitivity.

CAUTION Do not switch from one MULTIPLIER to another without reducing the supply if any d.c., or a.c. of more than a few milliamps, is being used to test the inductor.

Alternatively, sensitivity can be improved by increasing the test supply voltage. At maximum sensitivity, i.e. when using the x1000 multiplier, there may be a rather fuzzy trace on the CRT caused by frequency pick-up. This may be reduced by selecting AMPS on the Meter Volts/Amps switch.

If the trace is a vertical line the inductance is less than 10 H. In this case, successively push the 1 H, 100 mH etc. L RANGE buttons until the trace inclines to the left.

CAUTION If the input voltage, alternating or direct, exceeds 10 V then care must be taken not to switch to another range as damage may result to the instrument. The r.m.s. voltage limits are shown above each L RANGE SELECTOR.

If the inductance value exceeds 10 H the trace will lean far beyond the 45^{o} lines (i.e. towards the horizontal) and the x10 or a higher multiplier must be selected.

> NOTE: If the trace leans to the right the test component is capacitive.

The trace will probably be a circle, ellipse or reversed hysterisis loop shape and should now be change to a single line which is parallel to the two lines marked on the CRT screen. To do this requires finding the correct relationship between L and R balance.

Adjust the Loss Balance control (19) and the Ω SCALE SELECTOR (21) if the series mode is being used, until the trace is nearest a single line. This line will be straight only if there is is no iron distortion (see Section 2.12 on the effects of core saturation).

Now adjust the Coarse and Fine L Balance controls (24) and (25) together with the Loss Balance control (19), until the trace is parallel to the lines on the screen.

Switch the Mode switch (14) to METER BALANCE. Adjust the Tuning control (12) for peak reading on the meter, adjusting the Coarse and Fine sensitivity if necessary to obtain an on-scale indication.

> NOTE: When the trace is approximately parallel to the cursor lines, the test inductance corresponds approximately to the L Balance scales' reading multiplied by the L RANGE MULTIPLIER. The trace in a more horizontal position indicates that the test inductance is higher than the reading, and in a more vertical position that it is lower than the reading.

Balance for minimum meter reading with the L Balance (24) (25) and the Loss Balance (19) controls. If it is difficult to tune for loss balance, switch Ω SCALE SELECTOR (21) to another range. When the meter indication is at the bottom end of the scale increase sensitivity and adjust for minimum reading again.

> NOTE: Difficulty in achieving balance may arise if the wrong test frequency has been chosen or if series instead of parallel mode, or vice versa, has been selected.

When balance has been attained, read off the inductance and resistance values of the component - see Section 2.6.

Reduce the test supply to a safe level (especially d.c.) before disconnecting the inductor.

Once the inductance value has been measured, examination of the specifications and test data of similar inductors will enable you to test the inductor, as in Section 2.9, using more practical test parameters (e.g. direct voltage).

2.11 HUM PICK-UP AT MAINS FREQUENCY

When making tests with the test voltage at mains frequency, injection of hum pick-up into the bridge may introduce significant errors in the final result.

A check on the error should always be made and this can be done as follows:

Make the measurement as detailed in earlier sections and note the meter reading at balance (i. e. the minimum reading).

Reduce the test voltage to zero. The meter reading may now be greater than at balance; if so, it means that the hum pick-up is significant. Note the meter reading.

Apply the test voltage again.

Adjust the Fine L Balance control to obtain a meter indication equal to the hum pick-up indication. This will be obtained at two positions of the Fine L Balance control, one greater and one less than the original reading.

Note the two readings on the Fine L Balance scale. The inductor value lies within the range of these two readings.

Example:

Meter reading at balance is two divisions.

Dial readings etc. give inductance value of 450 mH.

Remove test supply; meter reading is now six divisions.

Reconnect supply and adjust Fine L Balance control for six division deflection on meter. This deflection is achieved at 482 mH and 478. 5 mH. Therefore, it is known that the inductor is between 478. 5 and 482 mH.

i. e. the pick-up error is:

$$\frac{482-480}{480} \times 100 = 0.4\%$$

or

$$\frac{480-478.5}{480} \times 100 = 0.4\%$$

The accuracy of the measurement will be 1. 4% including the bridge errors.

2.12 EFFECTS OF IRON DISTORTION

When the instrument is set for distortion check (i. e. , the Mode switch in the bottom position) linear inductors will give a trace which is a straight line inclined at 45° when the bridge is at approximate balance. When R or L balance is incomplete the trace will show as an ellipse or circle; Fig. 2. 9-1 gives an example of this.

In general, laminated-core inductors are non-linear as the iron in the core will eventually saturate; saturation occurs when the current is increased or the frequency is reduced at constant voltage.

With normal iron non-linearity the trace changes to that shown in example 2 of Fig. 2. 9 when the core is saturated with a. c. only; further increase in the current will produce a three-loop trace, the loops indicating the presence of 3rd harmonic in the current (an example of this is shown in Fig. 2. 9-3; Fig. 2. 9-5(a) shows similar conditions when the bridge is nearer balance).

If the a. c. excitation is held at a constant level very much below saturation, and the d. c. level is increased, a change in the slope of the trace will occur. A move towards the horizontal indicates an increase in inductance, and a move towards the vertical a decrease; see example 4 of Fig. 2. 9.

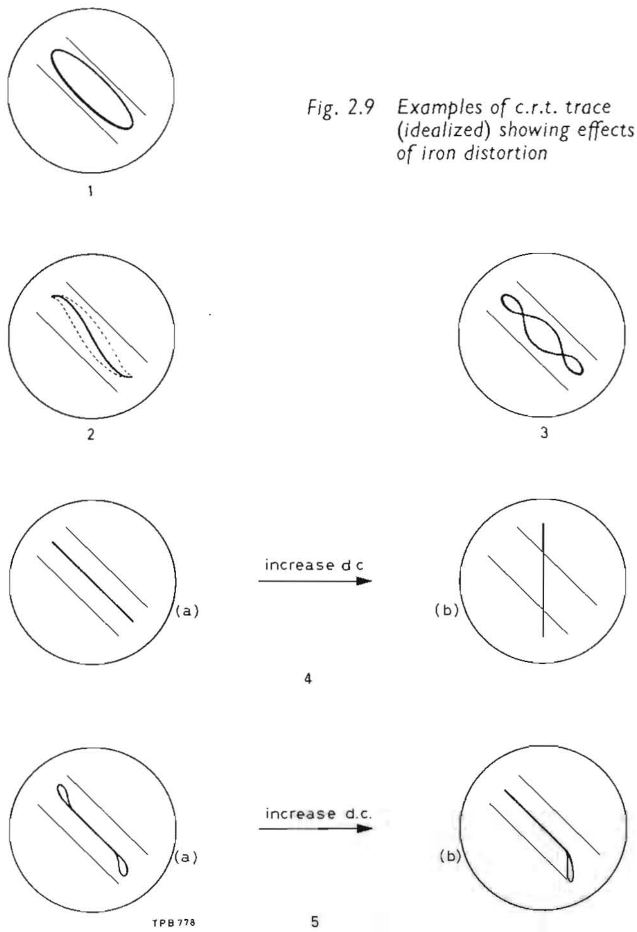


Fig. 2.9 Examples of c.r.t. trace (idealized) showing effects of iron distortion

When the a. c. excitation is at saturation level, the addition of d. c. will result in a trace with the distortion all at one end (see Fig. 2. 9-5); the amount of unbalanced distortion will vary according to the amount of d. c. applied.

The CRT picture alone can often give an adequate indication of the performance of the inductor, particularly to show the onset of non-linearity. The examples given in Fig. 2. 9 are an indication of the general shape that can be expected from given conditions; actual trace shapes will vary according to the a. c. and d. c. levels of excitation.

2.13 MEASUREMENT OF TRANSFORMER LEAKAGE INDUCTANCE

To find the leakage inductance, short circuit the transformer secondary winding of interest and measure the primary impedance using the procedure in Section 2. 10. The series mode should be used when making the measurement as the iron loss will be low. The test voltage applied should be such that the primary current will be the same as for normal working conditions.

The total leakage inductance is:

$$L1 + L2 = L - \frac{R_s^2}{\omega^2 L_s^2} \cdot L_p$$

where L1 is the primary leakage inductance
L2 is the secondary leakage inductance
L is the measured inductance
R_s is the secondary resistance excluding iron loss (i. e. the d. c. resistance, approximately)
L_s is the secondary inductance (series mode)
L_p is the primary inductance (series mode)

At higher frequencies (above about 1 kHz) the second term in the above equation may be negligible, and the leakage inductance will be that measured on the instrument.

On simple two-winding transformers it can generally be assumed that $\frac{L_1}{L_2} = \frac{L_p}{L_s}$

2.14 CALCULATION OF Q

The Q of the inductor under test can be found from the equation

$$Q = \frac{2\pi f L}{R}$$

where L and R are respectively the series inductance and series resistance of the test inductor as measured on the TF 2702, at the test frequency f.

However, it must be remembered that the Q will be calculated to the same order of accuracy as R is measured. Fig. 1. 3 gives an indication of the accuracy of the resistance measurement and should be referred to to estimate the accuracy of the Q calculation.

NOTE: for parallel measurements

$$Q = \frac{R}{2\pi f L}$$

where, in this case, L and R are the parallel inductance and resistance.

2.15 FINDING RESONANT FREQUENCY AND CAPACITANCE

The resonant frequency of an inductor may be found as follows.

Set the instrument for normal operation in the PRELIM BALANCE mode and using external supplies. Set the Meter Volts/Amps switch to AMPS and the A. C. METER RANGE selector to 50.

Connect a suitable variable frequency source to the EXT GEN terminals or the external a. c. jack, J.

Adjust the frequency for a minimum meter deflection. The frequency at which this minimum occurs is the resonant frequency.

If the sensitivity is insufficient to give a reasonable meter deflection before adjusting to the resonant frequency, the CRT trace can be used to indicate the null point as follows.

Adjust the sensitivity controls for a suitable CRT trace. As the frequency moves towards that of resonance, the vertical components of trace will become smaller and will be at a minimum at the resonant frequency.

Once the resonant frequency has been found, the self capacitance of the inductor can be calculated from the equation

$$C = \frac{1}{4\pi^2 f^2 L}$$

where f is the measured resonant frequency in Hz and L is the inductance value of the inductor under test.

2.16 USE AS A VOLT/AMMETER

The TF 2702 can be used to measure alternating voltage and current, direct. Voltage is measured in nine ranges, 50 mV to 500 V full scale, and current in six ranges, 50 mA to 20 A full scale; both are over the frequency range 20 Hz to 20 kHz.

Voltage measurement

Switch the Generator Selector to EXT GEN, the Volts/Amps switch to VOLTS, and the AC METER RANGE to the appropriate range.

Connect the voltage to be measured across the Lx terminals.

The reading accuracy is given in Section 1. 2 under MONITOR - Voltmeter.

Current measurement

Switch the Volts/Amps switch to AMPS and the AC METER RANGE to the appropriate range. Select the x1 L RANGE MULTIPLIER.

Connect the current to be measured between the Lx Lo terminal and the EXT GEN earth terminal.

The reading accuracy is given in Section 1. 2 under MONITOR - Ammeter.

2.17 ARRANGING NON-STANDARD TUNING FREQUENCIES

The tuning ranges, selected by the Frequency Range switch, are obtained by the selection of appropriate capacitors in the twin T network - see Section 3. 7, TUNE, and the circuit diagram, Fig. 6. 4.

If inductors are continually being tested at a particular frequency which is not in the tuning ranges available on the Frequency Range selector, capacitors can be inserted which are of the necessary value to give tuning at that frequency.

It is usually best to insert these capacitors in the UNTUNED position of the switch, as 5R38 is the only component which needs to be removed, the position on the other switch wafers being vacant. However, the capacitors can be removed from any unused switch position and replaced by the appropriate values. For example, if inductors are never tested at 40-60 Hz, 5C21, 5C35 and 5C27 can be replaced.

The required values of the new capacitors are given by 30/f μF for the vertical arm of the T network and 15/f μF for the other two arms; where f is the tuning frequency in Hz.

e. g. 5 kHz is the tuning frequency required and the UNTUNED position of the Frequency Range switch is to be used for this frequency.

Replace 5R38 with a 30/5000 μF capacitor (i. e. 0. 006 μF) and in the unused last position of switch wafers SC3F and SC1F insert capacitors of 15/5000 μF (i. e. 0. 003 μF). All capacitors should be ±2% of the calculated value.

The capacitors are mounted on board TM 8522, the location of which is shown in Fig. 4. 5.

2.18 A.C. + D.C. MIXER UNIT, TM 8339

2.18.1 Description

This unit is designed for high power use when testing inductors with d. c. above $\frac{1}{2}$ A or a. c. > 10 V at 50 Hz to > 100 V at 500 Hz. The mixing transformer has four ratios capable of carrying 10 A on the 30 V (a. c.) range, down to 0. 3 A on the 500 V range.

The specification for the unit is given in Section 1. 3.

2.18.2 Controls and connectors

(1) OUTPUT switch. ON/OFF switch; set to OUTPUT to connect test voltages to the Output terminals. At OFF, the Output terminals are short circuited.

(2) Output Range switch. Set to the voltage and current range appropriate to the supplies being used. Each range is labelled in alternating voltage and corresponding maximum direct current.

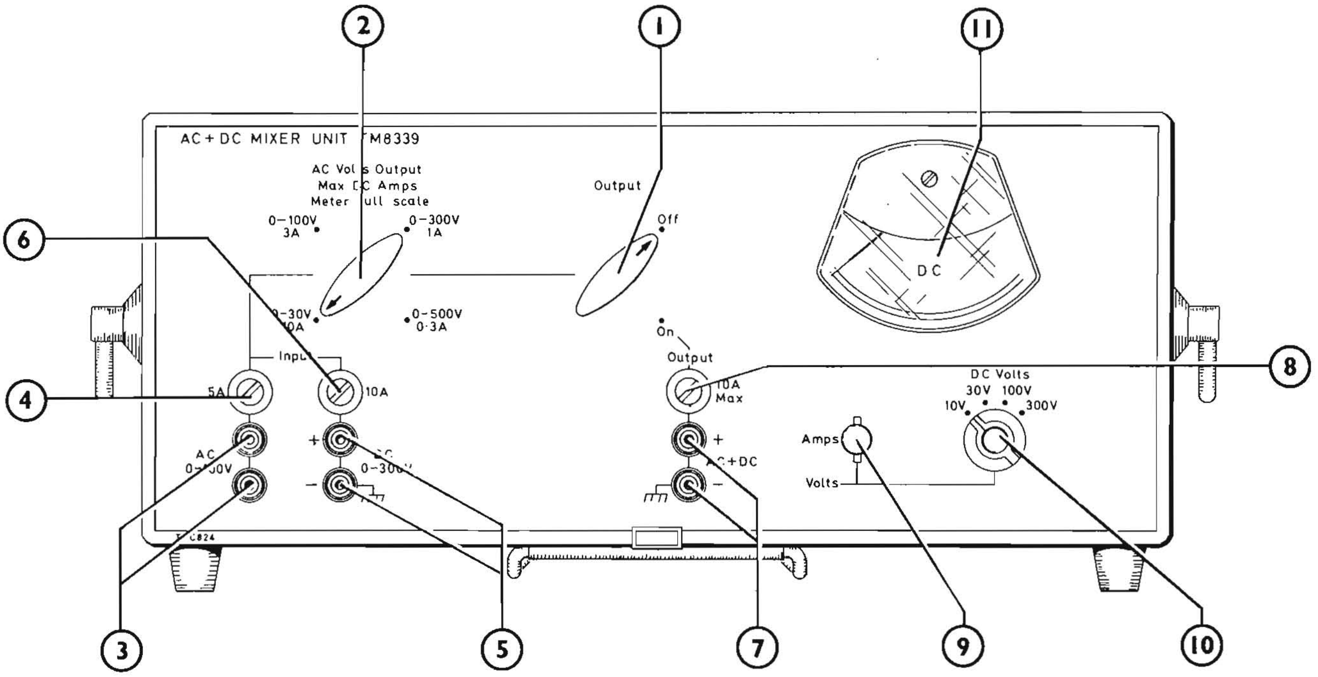


Fig. 2.10 TM 8339, controls and connectors

(3) A. C. Input terminals. Connect a. c. supply (100 V max.) to these terminals.

(4) 5 A a. c. fuse.

(5) D. C. Input terminals. Connect d. c. supply (300 V max.) to these terminals.

(6) 10 A d. c. fuse.

(7) Output terminals. AC + DC output delivered at these terminals.

(8) 10 A Output fuse.

(9) Volts/Amps switch. Determines whether input voltage or current is monitored on the meter. Hold in the VOLTS position when the input voltage (d. c.) is required to be monitored. The switch is spring loaded to return to the AMPS position.

(10) Meter Range switch (D. C. VOLTS). Set meter range according to input voltage (d. c.).

(11) Meter.

2.18.3 A.C. input supply

If a. c. at mains frequency is required, it is sufficient to connect the mains supply to the TM 8339 via a variable transformer (e. g. Variac).

At other frequencies the supply must be obtained from an audio oscillator via a power amplifier. The oscillator should cover the frequency range 20 Hz - 20 kHz; suitable instruments are mi TF 1101 or TF 2000.

The power amplifier should provide an output of between 150 VA and 500 VA depending on the VA rating of the test inductor, and be capable of working into an inductive load. A suitable amplifier would be of the 100 V line type as used in public address systems (e. g. Vortexion S 120/200).

2.18.4 D.C. input supply

The main requirement of the d. c. supply is that it should be adequately stable, readily controlled and generally proof against inductive load surges. Also good regulation of, say, 10% no load to full load is desirable with ripple content less than 1%.

A suitable d. c. source is the Wareham Ltd. 10 A D. C. Supply, type 9306, which gives an output of 5 A between 0 and 80 V and 10 A between 0 and 40 V. This power unit can be supplied by Marconi Instruments Ltd.

It should be noted that electronically regulated supplies are generally not suitable to drive the TM 8339 as they are too susceptible to a. c. or surge reverse currents.

2.18.5 Operation

Set the OUTPUT switch to OFF.

Set the Output Range switch to the required range.

Connect the a. c. and d. c. supplies to the appropriate terminals.

Connect the Output terminals to the TF 2702 EXT GEN terminals.

Set the d. c. supply to zero and the a. c. supply to the required level.

Set the OUTPUT switch to ON.

Following the procedure set out in Sections 2. 5. et seq., adjust the TF 2702 for a preliminary balance.

Slowly adjust the d. c. to the required level.

CAUTION above about 50 V, care must be taken not to apply the d. c. too quickly as surges caused by C1-C6 charging may blow the fuse.

Now make the measurement on the TF 2702 as normal. Do not change L RANGE MULTIPLIER with d. c. flowing in the test inductor. If it is necessary to do so, switch the TM 8339 OUTPUT switch to OFF and then make the adjustment.

WARNING Set the OUTPUT switch to off before disconnecting the test inductor.

WARNING When disconnecting the d. c. supply, remember that smoothing capacitor C1-C6 has a 5 min time constant and so there may be a lethal voltage across the d. c. input terminals some time after the supply has been removed. For example, if a 300 V input has been used there will be 100 V across the terminals after 5 minutes. The capacitor can be safely discharged through a resistance of, say, 1 kΩ but a short circuit should not be applied across the terminals.

2.18.6 Remote operation

Testing batches of inductors on a go/no-go basis, to verify that their value falls within given limits, can be done more rapidly by means of a relay which is connected to TM 8339 in such a way as to replace the OUTPUT switch, and which is energized by a protective cage round the inductor being tested. Fig. 2.11 shows the test set up in the ready position; i. e., with the cage up (allowing access to the inductor), the TM 8339 output switched off, and the a. c. and d. c. supplies adjusted for the next test inductor.

The relay should have one set of 10 A a. c. contacts (normally open) and two sets of 10 A d. c. contacts, arc quenched type (one set normally open the other normally closed).

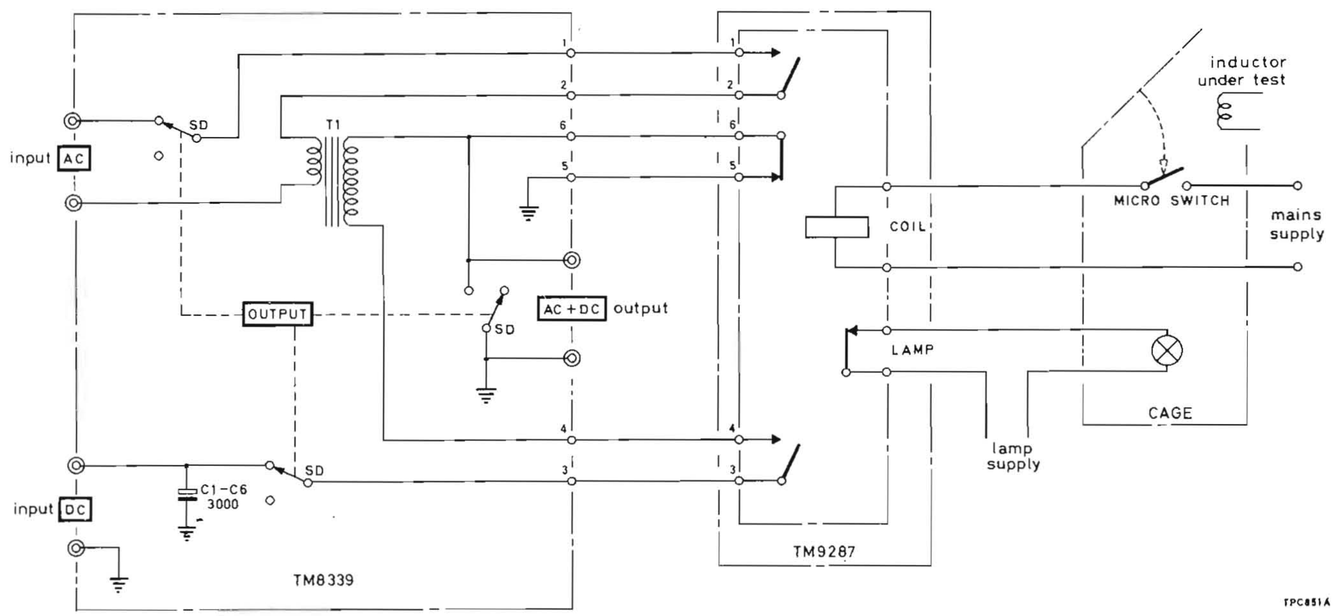


Fig. 2.11 Test set up for remote operation of TM 8339

The coil is energized by a micro-switch which is open when the cage is in a position which allows access to the test inductor and closed when the cage prevents further interference with the connecting leads.

One set of relay contacts is used to operate a lamp. On lifting the cage the lamp coming on indicates that the relay has operated and so the supplies have been disconnected from the TF 2702 and the inductor under test.

A remote switching unit suitable to perform the above function can be obtained from Marconi Instruments Ltd.

Chapter 3	Technical description

3.1 CIRCUIT SUMMARY

Fig. 3.1 shows the functional diagram for the TF 2702. The bridge is basically a standard ratio-arm bridge differing from the universal bridge in that it has a variable standard capacitance; this capacitance is the basis for the inductance scale. The standard arm also contains the loss balance resistor. For series L and R measurements, the Series/Parallel switch (SL) connects the standard capacitance and the loss balance resistor in parallel to form a Maxwell bridge - for parallel L and R measurement, the components are switched in series to form a Hay bridge.

Of the two resistor ratio-arms, one (the L range multipliers) is current limiting being in series with the test inductor, and the other (the L ranges) is voltage limiting having the applied test voltage across it.

The detector is shown in the final balance position, but alternatively may be switched to preliminary balance and the test inductor characteristic displayed on the CRT screen.

An oscillator provides a test voltage of 10 kHz, 1 kHz or mains frequency for low voltage testing; external d. c. can be superimposed on this supply.

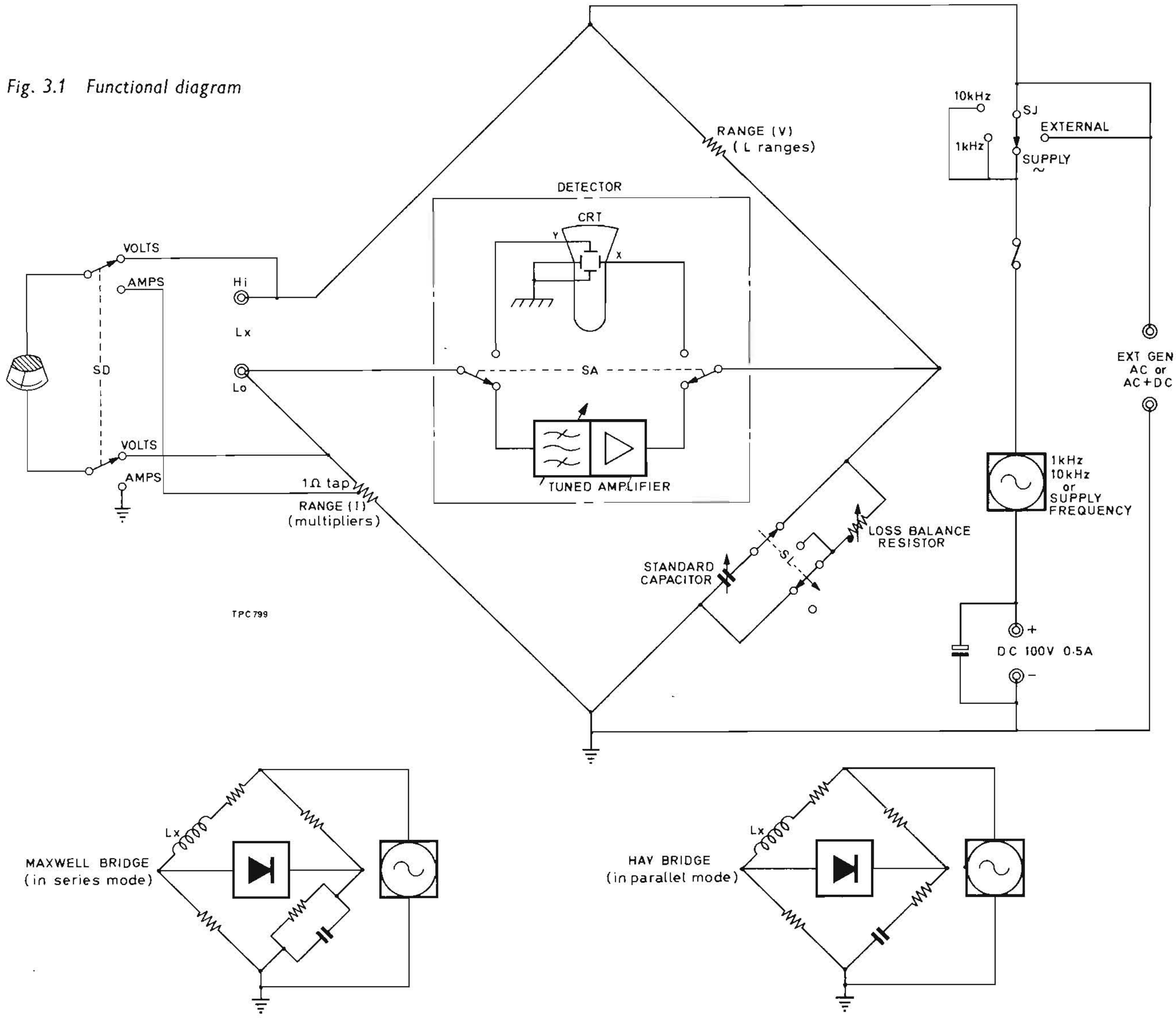


Fig. 3.1 Functional diagram

3.2 CURRENT RATIO-ARM (MULTIPLIERS)

(circuit diagram, Fig. 6.1)

This ratio-arm carries 10 A on x1, 3 A on x10, 0.3 A on x100 and 0.03 A on x1000, the multiplying factors corresponding to the resistance value which is in series with the inductor on test. Fig. 3.2 shows a simplified diagram of the resistors.

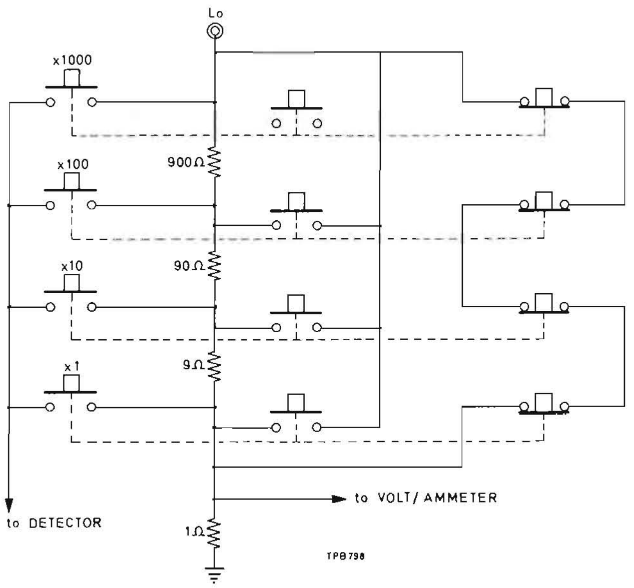


Fig. 3.2 Simplified diagram of multipliers' switching

The maximum dissipation of the arm is 100 W, this occurring on the x1 and x10 multipliers. The x1 multiplier is made up of two 2 Ω resistors connected in parallel and the x10 has two 18 Ω resistors, in parallel, connected in series with the x1 resistors. The four resistors, those for x1 and for x10, are mounted on a heat sink.

The x100 multiplier is obtained by connecting a 90 Ω resistor in series with the x1 and x10 resistors, and for x1000 a further 900 Ω is also switched in series.

Each of the x1, x10 and x100 multiplier resistors are ±1%, and are adjusted in situ to take account of the wiring resistance.

3.3 VOLTAGE RATIO-ARM (RANGES)

(circuit diagram, Fig. 6.1)

The voltage rating, or power, of the resistors in this ratio-arm determines the maximum test voltage which can be applied to the inductor under test. In the balanced condition the voltage across these resistors equals the voltage across the test terminals (Lx). Fig. 3.3 shows a simplified diagram of the switching in this arm.

The resistors increase in decade steps from 100 Ω to 10 MΩ, the 10 MΩ being in composite form to obtain better stability, better frequency characteristics and a suitable adjustment facility.

Capacitors 2C3, 2C4 and 2C5 compensate for stray capacitance in the circuit, and 2R2, 2C1 and 2C2 eliminate possible parasitic oscillations which may otherwise arise owing to the negative resistance of the variable capacitance amplifier at high frequencies.

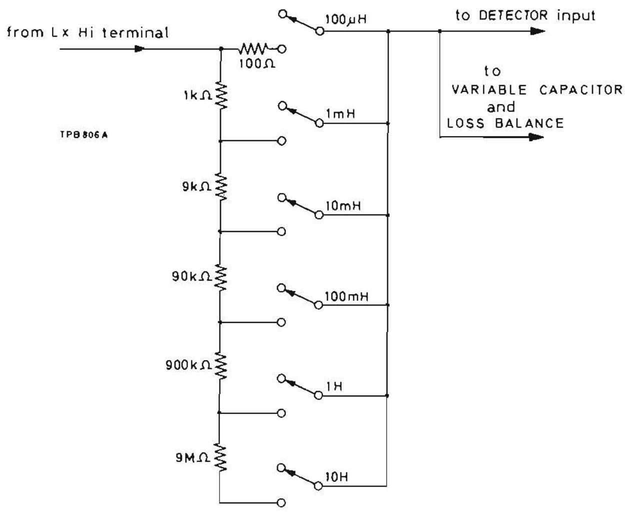


Fig. 3.3 Simplified diagram of ranges switching

3.4 STANDARD BRIDGE-ARM

(circuit diagram, Fig. 6.2)

The standard bridge-arm is a variable capacitor (Coarse L Balance switch) and a 0.03-0.11 μF capacitor (Fine L Balance control).

Five 0.2 μF capacitors (4C2 - 4C6) and a 0.1 μF capacitor (4C1) form the decade capacitor, and these are switched in sequence to get fixed increments of 0.1 μF up to a maximum of 1 μF. Each of the nominal values of capacitance is padded with a capacitor selected to achieve ±0.1% accuracy.

The capacitance of the decade is increased to 2 μF by switching in 4C7 - 4C11 (each 0.2 μF) to achieve the 'add 1' facility, so that the maximum L Balance scales reading is 2.1 rather than 1.1.

The 0.03 - 0.11 μF variable is an amplifier circuit involving valves (4V1 - 4V3) and a fixed polystyrene capacitor (4C24).

4V1 is a cathode follower which drives 4RV4 (Fine L Balance control) and serves as an isolating stage.

4V2 and 4V3 form a super cathode follower, 4V2 giving two stages of amplification and 4V3 providing a cathode follower output. Negative feedback to the input of 4V1 is about 96% of full output. The loop gain is about 45, giving an output resistance of about $\frac{1}{4}$ Ω.

4R28 enables the maximum output to be 98% of the input. This proportion of output to input is controlled mainly by the Fine L Balance control which varies the standard capacitance from 0.018 μF to about 2200 pF, causing a corresponding increase in potential on the slider of 4RV4 of 0 to 97% of the input.

The capacitance cannot be allowed to reach zero because of the probability of parasitic oscillations as the output approaches the input voltage. Phase compensation networks in the amplifier and differing coupling time-constants minimize the tendency to oscillate.

3.5 LOSS BALANCE

(circuit diagram, Fig. 6.2)

Loss balance is arranged in terms of resistance rather than Q because the standard ratio-arm in this bridge is a variable capacitor which avoids interaction between the L and R controls.

The Loss Balance dial is therefore more conveniently calibrated in terms of resistance, which is not frequency conscious, rather than Q, which is.

For parallel R and L measurements, 0 - 50 kΩ is connected in series with the decade capacitor. This resistance is made up of three potentiometers, 0 - 500 Ω (B scale), 330 Ω - 5 kΩ (A scale) and 3.3 - 50 kΩ (A/10 scale). The A/10 scale is adjusted by 4RV3 so that the start (3.3 kΩ) is arranged to match the A scale.

For series R and L, 0 - 500 kΩ is connected in parallel with the decade capacitor. In this case the resistance range is made up of the three potentiometers (which give 0 - 50 kΩ) and the A/10 scale, which is obtained by returning the earthy end of the A/10 scale potentiometer to a 90% voltage tap on the variable capacitor input cathode follower, 4V1. In this way the effective resistance of the potentiometer is increased ten times.

3.6 POWER SUPPLY AND OSCILLATOR

(circuit diagram, Fig. 6.3)

The power supply is of conventional design. Two tapped primary windings on the mains transformer, 3T1, permit a series or series-parallel arrangement to cover the input ranges 100 - 130 V and 200 - 250 V.

The earthing arrangements of the electrolytic reservoir-capacitor, 3C3, minimizes common impedance hum inducement.

The double triode, 3V1, combines the functions of oscillator and amplifier. The left-hand section of the valve acts as a phase shift oscillator, switched ladder networks providing the necessary circuit constants for the maintenance of oscillations at 1 kHz and 10 kHz. A three stage phase shift network is used at 1 kHz and a four stage at 10 kHz.

The anode load of the output section of 3V1 is a 10 kΩ potentiometer which controls the output level (i.e., the INT AC control). This is a.c. coupled to the output transformer, 3T2, when the oscillator is functioning. With the Generator Selector switch set to SUPPLY, the wiper of 3RV1 is direct coupled to 3T2 as, in this condition, there is no d.c. in the potentiometer. The potentiometer is then connected to a winding on the mains transformer.

3.7 DETECTOR AMPLIFIER

(circuit diagram, Fig. 6.4)

Preliminary c.r.t. balance

With the detector in the preliminary balance mode, the bridge ratio-arms are connected to identical cathode follower circuits rather than to the detector transformer, 5T3. A simplified circuit of the detector amplifier in the preliminary balance mode is shown in Fig. 3.4.

The cathode followers (5V1a and 5V1b) drive coarse and fine sensitivity attenuators, both these being adjustable by front panel COARSE and FINE SENSITIVITY controls. The coarse attenuator (5R9 - 5R11 and 5R12 - 5R14) has approximately 20 dB steps, and the fine attenuator is a potentiometer (5RV1a and 5RV1b) covering about 30 dB. Preset potentiometer 5RV3 is adjusted to balance the halves of 5RV1 over the useful range of the control.

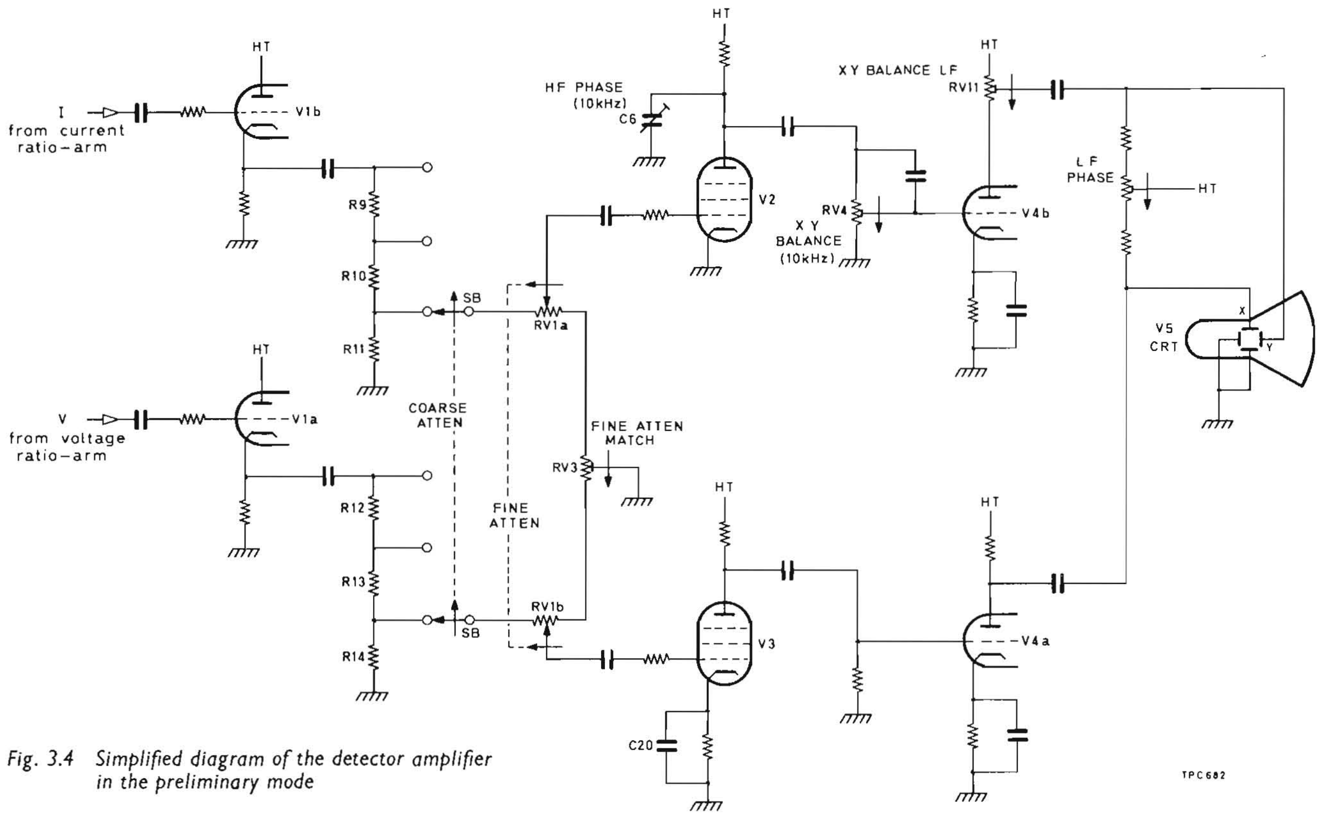
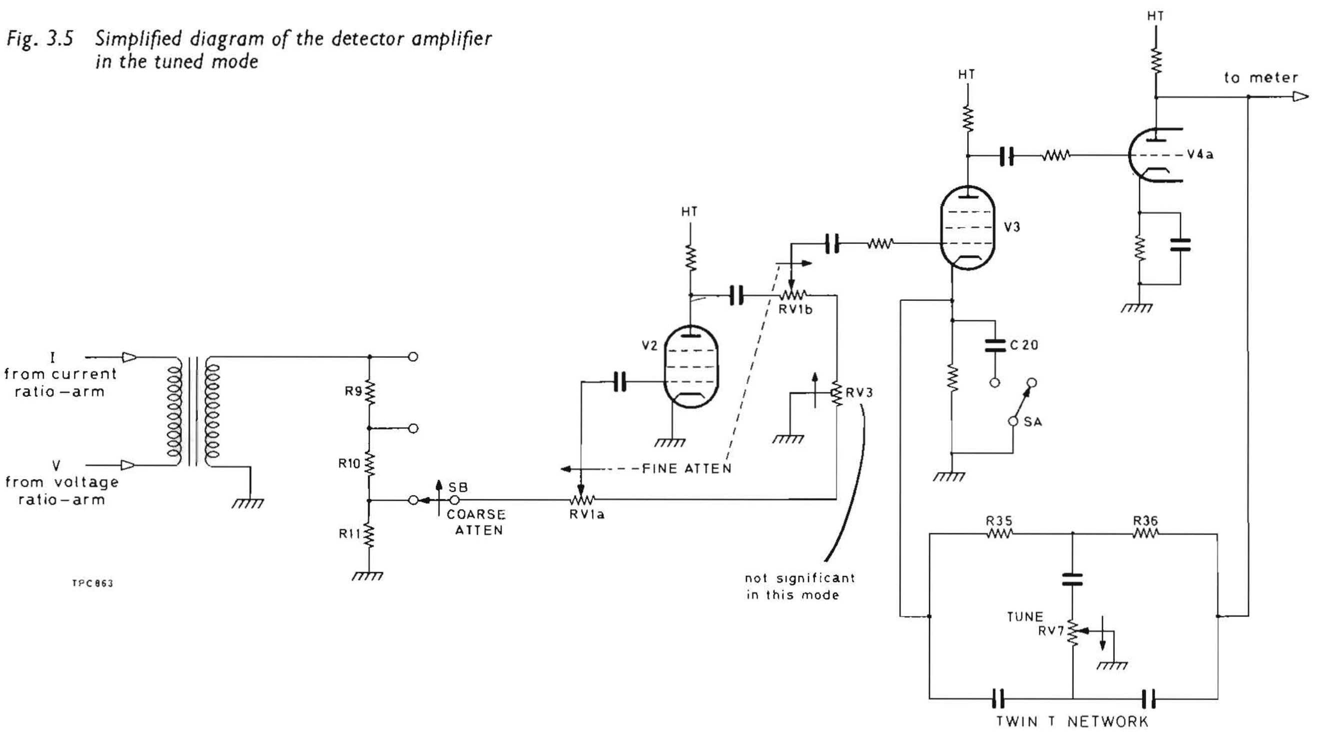


Fig. 3.4 Simplified diagram of the detector amplifier in the preliminary mode

Fig. 3.5 Simplified diagram of the detector amplifier in the tuned mode



The outputs from the sensitivity attenuators feed into pentode amplifiers (5V2 and 5V3) which are h.f. phase balanced by means of trimmer capacitor 5C6. These in turn drive output triode stages 5V4a and 5V4b; 5V4a triggers the X plates of the CRT, and 5V4b the Y plates.

As the Y plates of the CRT have, in general, more sensitivity than the X plates, 5RV11 reduces the output from the valve to the Y plate. 5RV11 is adjusted at l.f. and 5RV4 is most effective at 10 kHz.

Tune

With the detector in the tuned mode the cathode followers (5V1a and 5V1b) are not used, and the secondary of the detector transformer is switched straight to the coarse sensitivity attenuators. A simplified circuit of the detector amplifier in the tuned mode is shown in Fig. 3.5.

The output from the coarse attenuator drives pentode preamplifier 5V2 via the fine attenuator (5RV1a), and this valve feeds through 5RV1b to 5V3. 5V3 in turn drives the output triode 5V4a; the output to the meter is taken from the anode load of the triode.

Selective negative feedback from the output of 5V4a to the cathode of 5V3 is achieved by means of the twin T network. At the null frequency of this network there is theoretically no negative feedback to 5V3 and therefore no reduction in gain. At other frequencies the gain is reduced by negative feedback.

The values of the capacitors in the twin T have been calculated so that the TUNE control (5RV7) will be effective for particular frequency ranges as selected by the Frequency Range selector, SC (i.e., 40-60 Hz, 80-120 Hz, etc.). The UNTUNED position of SC substitutes a fixed resistor (5R38) which gives a lower gain.

If inductors are continually being tested at a frequency not in the tuning ranges available on SC, the capacitors in a relatively unused position of the selector can be replaced by others of the necessary value to give tuning at that frequency - see Section 2.17.

3.8 METER AMPLIFIER

(circuit diagram, Fig. 6.5)

The amplifier is fed via an overload protection resistor, 6R6, and overload shunt diodes 6MR1-6MR4, these being normally non-conducting.

This overload network is followed by two emitter followers (6VT1 and 6VT2) only one of which is switched on at any time, this being determined by the Mode switch. When the meter is being used to measure the voltage or current in the test inductor, 6VT1 is conducting; when the meter is being used as the balance indicator, 6VT2 is conducting.

The output from the emitter followers is a.c. coupled to the two stage amplifier 6VT3/6VT4. This amplifier has feedback from the output collector to the input emitter, via the meter and diodes. The input emitter resistance is adjusted by 6RV1 and 6RV2 to suit a basic 50 mV or 200 mV full scale meter deflection.

VT5 is used for d.c. biasing only, as the a.c. amplifier is direct coupled.

3.9 INSTRUMENT PROTECTION

In the event of the test inductor being accidentally disconnected whilst high current is passing through it, it is possible for high transient voltages to be passed to the Lx terminals. The Hi Lx terminal is protected against this by two gas discharge tubes (3GD2 and 3GD3) which break down as a pair at between 1200 V and 1800 V, and the Lo terminal by a similar, 100-150 V, tube.

If the multiplier switch is left with none of the buttons pressed in, overloading is prevented by leaving the 1 Ω resistor in the ratio arm via a series of switch contacts. Also, when no multiplier has been selected, R13 (across the x1000 contacts) prevents damage to the meter.

The variable capacitor amplifier is protected by a mechanical interlock on the Supply Range switch. This ensures that when the switch is set to AC > 10 V, the decade capacitor is at least 0.1 μF. If the capacitance was zero, a high alternating voltage and a near zero Fine L Balance setting could easily increase the amplifier input voltage beyond the overload point. This can't happen if the controls are at approximate balance and the a.c. is within the stated limits, but it could happen when searching for balance. The mechanical interlock limits the input to the amplifier to 90 V.

3.10 A.C. + D.C. MIXER UNIT, TM 8339

(circuit diagram, Fig. 6.7)

The a.c. and d.c. inputs are mixed in transformer T1, the d.c. having been smoothed in the 3000 μF composite capacitor C1-C6, and a.c. + d.c.

delivered at the output terminals. Overload protection is provided by GD1 and GD2 which break down as a pair between 1200 V and 1800 V.

The circuit on board TM 8737 provides a bypass for current induced when the OUTPUT switch, SD, is switched to OFF. Without this circuit the current would cause arcing across tags 2 and L2 of SD.

When SD is opened a surge of current from C8 triggers SCR MR2, making it conduct. This provides a path to earth for the current, through MR1 and MR2. When SD is closed, MR2 is biased off by R7 and the circuit in effect presents an open circuit to the current flowing in the instrument. MR3 is included to prevent ripple, which may be present on the d. c. supply, from triggering the SCR.

Chapter 4 Maintenance

4.1 GENERAL

This chapter of the manual is intended as a general guide to the servicing of the instrument. In case of difficulties which cannot be resolved with the aid of this book, please contact our Service Division, at the address on the rear cover, or your nearest Marconi Instruments representative. Always mention the type number and serial number of your instrument.

Semiconductor devices are used in the instrument, and although these have inherent long term reliability and mechanical ruggedness, they are susceptible to damage by overloading, reversed polarity, and excessive heat or radiation. Avoid hazards such as prolonged soldering, strong r.f. fields or other forms of radiation, the use of insulation testers, or accidentally applied short circuits.

It should be noted that all cruciform headed screws used in the instrument are Pozidriv screws; Pozidriv screwdrivers should be used in preference to Phillips screwdrivers to minimize the possibility of damage to the screw head.

4.2 POWER SUPPLY— TRANSFORMER CONNECTIONS

The instrument can be adjusted to operate from any 45 to 65 Hz supply within the ranges 100 to 130 V and 200 to 250 V.

The mains transformer has a double wound primary with its two tapped sections connected in series for 200-250 V operation or in series-parallel for 100-130 V.

Either of these arrangements may be selected by adjusting the position of the four plug-in links on the small panel at the rear of the instrument. These plugs make contact with the connections through a reversible masking plate as shown in Fig. 4.1.

SUPPLY VOLTAGE PANEL
To change voltage range, remove all links and reverse masking plate

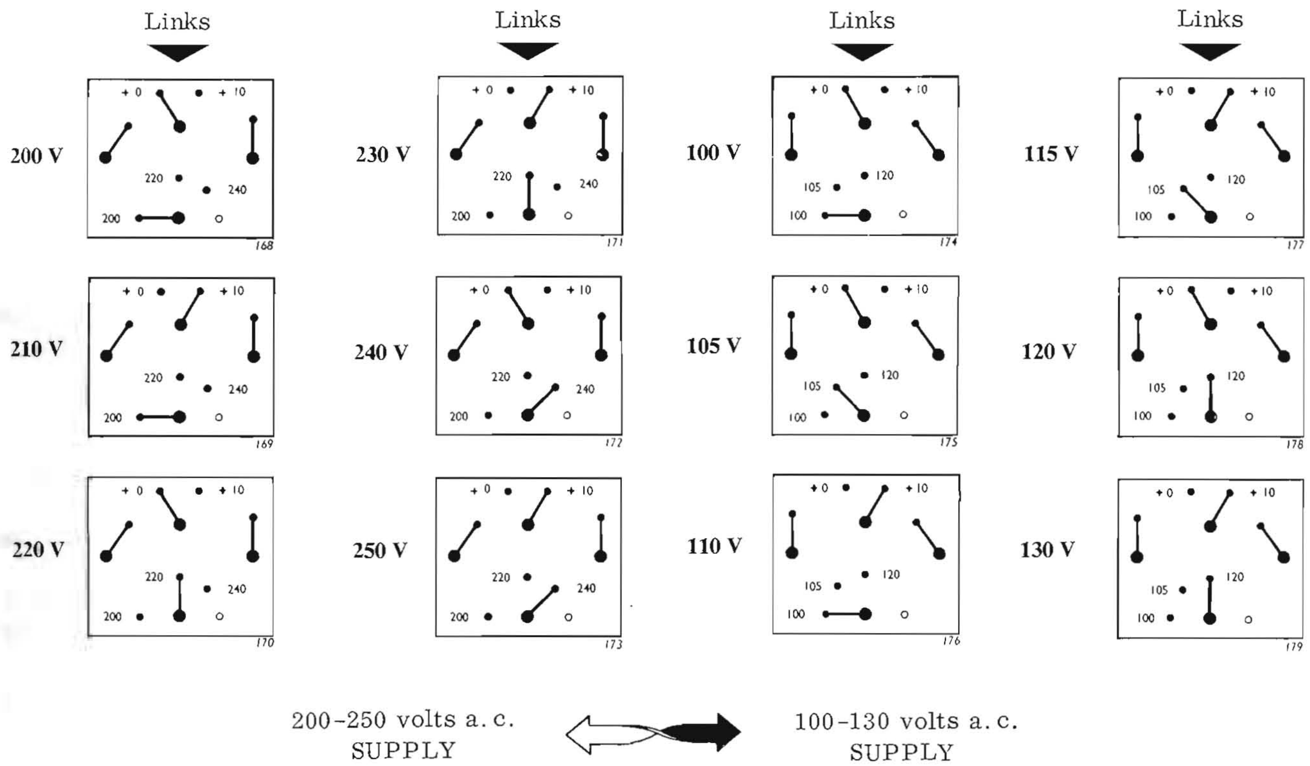


Fig. 4.1 Supply voltage plug settings

4.3 PROTECTION DEVICES

Fuses

Two fuses protect the instrument - one mains (FS1) and one test voltage (FS2). The mains fuse is connected in series with the primary of the mains transformer, and is a delay fuse of 1 A for 200-250 V or 2 A for 100-130 V. The test voltage fuse is connected in series with the primary of the internal mixing transformer and is a 500 mA quick acting fuse. Both fuse holders are screw cap and are mounted on the rear panel.

Gas discharge tubes

Three gas discharge tubes protect the instrument from transient overloads passing via the Lx terminals; they are mounted on the bottom of the chassis.

Because of the tubes' high current rating they are not susceptible to electrical damage and so should never need replacing. However, should the need to remove them arise, care is necessary to avoid breaking the glass at the end cap seal.

4.4 ACCESS TO COMPONENTS

To remove the outer case, extract the four coin-slotted 2 BA screws from the rear panel, withdraw the mains plug from the rear of the instrument and slide the chassis forward, out of the case. Figs. 4.5, 4.6 and 4.7 show the layout of those components and printed boards made available.

Components in the lower section can be got at by hinging back the top section; this is done as follows (see Fig. 4.2):

1) Remove the four cruciform headed 4 BA screws and the two 2 BA screws holding the top section to the bottom.

2) Push back the top section (it will move about 2 in).

3) Hinge back to the vertical position.

Distribution of the internal components is shown in Fig. 4.8.

CAUTION When the top section is hinged back, do not lean on the exposed surround as this will eventually fatigue the metal and break it.

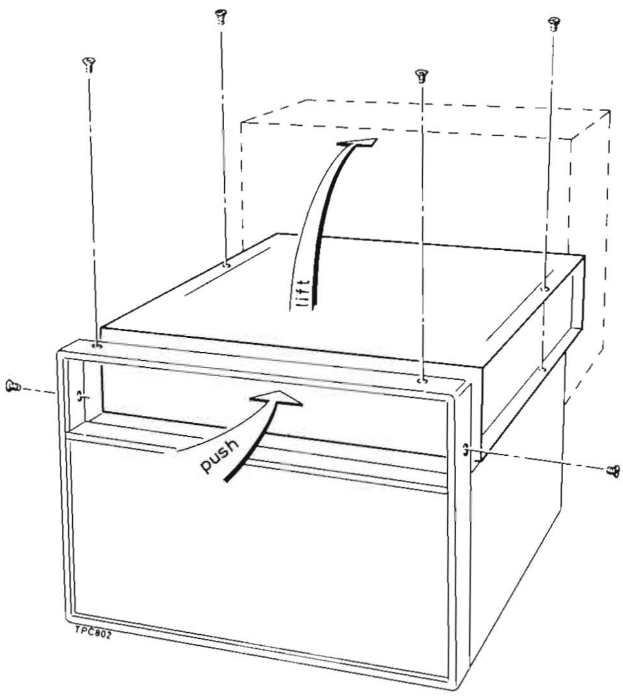


Fig. 4.2 Gaining access to bottom section of instrument

4.5 CLEANING THE MULTIPLIER SWITCHES

With careful use of the instrument none of the switches should need cleaning as the contact surfaces have a non-corroding coating.

However, if excessive current (>30 mA) is passing through the switches when they are being operated, arcing may occur and cause damage to the contacts necessitating their cleaning.

Each multiplier button operates two switches, one fixed to the top of the switch assembly and the other to the bottom; it is necessary to remove the complete assembly to reach the bottom set of switches. The switch assembly is held to the front panel by four screws; to release it, remove the top two screws and slacken the bottom two.

An individual switch is disassembled by disconnecting any wiring to it and then removing the two self-tapping screws that fix it to the assembly. Fig. 4.3 is an exploded view of one switch showing its construction. The switch contacts should be cleaned to obtain a smooth surface. As the act of cleaning the contact will remove its non-corroding surface, it should be smeared with some grease intended to protect against the tarnishing of arcing contacts.

Reassemble the switch as a unit and, holding it together with the bottom cover, position it on

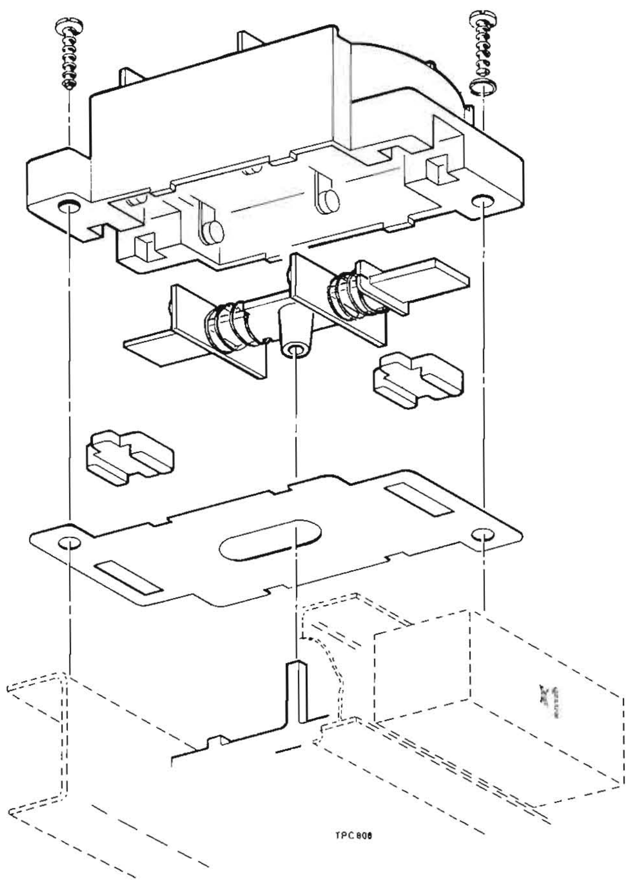


Fig. 4.3 Exploded view of one multiplier switch

the main assembly. Note that the washer goes on the front fixing screw (nearest the button) to act as a spacer.

4.6 FUNCTIONAL CHECKS

There are certain fault conditions under which the instrument may appear to be working correctly but in fact is giving inaccurate results. The following tests give a quick check that the instrument is functioning correctly. Standard inductors are required for absolute accuracy checks.

Resistance ratio-arms

Errors can be caused by a ratio-arm resistor value going outside its tolerance or by a bad switch contact. 100 mH and 1 H inductors are required for the following tests which compare different ratio-arms.

Connect the 100 mH inductor to the test terminals (Lx) and measure it using the method described in Section 2.9; use internal supplies, x1000 L RANGE MULTIPLIER and 100 μH L RANGE. Note the inductance value measured. Repeat the measurement with the MULTIPLIER and RANGE switches set to x100 and 1 mH, x10 and 10 mH, and x1 and 100 mH in turn. The inductance value measured should be about the same in each case.

A fault will show by there being a discrepancy between one result and the others. When a fault is indicated, check the ratio-arm resistors (particularly 1R2-1R5, located on inside of rear panel - see Section 4.10) before checking the switch contacts.

Replace the 100 mH inductor with the 1 H. Switch to x1 and 1 H and measure the inductance; the Coarse L Balance decade switch should be at the high end of the scale (i.e. at or near 1.0). Now switch the L RANGE to 10 H and measure the inductor; the inductance value should be the same as before, with the decade switch at the low end of the scale. If there is a significant difference between the two results, check the 1 H and 10 H L RANGE switches, and resistors 2R6 and 2R9 on TM 8520 (mounted under the switch assembly).

Detector amplifier

A low emission valve on the Detector Amplifier board, TM 8521, will show as spurious distortion on the CRT trace when finding a preliminary balance.

To check, connect an inductor of linear characteristic to the input terminals and find a preliminary balance. Vary the sensitivity controls. The trace should remain straight and undistorted up to the useful limits of the CRT. In the case of a fault being indicated, 5V4 is the valve most likely to be weak.

Fine L balance

A low emission valve on TM 8519 may give inaccurate readings on the Fine L Balance dial. A check can be made as follows:

Measure a 100 mH inductor using the x10 multiplier and the 100 mH range, with the Coarse L Balance decade switch set to .0. The Fine L Balance dial should read 100.

Now switch to x100, and rebalance. The Fine L Balance dial should now read 10 to give the same inductance value.

The above test can, of course, be made with any standard inductor, as long as balance can be achieved towards the limits of the Fine L Balance dial scale.

NOTE: a certain amount of cross checking of ranges and multipliers can be done by the selection of range and multiplier switches; e.g. in the above example (Fine L Balance check) the 1 H and 10 H ranges can be checked by selecting them, in turn, with the x1 multiplier and doing the same measurement. If one of the readings obtained does not coincide with the original result, a faulty range resistor or switch contact is indicated.

4.7 POWER SUPPLY VOLTAGES

The voltages given in this section should be obtained when the instrument is connected to a 240 V supply; use a voltmeter such as the Avo model 8 to make the measurement. Power supply board TM 8518 is mounted underneath the instrument on the bottom of the chassis, and the voltages are monitored from tags on this board.

Table 4.1 shows the transformer secondary voltages; Table 4.2 shows the d.c. levels.

TABLE 4.1

Measured between TM 8518 tags	*Voltage a.c.*	*Limits*
11 and 12	320 V	±5%
16 and switch SJ2F pin 3	110 V	±5%
20 and 21	6.8 V	±5%
22-23 (CT) -24	22-0-22	±5%

Note: tag 16 is at 340 V (d.c.) potential.

TABLE 4.2

Measured between TM 8518 tags	*Voltage d.c.*	*Limits*
25 and 26 (+)	27.5 V	±10%
17 (+) and 19	340 V	±5%
15 (+) and 19	376 V	±5%

Note: (+) = positive lead connected to this tag.

4.8 TEST EQUIPMENT

The following test equipment is required to perform the adjustments detailed in subsequent sections. It should be noted that limits given in these sections are for guidance only and are not guaranteed performance specifications unless they are also quoted in the Data Summary.

(a) In-situ bridge, e.g. mi TF 2701.
(b) Kelvin double bridge.
(c) 10 MHz Counter; e.g. mi TF 1417 Series or TF 2401 Series.
(d) Oscilloscope, 10 kHz bandwidth; e.g. mi TF 1331A.
(e) Valve voltmeter; e.g. mi TF 2600.
(f) R.C. oscillator; e.g. mi TF 1101.
(g) 20,000 Ω/V voltmeter; e.g. Avometer, model 8.
(h) A.C. supplies, 5 V ±$\frac{1}{4}$% and 2 V ±$\frac{1}{4}$%.
(i) D.C. bridge; e.g. mi TF 2700.
(j) 1% resistors, 1 kΩ, 62 Ω, 6.2 kΩ, 62 kΩ.
(k) Standard inductors, 10 mH, 1 H, 10 H. 10 H to be standardized at 100 Hz the others at 1 kHz; resistance to be $<$ 1000 Ω per H.
(l) Transformer, 145 V output. Used with r.c. oscillator to supply required voltage for 10 H, x1 calibration.
(m) Resistance box.

4.9 STANDARD CAPACITOR

Test equipment required: (a)

The standard capacitor comprises five 0.1 μF capacitors, a 0.1 μF and a 1 μF, all with a tolerance on them of 0.1%. Each capacitor is padded with selected capacitors to achieve the required tolerance.

A comparison check can be made to ensure that the various capacitors are within the stated limits. This method allows use of any reasonably accurate bridge (about 1%) but the assumption is made that not all the 0.2 μF capacitors have become faulty at the same time. The check is made with the TF 2702 disconnected from the mains supply.

First check the five 0.2 μF capacitors (4C2 to 4C6). Disconnect them at one end and measure the capacitance of each with the in-situ bridge.

NOTE: The capacitance of each component includes that of the lead to switch SK (Coarse L Balance) on SN (Test Supply Range) and this lead should be included in the measurement.

The five capacitors should give exactly the same bridge reading. If a marked difference is shown in any capacitance value, it should be tested further on a highly accurate bridge.

The 0.1 μF capacitor, 4C1, can be checked against any normal two of the 0.2 μF capacitors connected in series. To get a measurement simply connect the bridge terminals to two of the capacitors' leads which have been disconnected from the switch tags.

Once the 0.2 μF capacitors have been checked and found to be within limits, connect them in parallel and check the 1 μF capacitor (4C7 to 4C11) against them.

4.10 SETTING UP THE MULTIPLIERS

This procedure is carried out to adjust the ratio arm to the correct resistance when the multiplier resistors have drifted from their specified value.

Test equipment required: (b)

NOTE: A Kelvin double bridge has its own coupling leads which must be connected as close as possible to the point of measurement. No allowance need be made for the resistance of these leads as the measurement is of the four terminal type.

Set x1

Disconnect, from the top of the multiplier switch, the lead which goes to the detector (i. e. the white, flexible lead).

Connect the Kelvin double bridge between special earth Ex (the front panel earth terminal) and the switch tag behind that from which the detector was removed (second tag from the left, on the x1 switch, with three thick leads soldered to it).

Switch the Kelvin double bridge to the 1 Ω range.

Press the x1 multiplier switch and adjust 1RV3 to obtain a reading as near as possible to 1 Ω $-\frac{1}{4}$% on the Kelvin bridge.

It may be that preset 1RV3 cannot be adjusted enough to get a correct reading, or that it is near the end of its travel. In either case it is necessary to change the value of resistor 1R12 or to remove it altogether. If this still doesn't allow a correct reading to be obtained, adjust the length of the resistance wire which is connected to the end of 1R4 in series with the lead to the x1 switch. Note that this resistance wire must be bent to a non-inductive shape.

Replacing 1R2, 1R3, 1R4 or 1R5

Should it be impossible to set up the x1 or x10 multipliers, resistors 1R4 or 1R5 (for x1) or 1R2 or 1R3 (for x10) probably need replacing.

Any of these resistors which are replaced should be aged for 100 hours in the instrument before the multiplier is finally set up; aging usually results in a decrease in resistance. Aging can be done by short circuiting the Lx terminals and adjusting the test voltage until 10 A is flowing in 1R4 in parallel with 1R5 (5 A each) for x1, or 3 A shared between 1R2 and 1R3 for x10. If the instrument is always used at a working current of below 7 A, aging is not necessary.

After aging, set up the multipliers as given in SET X1 and X10 above, but set the resistance value $\frac{1}{4}$% low to compensate for the increase due to the temperature coefficient of the resistors when they are used at maximum power (10 A on x1 and 3 A on x10).

x100

With the test set up as for the x1 and x10 multipliers, press the x100 multiplier switch and set the Kelvin double bridge to the 100 Ω range.

Adjust preset 1RV1 to obtain a reading of 100 Ω ±0.1% on the Kelvin bridge.

Check that the preset is not at the end of its travel, before making the final adjustments. If the correct resistance value cannot be obtained check 1R6.

Check x1000

Press the x1000 multiplier switch and set the Kelvin double bridge to the 1000 Ω range. Balance and check that a reading of 1000 Ω ±0.15% is obtained; if it isn't, test 1R1.

Disconnect the Kelvin double bridge and replace the detector lead.

4.11 OSCILLATOR CHECK

Test equipment required: (c), (d), (e) and (f)

Connect the A input of the counter to the Lx Hi terminal.

Switch the TF 2702 to the 10 H range and x1 multiplier. Set the Generator Selector to 1 kHz and the INT AC control to maximum.

Adjust 3RV2 (on TM 8518) for a counter reading of 1 kHz ±1%.

Now set the Generator Selector to 10 kHz and adjust 3RV3 (on TM 8518) for a counter reading of 10 kHz ±1%.

Remove the counter and connect the valve voltmeter across the Lx terminals.

With the Generator Selector set to 1 kHz and 10 kHz the off load voltage should be 4 V ±1 V r.m.s.; with the selector set to SUPPLY the off load voltage should be between 10 V and 13 V.

Connect the R.C. Oscillator to the External A.C. Jack Socket, and set its controls to 1 kHz at 1 V output.

Set the TF 2702 Generator Selector to 1 kHz.

The voltage at the Lx terminals, monitored with the valve voltmeter, should be 1 V approximately.

Remove the R.C. oscillator and the voltmeter.

Connect the oscilloscope to the Lx terminals and check that the waveform is sinusoidal at 1 kHz and 10 kHz internal supply.

NOTE: The effects of any residual distortion on the internal supplies will be eliminated by the tuned amplifier in the detector.

4.12 METER CHECK

Test equipment required: (e), (f), (g) and (h)

Set full scale

Set the TF 2702 controls as follows:

Volts/Amps switch to AMPS.
Mode switch to PRELIM CRT BALANCE.
L RANGE MULTIPLIER to x1.
L RANGE to 10 H.
Generator Selector to EXT GEN.
Test Supply Range switch to AC > 10 V.
Connect the Avometer to the junction of 6R18/6R19 and earth (negative lead to earth), and adjust 6RV3 (set 7 V) for a reading of 7 V (d.c.).

Disconnect the Avometer.

Now set the Volts/Amps switch to VOLTS, the Generator Selector to EXT GEN and the AC METER RANGE switch to 5.

Connect the 5 V supply to the Lx terminals and adjust 6RV1 for a full scale meter reading on the TF 2702.

Replace the 5 V a.c. supply with the 2 V supply.

Switch the AC METER RANGE switch to 2 and adjust 6RV2 for full scale on the meter.

Frequency response

Connect the valve voltmeter and the RC oscillator across the Lx terminals.

Set the AC METER RANGE switch to 2.

Set the RC oscillator to 20 Hz and adjust its output for full scale on the TF 2702 meter.

The valve voltmeter should read 2 V ±6%.

Set the AC METER RANGE switch to 5 and the oscillator output for a TF 2702 full scale meter reading.

In this case the valve voltmeter should read 5 V ±6%.

Repeat the above procedure with an oscillator frequency of 20 kHz; the same limitis as above will apply.

Disconnect the voltmeter and oscillator.

Ammeter accuracy check

Set the TF 2702 controls as follows:

L RANGE MULTIPLIER to x1.
Volts/Amps switch to Amps.
Mode switch to PRELIM BALANCE.
AC METER RANGE switch to 0.2.

Generator Selector to SUPPLY.
Connect the Avometer (set for 100 mA a.c.) across the Lx terminals.
Adjust the INT AC control for a reading of 100 mA on the Avometer.

The reading on the TF 2702 meter should be 100 mA ±5 mA.

4.13 DETECTOR AMPLIFIER CHECK

Test equipment required: (e), (f), (i) and (j)

Setting up the c.r.t. trace

If the trace is not at 45° under balance conditions it can be due to any of the following reasons.

1) COARSE SENSITIVITY switch attenuator out of tolerance.
2) Mismatch in the twin FINE SENSITIVITY potentiometers.
3) 5RV11 out of adjustment.
4) 5RV4 out of adjustment.
5) 5C6 out of adjustment (high frequencies).

Short circuit the detector 'I' and 'V' leads on the Mode switch (i.e., SA3F tags 12 and 18) to simulate an ideal balance.

Adjust 5RV9 and 5RV10 (on TM 8522) for a central spot on the CRT.

Now set the controls as follows:

SENSITIVITY controls to maximum.
Ω SCALE SELECTOR to A.
Series/Parallel switch to PARALLEL.
L RANGE MULTIPLIERS to x100.
Generator Selector to EXT GEN.

Inject a 1 kHz signal between the Lo and earth terminals, at a level which will give a reasonably sized trace. This trace will be at 45° (parallel to the cursor lines) if everything is functioning correctly.

Switch the COARSE SENSITIVITY switch through its positions; the trace should remain at 45°. If, on positions 2 and 1 of the switch, the trace deviates from 45° look for a faulty resistor on the switch attenuator (5R9-5R14).

Now set the COARSE SENSITIVITY switch back to position 3, and adjust the FINE SENSITIVITY control over its range. Again the trace should remain parallel to the cursor lines. If the trace tilts away from 45° towards the maximum end of the potentiometer, adjust 5RV3 to correct it.

NOTE: over the last 1/8 in or so of travel of the potentiometer, a slight irregularity in angle may have to be tolerated as adjusting for 45° here will cause the trace to be at the wrong angle over the rest of the control's range.

Set the SENSITIVITY controls to maximum.

If necessary, adjust 5RV11 for a 45° trace.

Now set the oscillator for a 10 kHz signal. If necessary, adjust 5RV4 and 5C6 for a 45° trace.

Check that the trace remains at 45° when the input is set to 1 kHz again.

Now set the oscillator to 20 Hz and the Frequency Range Selector to UNTUNED. Adjust 5RV6 for the best straight line trace.

Preliminary balance sensitivity

Leave the test set-up as for the previous test, and connect the valve voltmeter across the Lo and earth terminals of the TF 2702. Adjust the oscillator for an input frequency of 1 kHz.

Measure the input voltage needed to achieve a full length CRT trace. This should be $<$ 10 mV. A short or distorted trace indicates the probability of a faulty valve on the detector amplifier board (TM 8521).

Repeat the check at 100 Hz and 10 kHz.

Remove the short circuit from the 'I' and 'V' leads.

Tuned detector

(a) RESISTANCE CHECK

Switch off TF 2702, and set the Frequency Range Selector to 800-1200.

Now check that the resistance of 5R35 and 5R36 in parallel is equal to the resistance of 5R37, 5RV8 and 5RV7 (TUNE control) in series, as follows.

Short circuit tags 2 and 21 on TM 8552 and measure the resistance between tags 2 and 11 (nominally 7.05 kΩ) using the d.c. bridge. Note the reading and remove the short circuit.

Connect the bridge between the junction of 5R37 and 5C26 and the junction of 5RV8 and 5C27.

Adjust 5RV8 for a bridge reading equal to that measured above.

(b) SET HUM BUCKER

NOTE: When doing this test, a screen to simulate the instrument cover, should be used. This is particularly necessary near the detector amplifier board.

Set the TF 2702 controls as follows:

Generator Selector to EXT GEN.
Frequency Range Selector to 40-60.
COARSE SENSITIVITY switch to 1.
FINE SENSITIVITY control to maximum.
Adjust 5RV5 for minimum deflection on the meter.

(c) FREQUENCY RESPONSE CHECK
(Test (d) can be combined with this test).

Switch on the TF 2702 and allow it to warm up.
Set the controls as follows.
Series/parallel switch to SERIES.
L RANGE to 10 H.
L RANGE MULTIPLIER to x10.
COARSE SENSITIVITY switch to 3.
FINE SENSITIVITY control to maximum.
AC METER RANGE to 5.
Ω SCALE SELECTOR to B.
Generator Selector to EXT GEN.
Mode switch to METER BALANCE TUNE.
Frequency Range Selector to 40-60.
Set up the test equipment as shown in Fig. 4.4.

Set the TUNE control fully counter clockwise and adjust the input frequency for a maximum on the meter; this should occur at a frequency of approximately 40 Hz.

Now set the TUNE control fully clockwise and readjust the input frequency for a meter maximum; this should occur at approximately 60 Hz.

Repeat the above procedure, at the extreme settings of the TUNE control, for each setting of the Frequency Range Selector. In each case, with the TUNE control fully counter clockwise the frequency for a meter maximum should be approximately the lower limit on the Frequency Range Selector setting; and, with the TUNE control fully clockwise, the frequency should be approximately the higher limit.

If an anomalous reading indicates a fault, check the capacitor on TM 8522 appropriate to the Frequency Range Selector setting.

(d) SENSITIVITY CHECK

Leave the controls as for the previous test, with the Frequency Range Selector set to 40-60, and maintain the same test set up.

Set the RC oscillator output to 40 Hz and adjust the TUNE control for maximum deflection on the meter; adjust the oscillator input level until the meter reads full scale.

The oscillator output voltage, as monitored on the valve voltmeter, should be no more than the figure given under Sensitivity in Table 4.3.

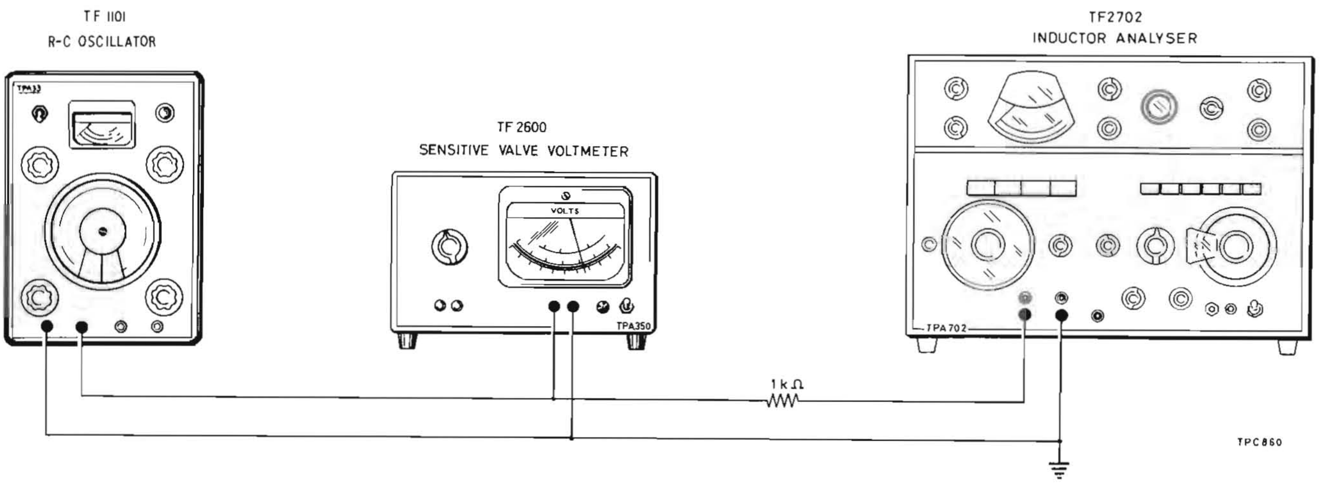


Fig. 4.4 Test set up for checking the frequency response of the tuned detector. 10 mV on the voltmeter represents 100 μV at the TF 2702 terminals

Repeat at 60 Hz and at the lower and higher limits of each Frequency Range Selector setting; also repeat at 20 Hz and 20 kHz in the UNTUNED position of the Frequency Range Selector.

TABLE 4.3

Frequency range	*Sensitivity*
40-60	60 μV
80-120	65 μV
350-500	75 μV
800-1200	95 μV
2k-3k	100 μV
10k-15k	160 μV
UNTUNED	600 μV

4.14 RATIO-ARM TIME CONSTANT CHECK

Test equipment required: (j) and (k)

Set the TF 2702 controls as follows:

L RANGE to 10 mH.
L RANGE MULTIPLIER to x1.
Series/Parallel switch to SERIES.
Generator Selector to 1 kHz.

Connect the 10 mH inductor across the Lx terminals and obtain balance.

Add the 62 Ω resistor in series with the inductor and again obtain balance.

The change in inductance reading should not exceed ½%. If the change is greater than +½% reduce the value of 1C4; if the change is greater than -½% increase 1C4 by 0.22 μF per 0.2%. Switch to 1 mH and x10, and repeat the above procedure to check 1C2.

4.15 SETTING UP THE VOLTAGE RATIO-ARM

Test equipment required: (f), (j), (k) and (l)

10 H

Set the TF 2702 controls as follows:

L RANGE to 10 H.
L RANGE MULTIPLIER to x1.
Series/Parallel to SERIES (as most standard inductors are series calibrated.)
Generator Selector to EXT GEN.
Test Supply Range switch to AC > 10 V.
Mode switch to PRELIM BALANCE.
Volts/amps switch to AMPS.
AC METER RANGE switch to 0.05.
Frequency Range switch to 80-120.
Connect the 10 H inductor to the Lx terminals.
Connect the RC oscillator, set to 110 Hz with the output at zero, to the input of the transformer; connect the transformer output to the TF 2702 Test Supply terminals (AC).

Set the Coarse and Fine L Balance controls to the standardized value of the inductor being used.

Increase the oscillator output until the current passing through the inductor is 15 mA, monitored on the meter.

NOTE: do not exceed the current limitation of the inductor.

Switch the Mode switch to METER BALANCE and adjust the TUNE control for maximum meter deflection.

Adjust 2RV1 (at rear of L RANGE switches, on TM 8520) and the Loss Balance controls to achieve best balance (i.e. minimum meter deflection).

Replace the 10 H inductor with the 1 H standard. Select the 1 H L RANGE and the x10 L RANGE MULTIPLIER. Set the Frequency Range switch to 800-1200 and the Series/Parallel switch to PARALLEL.

Increase the oscillator frequency to 1 kHz and adjust the voltage to the maximum available within the inductor and bridge ratings.

Establish bridge balance (i.e. minimum meter reading). Connect the 6.2 kΩ resistor in parallel with the test inductor. Rebalance the bridge using only the Loss Balance control and 2C5 to achieve minimum meter reading.

1 H

Leave the 1 H inductor connected to the Lx terminals.

Connect the RC oscillator directly to the Test Supply terminals (AC) and set it to 1 kHz.

Set the TF 2702 controls as follows:

Series/Parallel switch to PARALLEL.
L RANGE to 1 H.
L RANGE MULTIPLIER to x1.
Increase the oscillator output until the TF 2702 meter reads 5 mA.

NOTE: do not exceed the current limitation of the inductor. Balance the bridge and note the reading.

Connect the 6.2 kΩ resistor in parallel with the test inductor and adjust 2C4 for balance (minimum meter reading) within ±1% of the reading noted.

4.16 LOSS BALANCE SCALE ADJUSTMENT

Test equipment required: (m)

Set the TF 2702 controls as follows:

Generator Selector to SUPPLY.
Series/Parallel switch to SERIES.
L RANGE to 10 mH.
L RANGE MULTIPLIER to x1000.
Coarse L Balance decade to .0.
Fine L Balance control to 0.03.
Ω SCALE SELECTOR to A/10.
Loss Balance dial, A scale to 20 Ω.

Connect the resistance box, set to 2 kΩ, across the Lx terminals.

Adjust 4RV3 until the best balance is obtained (i.e. minimum meter deflection).

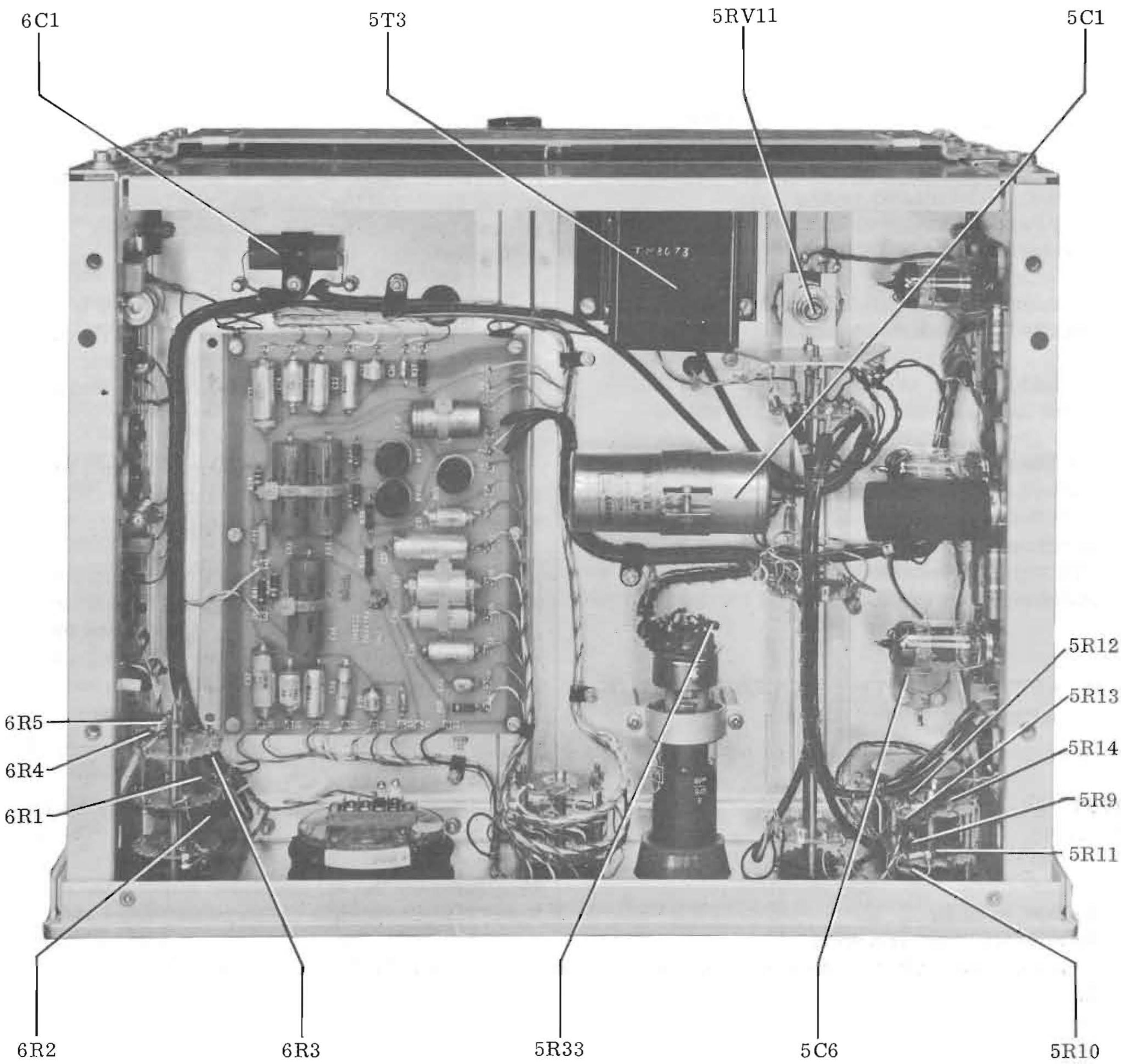


Fig. 4.5 Component layout: top of instrument

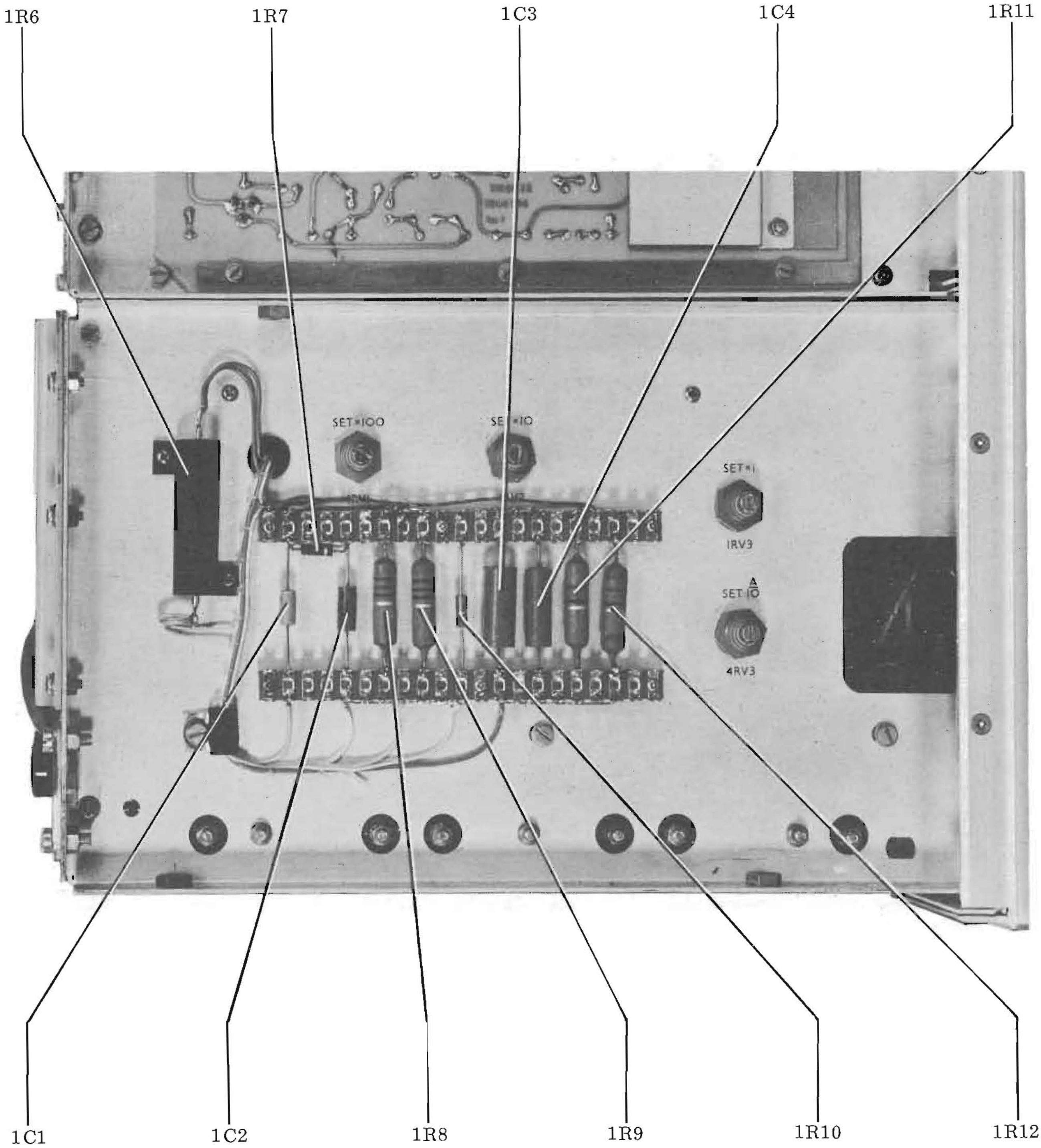


Fig. 4.6 Component layout: left-hand side of instrument as seen from the front

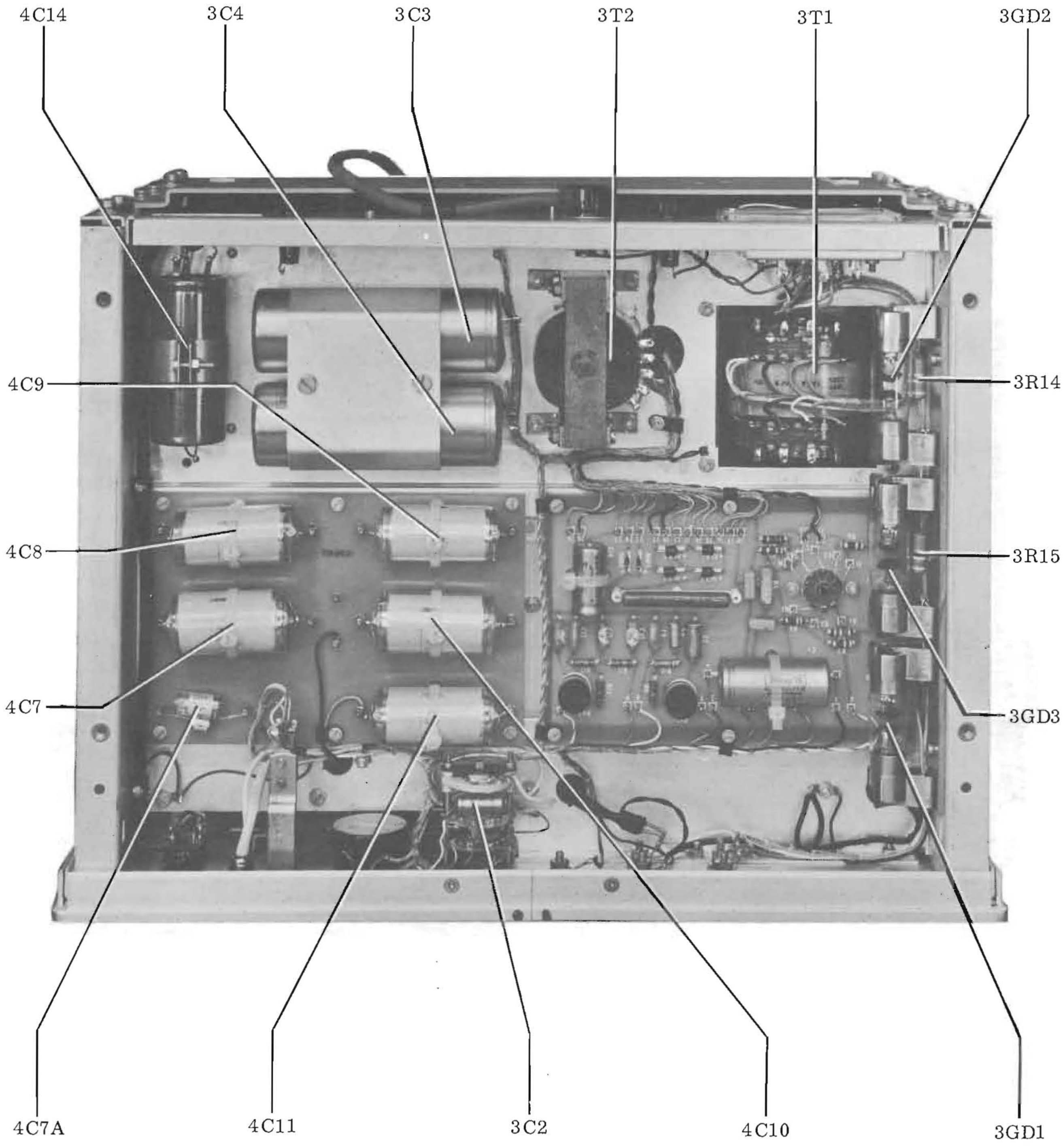


Fig. 4.7 Component layout: bottom of instrument

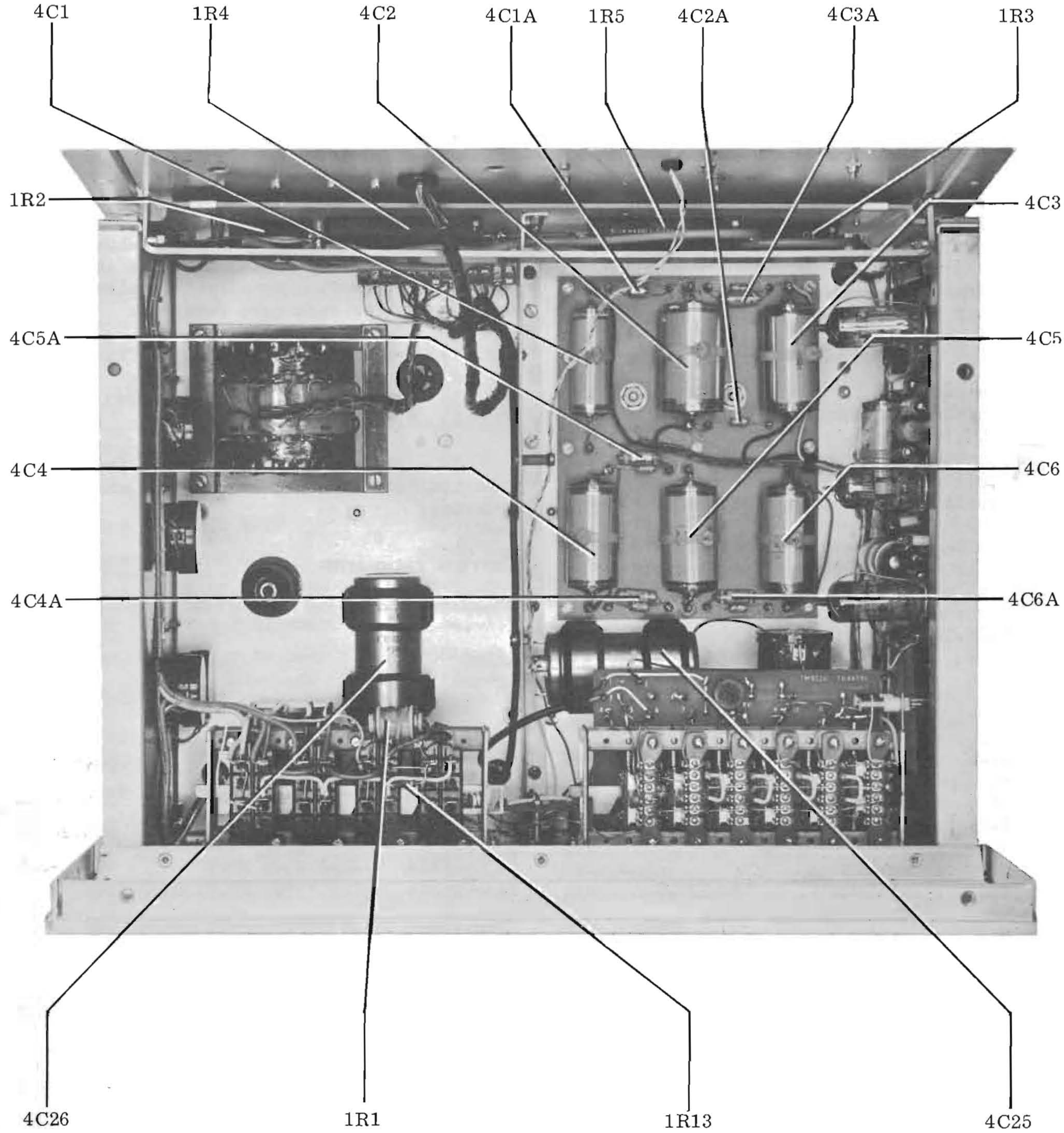


Fig. 4.8 Component layout: internal view

Chapter 5

Replaceable parts

Introduction

Each of the circuit diagrams has been given an identity number as follows:

Current ratio-arm, 1
Voltage ratio-arm, 2
Power supply and oscillator, 3
Standard bridge-arm and loss balance, 4
Detector amplifier, 5
Meter circuit, 6.

The complete reference of a part consists of the number followed by its circuit reference, e.g., 4C5, 6R9, etc. and this should be stated on any order, letter etc. For convenience, on the circuit diagrams the circuit reference is abbreviated by dropping the prefix number.

Replaceable parts are grouped in order of the prefix number and itemized in alpha-numerical order of circuit references with miscellaneous parts at the end of each list. The following abbreviations are used:

C	:	capacitor
Carb	:	carbon
Cer	:	ceramic
Elec	:	electrolytic
FS	:	fuse
JK	:	jack
L	:	inductor
M	:	meter
Met	:	metal
Min	:	minimum
MR	:	semiconductor diode
Ox	:	oxide
PL	:	plug
Plas	:	plastic
PLP	:	pilot lamp
R	:	resistor
RV	:	variable resistor
S	:	switch
SKT	:	socket
T	:	transformer
TE	:	total excursion
TH	:	thermistor
TP	:	terminal
V	:	valve
Var	:	variable
VT	:	transistor
WW	:	wire wound
†	:	value selected during test; nominal value listed
W	:	watts at 70°C
W*	:	watts at 55°C
W**	:	watts at 25°C
W***	:	watts at 20°C
W°	:	watts at unspecified temperature

Ordering

Orders for replacement parts should be sent to our Service Division at the address on the back cover. Specify the following information for each part required:

1) Type and serial number of instrument.
2) Circuit reference.
3) Description.
4) M.I. code number.

If a part is not listed state its function, location and description when ordering.

Current ratio-arm

When ordering, prefix circuit reference with **1**

Circuit reference	*Description*	*M.I. code*
C1	Paper 500pF ±20% 600V	26174-122
C2	Plas 0.01μF ±10% 400V	26512-204
C3	Plas 0.47μF ±10% 250V	26512-264
C4 †	Plas 0.22μF ±10% 250V	26512-244
R1	900Ω ±0.1%	44364-307
R2	WW 18.4Ω ±1% 50W**	25377-538
R3	WW 18.4Ω ±1% 50W**	25377-538
R4	WW 2Ω ±1% 50W**	25377-512
R5	WW 2Ω ±1% 50W**	25377-512
R6	WW 92Ω ±1% 50W**	25377-362
R7	Carb 680Ω ±10% ½W*	24342-076
R8	Carb 560Ω ±10% 1W	24347-627
R9	Carb 560Ω ±10% 1W	24347-627
R10	Metox 1Ω ±7% TE⅜W*	24582-555
R11	Carb 68Ω ±10% 1W	24347-643
R12	Carb 68Ω ±10% 1W	24347-643

When ordering, prefix circuit reference with **1**

Circuit reference	Description	M.I. code
RV1	WW 10kΩ ±10% 2½W	25823-444
RV2	WW 500Ω ±10% 2½W	25823-408
RV3	WW 50Ω ±10% 2½W	25823-403
SF	L RANGE MULTIPLIERS (complete switch assembly)	44333-408

Voltage ratio-arm

When ordering, prefix circuit reference with **2**

C1	Plas 0.022µF 400V	26582-234
C2	Plas 0.022µF 400V	26582-234
C3	Cer 4.7pF ±0.5pF 750V	26324-055
C4	Cer 0.5 - 5pF trimmer	26845-123
C5	Cer 0.5 - 5pF trimmer	26845-123
C6	Special	
R1	Met 100Ω ±0.1% 1W***	24727-310
R2	Carb 100Ω ±10% ½W*	24342-050
R3	Met 1kΩ ±0.1% 1W***	24727-371
R4	Met 9kΩ ±0.1% 1W***	24727-399
R5	Met 90kΩ ±0.1% 1W***	24727-429
R6	Met 900kΩ ±0.1% 1W***	24727-469
R7	Carb 47kΩ ±10% ½W*	24342-126
R8	Carb film 732kΩ ±1% ½W	24156-732
R9	Carb film 4MΩ ±1% 1W	24217-400
RV1	Carb 100kΩ ±20% ¼W	25611-138
SG	L RANGES (complete switch assembly)	44333-407
TH1	VA 1056	25685-487

Power supply and oscillator

When ordering, prefix circuit reference with **3**

C1	Elec 100µF 150V	26417-495
C2	Elec 1µF 300V	26417-452
C3	Elec 250µF 450V	26427-560
C4	Elec 250µF 450V	26427-560
C5	Plas 0.01µF 400V	26582-232
C6	Plas 0.01µF 400V	26582-232
C7	Plas 0.047µF ±5% 400V	26511-340
C8	Plas 0.01µF ±5% 400V	26511-316
C9	Plas 0.0033µF ±5% 400V	26511-129
C10	Plas 0.0015µF ±5% 400V	26511-120
C11	Plas 0.0015µF ±5% 400V	26511-120
C12	Plas 0.0015µF ±5% 400V	26511-120
C13	Plas 0.0015µF ±5% 400V	26511-120
C14	Elec 100µF 50V	26417-160
FS1	1A for 200V (2A for 100V)	23411-058 (23411-060)
FS2	500mA	23411-005
GD1	15F	23417-302
GD2	15D	23417-318
GD3	15D	23417-318
JK1	A.C. input	23421-659
MR1	DD 058	28358-817
MR2	DD 058	28358-817
MR3	DD 058	28358-817
MR4	DD 058	28358-817
MR5	1S 923	28356-018
MR6	1S 923	28356-018
PL1	Mains plug	23423-151
PLP1	Mains	23733-115

For symbols and abbreviations see introduction to this chapter

When ordering, prefix circuit reference with **3**

Circuit reference	Description	M.I. code
R1	WW 470Ω ±5% 6W	25127-769
R2	Carb 2.2MΩ ±10% ½W*	24342-174
R3	Carb 330Ω ±10% ½W*	24342-063
R4	Carb 330Ω ±10% ½W*	24342-063
R5	Carb 33kΩ ±10% 1W*	24343-122
R6	Carb 330Ω ±10% ½W*	24342-063
R7	Carb 330Ω ±10% ½W*	24342-063
R8	Carb 470kΩ ±10% ½W*	24342-152
R9	Met ox 10kΩ ±7%TE ⅜W*	24552-110
R10	Met ox 91kΩ ±7%TE ⅜W*	24552-134
R11	Met ox 10kΩ ±7%TE ⅜W*	24552-110
R12	Met ox 10kΩ ±7%TE ⅜W*	24552-110
R13	Met ox 4.7kΩ ±7%TE ⅜W*	24552-100
R14	Carb 470kΩ ±10% 1W*	24343-152
R15	Carb 470kΩ ±10% 1W*	24343-152
RV1	INT AC WW 10kΩ ±10% 2½W	25823-444
RV2	Carb 22kΩ ±20% ¼W	25611-030
RV3	Carb 22kΩ ±20% ¼W	25611-030
SH	DPCO. SUPPLY	44334-003
SJ	4 pos. 3 sect. Generator selector	44323-506
T1	Mains	43527-007
T2	Internal mixing	43466-017
V1	12 AT7	28124-602
TP1-TP5	Lx and test supply	23235-176
1" bar knob for Generator Selector		41145-208
Knob for INT AC control		41142-210

Standard bridge-arm and loss balance

When ordering, prefix circuit reference with **4**

Circuit reference	Description	M.I. code
C1	Plas 0.099μF ±1% 350V	26516-839
C1A †	Pads C1 to achieve 0.1μF ±0.1%	
C2	Plas 0.198μF ±1% 350V	26516-859
C2A †	Pads C2 to achieve 0.2μF ±0.1%	
C3	Plas 0.198μF ±1% 350V	26516-859
C3A †	Pads C3 to achieve 0.2μF ±0.1%	
C4	Plas 0.198μF ±1% 350V	26516-859
C4A †	Pads C4 to achieve 0.2μF ±0.1%	
C5	Plas 0.198μF ±1% 350V	26516-859
C5A †	Pads C5 to achieve 0.2μF ±0.1%	
C6	Plas 0.198μF ±1% 350V	26516-859
C6A †	Pads C6 to achieve 0.2μF ±0.1%	
C7	Plas 0.198μF ±1% 350V	26516-859
C7A †	Pads C7-C11 to achieve 1μF ±0.1%	
C8	Plas 0.198μF ±1% 350V	26516-859
C9	Plas 0.198μF ±1% 350V	26516-859
C10	Plas 0.198μF ±1% 350V	26516-859
C11	Plas 0.198μF ±1% 350V	26516-859
C12	Plas 1μF 400V	26512-284
C13	Elec 5μF 70V	26417-118
C14A	Elec 30μF	26437-837
C14B	Elec 40μF	
C14C	Elec 20μF	
C15	Elec 100μF 150V	26417-495
C16	Elec 5μF 70V	26417-118
C17	Paper 0.1μF 350V	26174-173
C18	Paper 0.03μF 350V	26174-157
C19	Paper 0.1μF 350V	26174-173
C20	Paper 100pF 600V	26174-112
C21	Paper 0.002μF 350V	26174-129
C22	Elec 8μF 200V	26417-474
C23	Elec 8μF 200V	26417-474
C24	Plas 0.11μF ±1% 350V	26516-846
C25	Elec 50+50μF 450V	26437-373
C26	Elec 500μF 200V	26427-109

For symbols and abbreviations see introduction to this chapter

When ordering, prefix circuit reference with **4**

Circuit reference	Description	M.I. code
R1	Met ox 220kΩ ±7%TE $\frac{3}{8}$W*	24552-143
R2	Met ox 100kΩ ±7%TE $\frac{3}{8}$W*	24552-135
R3	Carb 3.3MΩ ±10% $\frac{1}{2}$W*	24342-178
R4	Carb 1kΩ ±10% $\frac{1}{2}$W*	24342-080
R5	WW 4.7kΩ ±5% 3W	25125-100
R6	Carb 100Ω ±10% $\frac{1}{2}$W*	24342-050
R7	Met ox 750kΩ ±7%TE $\frac{3}{8}$W*	24552-077
R7A †	Met ox 3.3kΩ nom	24552-094
R8	WW 6.8kΩ ±5% 3W	25125-106
R9	Met ox 220kΩ ±7%TE $\frac{3}{8}$W*	24552-143
R10	Carb 1MΩ ±10% $\frac{1}{2}$W*	24342-166
R11	Carb 1kΩ ±10% $\frac{1}{2}$W*	24342-080
R12	Met ox 100kΩ ±7%TE $\frac{3}{8}$W*	24552-135
R13	Carb 1.5kΩ ±10% $\frac{1}{2}$W*	24342-084
R14	Carb 47kΩ 10% 1W*	24343-126
R15	Carb 5.6kΩ ±10% $\frac{1}{2}$W*	24342-103
R16	Carb 1.5MΩ ±10% $\frac{1}{2}$W*	24342-170
R17	Carb 680kΩ ±10% $\frac{1}{2}$W*	24342-158
R18	Carb 1kΩ ±10% $\frac{1}{2}$W*	24342-080
R19	Carb 150Ω ±10% $\frac{1}{2}$W*	24342-054
R20	Carb 470Ω ±10% $\frac{1}{2}$W*	24342-069
R21	Carb 33kΩ ±10% 1W*	24343-122
R22	Carb 27kΩ ±10% 1W*	24343-120
R23	Carb 100kΩ ±10% $\frac{1}{2}$W*	24342-135
R24	Carb 100kΩ ±10% $\frac{1}{2}$W*	24342-135
R25	Carb 1kΩ ±10% $\frac{1}{2}$W*	24342-080
R26	WW 4.7kΩ ±5% 3W	25125-100
R27	Carb 100Ω ±10% $\frac{1}{2}$W*	24342-050
R28	Met ox 270Ω ±7%TE $\frac{3}{8}$W*	24552-061
R28A †	Met ox 560Ω nom $\frac{3}{8}$W*	24552-072
R29	WW 6.8kΩ ±5% 3W	25125-106
R30	Carb 47kΩ ±10% $\frac{1}{2}$W*	24342-126
R31	Carb film 330Ω ±1% $\frac{1}{4}$W	24133-066
RV1	FINE Ω 25Ω ±10% 1W	25815-141
RV2A	Loss Balance 50kΩ ±5% 4W	44371-521
RV2B	Loss Balance 5kΩ ±5% 4W	44371-521
RV2C	Loss Balance 500Ω ±5% 4W	44371-521
RV3	WW 5kΩ ±10% $2\frac{1}{2}$W	25823-430
RV4	Fine L Balance 10kΩ ±5% 4W	44371-224
SK	Coarse L Balance 11 pos. 2 sect.	44326-220
SL	Series/Parallel 2 pos. 1 sect.	44321-134
SM	Ω SCALE SELECTOR 4 pos. 1 sect.	44323-111
SN	Test Supply Range 3 pos. 6 sect.	44322-129
V1	EF 184	28154-627
V2	12 AT 7	28124-602
V3	EF 184	28154-627

Description	M.I. code
Coarse L Balance knob assembly	41141-213
1" bar knob for Series/Parallel switch	41145-208
1" bar knob for Ω SCALE SELECTOR	41145-208
$1\frac{1}{2}$" bar knob for Test Supply Range switch	41145-206
Knob for FINE Ω control	41141-206
$1\frac{1}{2}$" knob for Fine L Balance	41141-204
Cursor for Fine L Balance control	31182-106
Interlock: Behind Test Supply Range switch (includes Add 1 marking)	41183-407
Interlock: Behind Coarse L Balance switch	41183-406

Detector amplifier

When ordering, prefix circuit reference with **5**

Circuit reference	Description	M.I. code
C1	Elec 250µF 350V	26427-559
C2	Paper 0.1µF 350V	26174-173
C3	Paper 0.1µF 350V	26174-173
C4	Elec 8µF 200V	26417-474
C5	Elec 8µF 200V	26417-474

For symbols and abbreviations see introduction to this chapter

When ordering, prefix circuit reference with **5**

Circuit reference	Description	M.I. code
C6	Cer 20-120pF	26844-416
C7	Elec 1µF 300V	26417-452
C8	Plas 0.01µF 400V	26582-232
C9	Plas 0.01µF 400V	26582-232
C10	Elec 8µF 200V	26417-474
C11	Plas 0.1µF 400V	26512-232
C12	Elec 8µF 200V	26417-474
C13	Plas 150pF 400V	26516-291
C14	Plas 0.1µF 400V	26512-232
C15	Elec 100µF 6V	26417-154
C16	Elec 100µF 6V	26417-154
C17	Paper 500pF 600V	26174-122
C18	Paper 0.05µF 350V	26174-167
C19	Paper 0.05µF 350V	26174-167
C20	Elec 500µF 12V	26417-172
C21	Plas 0.3µF ±2% 150V	26517-432
C22	Plas 0.15µF 2% 150V	26517-428
C23	Plas 0.0343µF ±2% 125V	26516-810
C24	Plas 0.015µF ±2% 125V	26516-763
C25	Plas 0.006µF ±2% 125V	26516-674
C26	Plas 0.00114µF ±2% 125V	26516-499
C27	Plas 0.6µF ±2% 150V	26517-438
C28	Plas 0.3µF ±2% 150V	26517-432
C29	Plas 0.0686µF ±2% 125V	26516-831
C30	Plas 0.03µF ±2% 125V	26516-805
C31	Plas 0.012µF ±2% 125V	26516-723
C32	Plas 0.0024µF ±2% 125V	26516-575
C33	Paper 500pF 600V	26174-122
C34	Plas 1µF 400V	26512-284
C35	Plas 0.3µF ±2% 150V	26517-432
C36	Plas 0.15µF ±2% 150V	26517-428
C37	Plas 0.0343µF ±2% 125V	26516-810
C38	Plas 0.015µF ±2% 125V	26516-763
C39	Plas 0.006µF ±2% 125V	26516-674
C40	Plas 0.00114µF ±2% 125V	26516-499
C41	Cer 68pF 750V	26324-868
C42	Plas 1µF 400V	26512-284
C43	Plas 1µF 400V	26512-284

Circuit reference	Description	M.I. code
R1	Carb 1.5kΩ ±10% ½W*	24342-084
R2	Carb 1MΩ ±10% ½W*	24342-166
R3	Carb 220Ω 10% ½W*	24342-058
R4	Carb 18kΩ ±10% 1W*	24343-116
R5	Carb 1.5kΩ ±10% ½W*	24342-084
R6	Carb 1MΩ ±10% ½W*	24342-166
R7	Carb 220Ω ±10% ½W*	24342-058
R8	Carb 18kΩ ±10% 1W*	24343-116
R9	Met ox 18kΩ ±7%TE ⅜W*	24552-116
R10	Met ox 1.8kΩ ±7%TE ⅜W*	24552-086
R11	Met ox 180Ω ±7%TE ⅜W*	24552-056
R12	Met ox 18kΩ ±7%TE ⅜W*	24552-116
R13	Met ox 1.8kΩ ±7%TE ⅜W*	24552-086
R14	Met ox 180kΩ ±7%TE ⅜W*	24552-056
R15	Carb 10kΩ ±10% ½W*	24342-110
R16	Carb 10MΩ ±10% ½W*	24342-191
R17	Met ox 100kΩ ±7%TE ⅜W*	24552-135
R18	Carb 470kΩ ±10% ½W*	24342-152
R19	Carb 10kΩ ±10% ½W*	24342-110
R20	Carb 10MΩ ±10% ½W*	24342-191
R21	Carb 100kΩ ±10% ½W*	24342-135
R22	Carb 2.2kΩ ±10% ½W*	24342-088
R23	Carb 470kΩ ±10% ½W*	24342-152
R24	Met ox 470Ω ±7%TE ⅜W*	24552-069
R25	Carb 1.5kΩ ±10% ½W*	24342-084
R26	Carb 1.5kΩ ±10% ½W*	24342-084
R27	Carb 1MΩ ±10% ½W*	24342-166
R29	Carb 470Ω ±10% ½W*	24342-069
R30	Carb 470Ω ±10% ½W*	24342-069
R31	Carb 470kΩ ±10% ½W*	24342-152
R32	Carb 470kΩ ±10% ½W*	24342-152
R33	Carb 470kΩ ±10% ½W*	24342-152
R34	Carb 47kΩ ±10% 1W	24343-126
R35	Carb film 14.1kΩ ±1% ¼W	24135-141
R36	Carb film 14.1kΩ ±1% ¼W	24135-141
R37	Carb film 1.3kΩ ±1% ¼W	24134-130
R38	Carb 1.5kΩ ±10% ½W*	24342-084
R39	Carb 330Ω ±10% ½W*	24342-063

For symbols and abbreviations see introduction to this chapter

When ordering, prefix circuit reference with **5**

Circuit reference	Description	M.I. code
R40	Carb 150kΩ ±10% $\frac{1}{2}$W*	24342-139
R41	Carb 1MΩ ±10% $\frac{1}{2}$W*	24342-166
R42	Carb 1MΩ ±10% $\frac{1}{2}$W*	24342-166
R43	Carb 1MΩ ±10% $\frac{1}{2}$W*	24342-166
RV1	FINE SENSITIVITY 20kΩ + 20kΩ	44371-222
RV3	Carb 470Ω ±20% $\frac{1}{4}$W	25611-010
RV4	Carb 1MΩ ±20% $\frac{1}{4}$W	25611-050
RV5	Carb 470Ω ±20% $\frac{1}{4}$W	25611-010
RV6	Carb 1MΩ ±20% $\frac{1}{4}$W	25611-050
RV7	TUNE 5.2kΩ ±5% 3W	44371-220
RV8	Carb 2.2kΩ ±20% $\frac{1}{4}$W	25611-018
RV9	Carb 470kΩ ±20% $\frac{1}{4}$W	25611-046
RV10	Carb 470kΩ ±20% $\frac{1}{4}$W	25611-046
RV11	Carb 50kΩ ±20% 2W	25645-421
SA	Mode 2 pos. 3 sect.	44321-703
SB	COARSE SENSITIVITY 3 pos. 2 sect.	44322-417
SC	Frequency Range 7 pos. 3 sect.	44325-112
T3	Bridge	43551-010
V1	12 AT 7	28124-602
V2	EF 86	28154-207
V3	EF 86	28154-207
V4	12 AT 7	28124-602
V5	DH3-91	28235-114

1" bar knob for Mode switch	41145-208
1" bar knob for COARSE SENSITIVITY switch	41145-208
1" bar knob for Frequency Range selector	41145-208
Knob for FINE SENSITIVITY switch	41142-210
Knob for TUNE control	41142-210
Cursor for c.r.t.	31186-108

Meter circuit

When ordering, prefix circuit reference with **6**

Circuit reference	Description	M.I. code
C1	Plas 1µF 400V	26512-284
C2	Plas 0.33µF 250V	26512-256
C4	Plas 0.1µF 250V	26582-208
C5	Plas 0.1µF 250V	26582-208
C6	Elec 100µF 25V	26417-158
C7	Paper 100pF ±20% 600V	26174-112
C8	Elec 10µF 25V	26414-121
C9	Elec 10µF 25V	26414-121
C10	Elec 250µF 25V	26417-167
C11	Elec 100µF 6V	26417-154
C12	Plas 0.1µF 250V	26582-208
M1	500µA	44572-102
MR1	1S 44	28357-548
MR2	1S 44	28357-548
MR3	1S 44	28357-548
MR4	1S 44	28357-548
MR5	1S 44	28357-548
MR6	1S 44	28357-548
MR7	ZB 15 5%	28372-306
R1	Met film 1MΩ ±$\frac{1}{2}$% $\frac{1}{2}$W	24000-004
R2	Met film 100kΩ ±$\frac{1}{2}$% $\frac{1}{2}$W	24000-003
R3	Met film 10.1kΩ ±$\frac{1}{2}$% $\frac{1}{4}$W	24635-502
R4	Met film 1kΩ ±$\frac{1}{2}$% $\frac{1}{4}$W	24635-011
R5	Met film 111Ω ±$\frac{1}{2}$% $\frac{1}{4}$W	24634-610
R6	WW 10kΩ ±5% 4$\frac{1}{2}$W	25126-610
R7	Carb 2.2MΩ ±10% $\frac{1}{2}$W*	24342-174
R8	Carb 330kΩ ±10% $\frac{1}{2}$W*	24342-148
R9	Carb 15kΩ ±10% $\frac{1}{2}$W*	24342-114
R10	Carb 22kΩ ±10% $\frac{1}{2}$W*	24342-118

For symbols and abbreviations see introduction to this chapter

When ordering, prefix circuit reference with **6**

A.C. + D.C. MIXER UNIT, TM 8339

Circuit reference	Description	M.I. code
R11	Carb 2.2MΩ ±10% ½W*	24342-174
R12	Carb 4.7kΩ ±10% ½W*	24342-100
R13	Carb 1MΩ ±10% ½W*	24342-166
R14	Met ox 33kΩ ±7%TE ⅜W*	24552-122
R15	Carb 47Ω ±1% ¼W	24132-470
R16	Met film 150Ω ±1% ¼W	24636-615
R17	Carb 47Ω ±10% ½W*	24342-037
R18	Carb 2.2kΩ ±10% ½W*	24342-088
R19	Carb 180Ω ±10% ½W*	24342-056
R20	Carb 150Ω ±10% ½W*	24342-054
R21	Carb 68kΩ ±10% ½W*	24342-131
R22	Carb 680Ω ±10% ½W*	24342-076
R23	Carb 33kΩ ±10% ½W*	24342-122
R24	Carb 3.9kΩ ±10% ½W*	24342-096
R25	Carb 1kΩ ±10% 1W*	24343-080
RV1	Carb 1kΩ ±20% ¼W	25611-014
RV2	Carb 2.2kΩ ±20% ¼W	25611-018
RV3	Carb 47kΩ ±20% ¼W	25611-034
SD	Meter Volts/Amps 2 pos. 2 sect.	44321-411
SE	AC METER RANGE 9 pos. 3 sect.	44325-806
VT1	2N 3707	28453-828
VT2	2N 3707	28453-828
VT3	2N 3707	28453-828
VT4	2N 3707	28453-828
VT5	2N 3707	28453-828
	1" bar knob for Meter Volts/Amps switch	41145-208
	1" bar knob for AC METER RANGE switch	41145-208

Circuit reference	Description	M.I. code
C1	Elec 500μF 350V	26427-569
C2	Elec 500μF 350V	26427-569
C3	Elec 500μF 350V	26427-569
C4	Elec 500μF 350V	26427-569
C5	Elec 500μF 350V	26427-569
C6	Elec 500μF 350V	26427-569
C7	Plas 0.01μF ±10% 400V	26512-204
C8	Plas 1μF ±10% 250V	26512-280
FS1	10A	23411-265
FS2	5A	23411-263
FS3	10A	23411-265
GD1	15D	23417-318
GD2	15D	23417-318
M1	500μA	44572-103
MR1	1S 413	28357-022
MR2	TI40A1	28358-718
MR3	1S 923	28356-018
R1	Carb 100kΩ ±10% 1W	24343-135
R2	Special	22/23/25-TM8740
R3	Carb film 600kΩ ±1% ¼W	24136-600
R4	Carb film 200kΩ ±1% ¼W	24136-200
R5	Carb film 59.7kΩ ±1% 1W	24215-597
R6	Carb film 19.6kΩ ±1% 1W	24215-196
R7	Carb 2.2kΩ ±10% ½W*	24332-088
R8	Carb 100Ω ±10% ½W*	24332-050
R9	Carb 1MΩ ±10% ½W*	24332-166
R10	Carb 100kΩ ±10% 1W	24343-135
R11	Carb 100kΩ ±10% 1W	24343-135

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
SA	Output Range 4 pos.	23462-075
SB	Volts/Amps 2 pos.	44321-136
SC	Meter Range 4 pos.	44324-507
SD	OUTPUT 2 pos.	23462-055
T1	Mixing	43448-001
TP1	AC INPUT	23235-176
TP2	AC INPUT	23235-176

Circuit reference	Description	M.I. code
TP3	DC INPUT	23235-176
TP4	DC INPUT	23235-176
TP5	AC + DC OUTPUT	23235-176
TP6	AC + DC OUTPUT	23235-176
TP7		23236-637
	1" bar knob for Meter Range switch	41145-208
	Knob for Output Range switch	31147-123
	Knob for OUTPUT switch	31147-123

For symbols and abbreviations see introduction to this chapter

Chapter 6

Circuit diagrams

CIRCUIT NOTES

1. COMPONENT VALUES

Resistors: No suffix = ohm, k = kilohm, M = megohm.
Capacitors: No suffix = microfarad, p = picofarad.
Inductors: No suffix = henry, m = millihenry, μ = microhenry.
† value selected during test, nominal value shown.

2. VOLTAGES

Printed in italics. Voltages are d. c. and relative to chassis unless otherwise indicated. Measured with a 20 kΩ/V meter.
→ arrow indicates voltage source point.

3. SYMBOLS

+→ arrow indicates clockwise rotation of knob.

⊘ preset component.

FUNCTION panel marking.

—□— (2) printed board tag number.

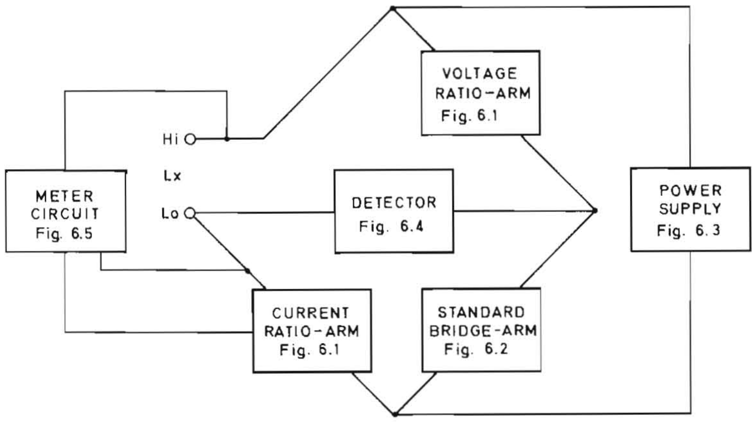
—o— other tag.

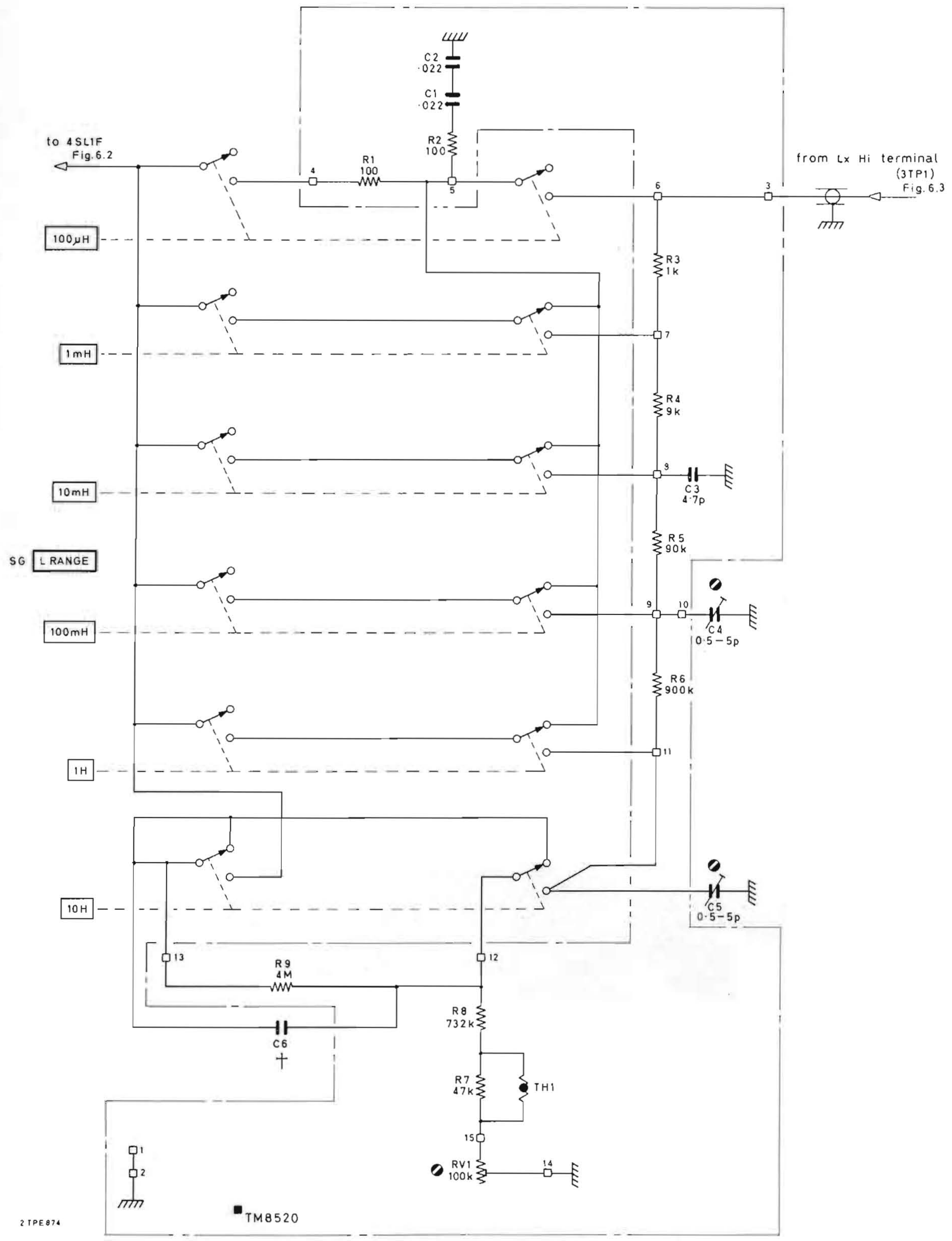
▬ ▬ ▬ negative feedback.

4. SWITCHES

Rotary switches are drawn schematically. Numbers of letters indicated control knob setting as shown in the key diagrams. Sequence of sections reading from the control knob end is as follows:

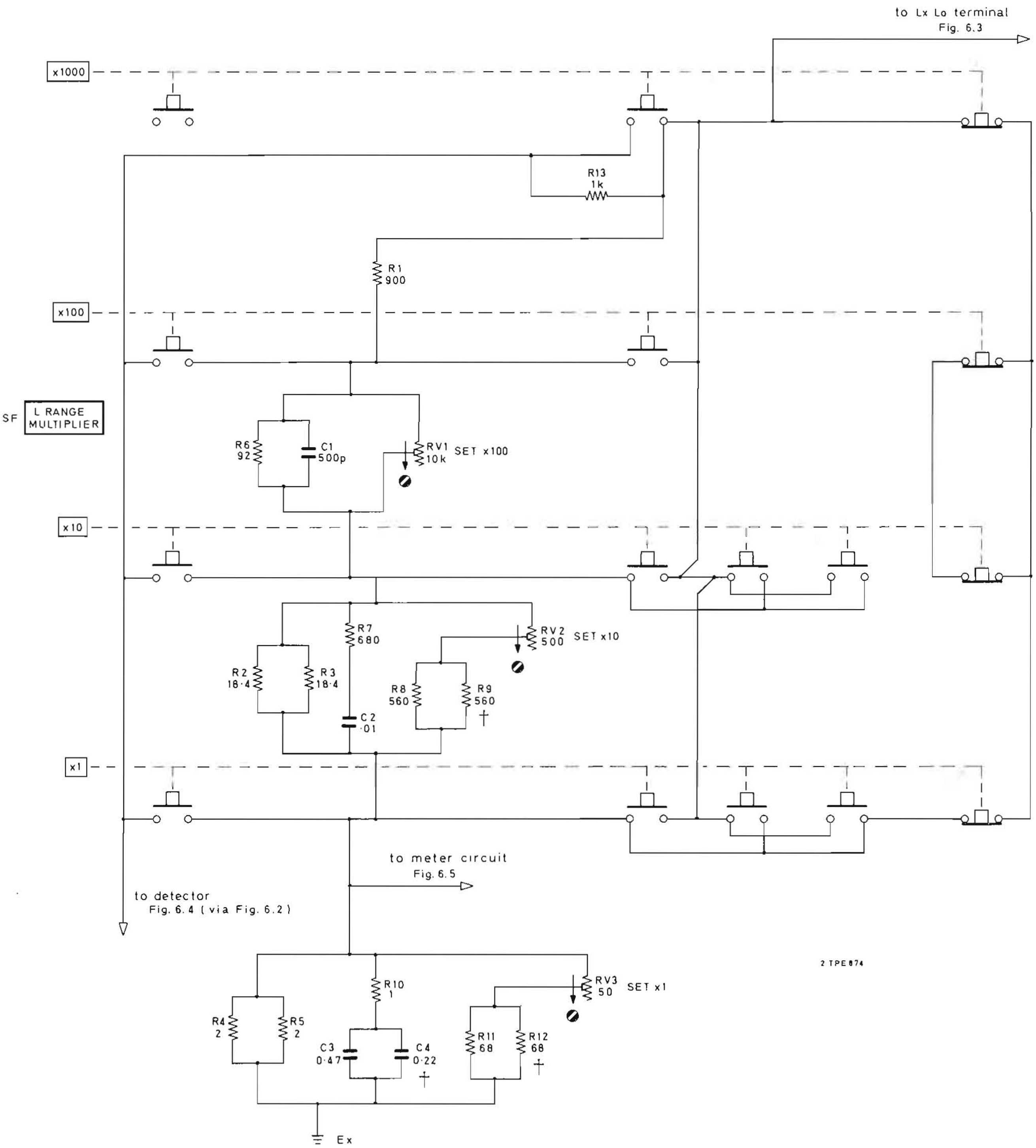
1F	=	1st section, front.
1B	=	1st section, back.
2F	=	2nd section, front,
etc.		


VOLTAGE RATIO-ARM Fig. 6.1
Hi
Lx
Lo
METER CIRCUIT Fig. 6.5
DETECTOR Fig. 6.4
POWER SUPPLY Fig. 6.3
CURRENT RATIO-ARM Fig. 6.1
STANDARD BRIDGE-ARM Fig. 6.2



VOLTAGE RATIO – ARM R (V)

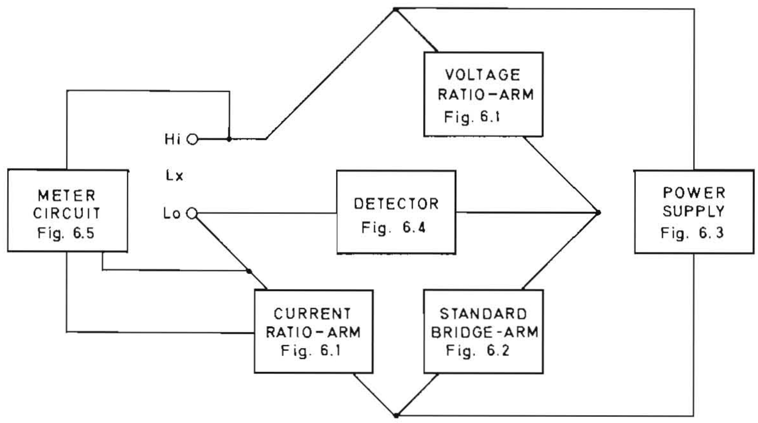
all components to be prefixed 2



CURRENT RATIO–ARM R(I)

all components to be prefixed 1

Fig. 6.1 Current ratio-arm and voltage ratio-arm



VOLTAGE RATIO-ARM Fig. 6.1
Hi
Lx
Lo
METER CIRCUIT Fig. 6.5
DETECTOR Fig. 6.4
POWER SUPPLY Fig. 6.3
CURRENT RATIO-ARM Fig. 6.1
STANDARD BRIDGE-ARM Fig. 6.2

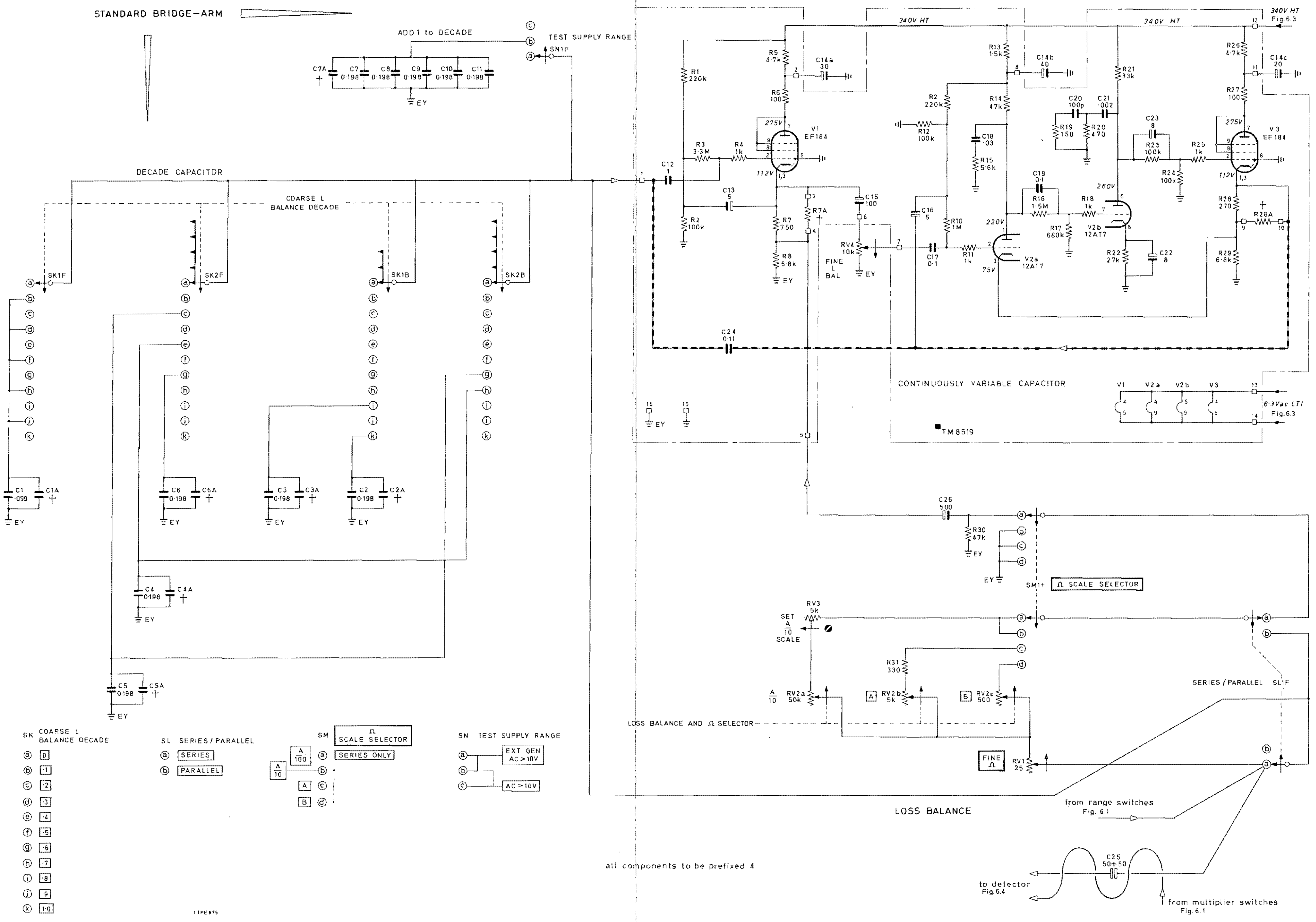
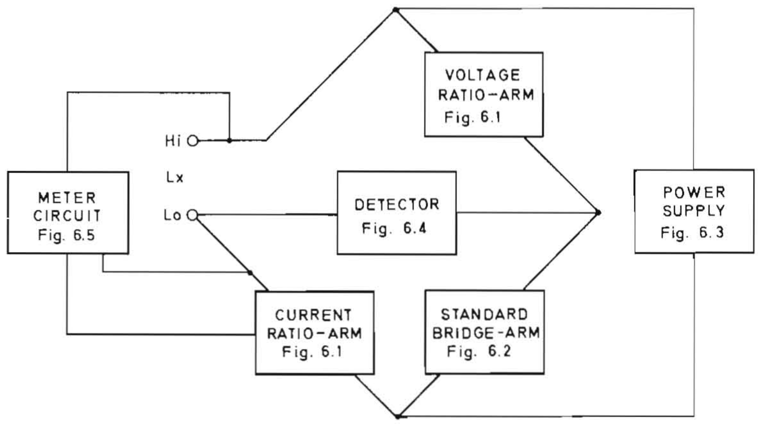


Fig. 6.2 Standard bridge-arm and loss balance


VOLTAGE RATIO-ARM Fig. 6.1
Hi
Lx
Lo
METER CIRCUIT Fig. 6.5
DETECTOR Fig. 6.4
POWER SUPPLY Fig. 6.3
CURRENT RATIO-ARM Fig. 6.1
STANDARD BRIDGE-ARM Fig. 6.2

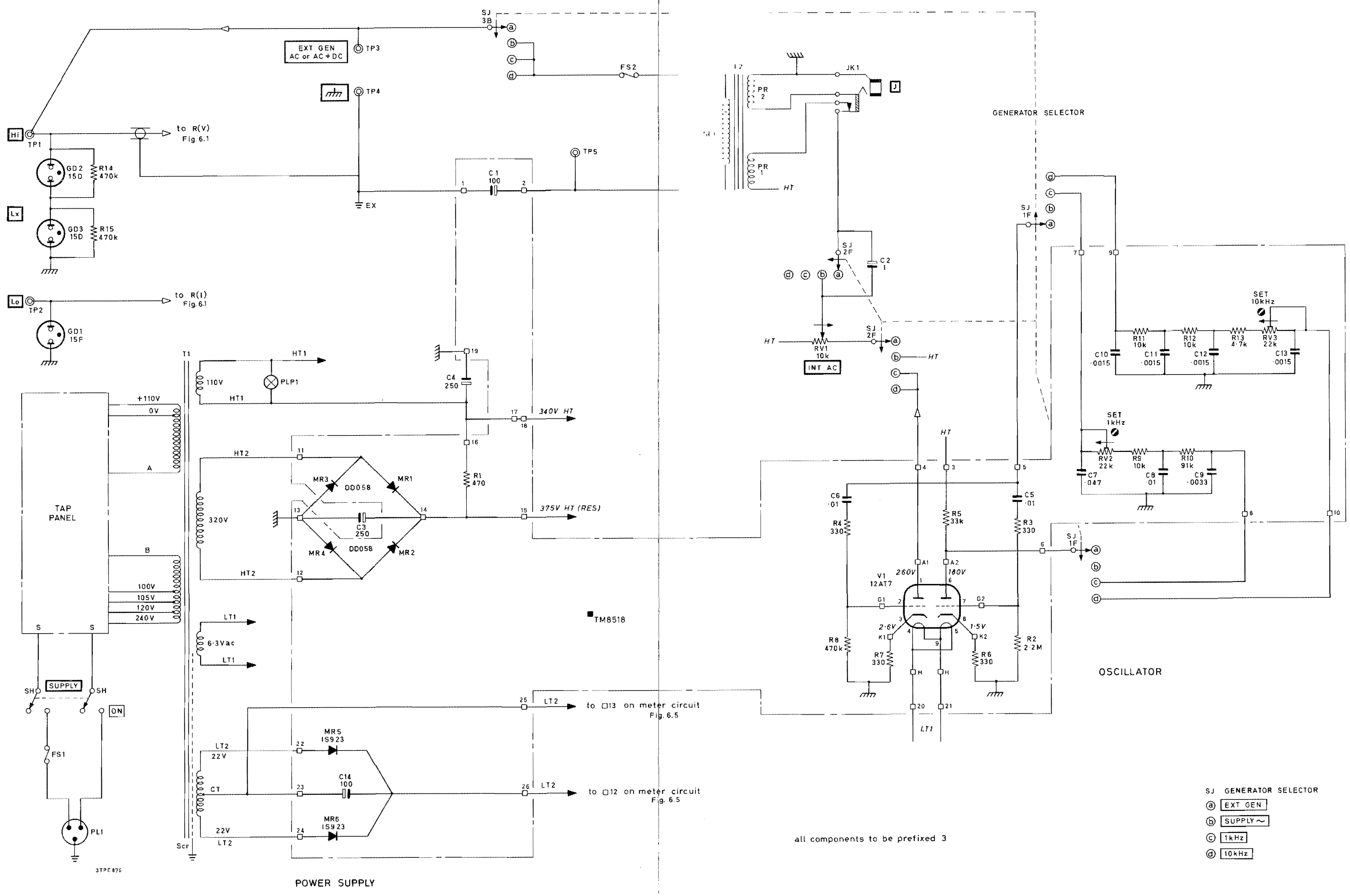
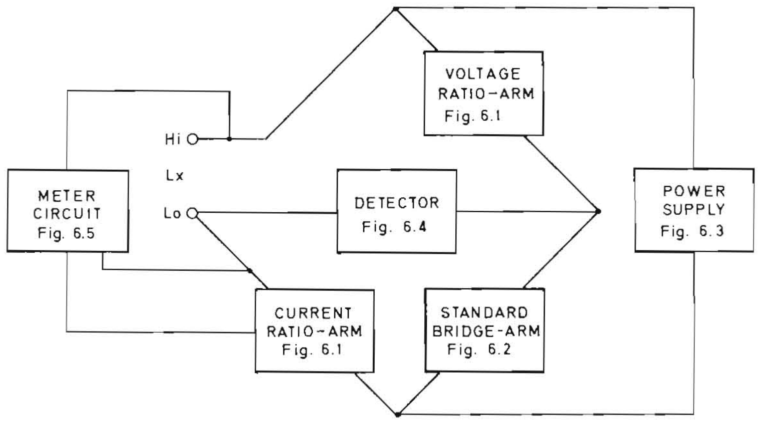
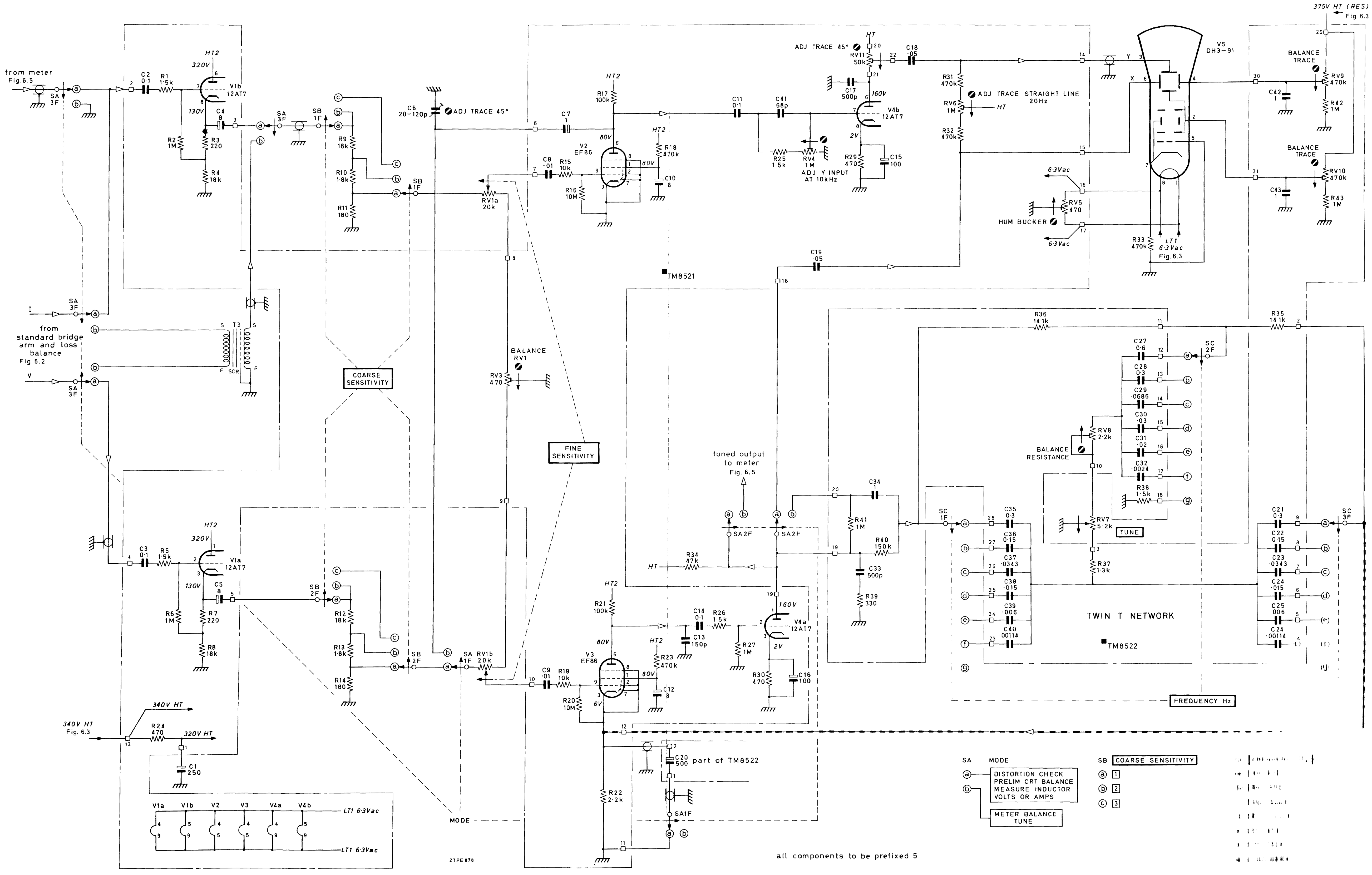
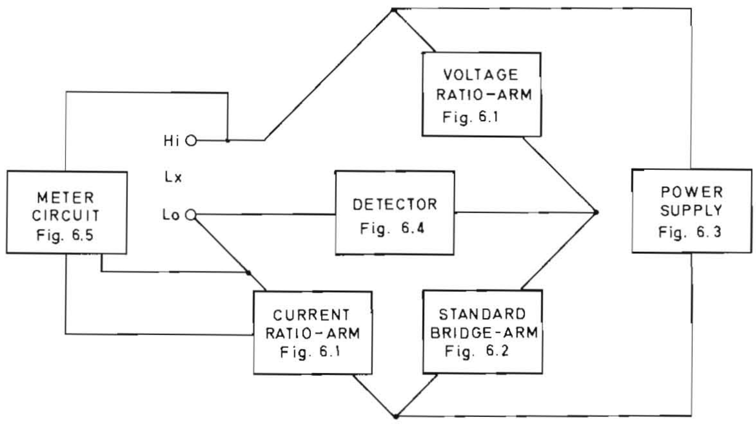


Fig. 6.3 Power supply and oscillator


VOLTAGE
RATIO-ARM
Fig. 6.1
Hi
Lx
Lo
METER
CIRCUIT
Fig. 6.5
DETECTOR
Fig. 6.4
POWER
SUPPLY
Fig. 6.3
CURRENT
RATIO-ARM
Fig. 6.1
STANDARD
BRIDGE-ARM
Fig. 6.2


from meter
Fig. 6.5
from standard bridge arm and loss balance
Fig. 6.2
COARSE SENSITIVITY
FINE SENSITIVITY
BALANCE RV1
ADJ TRACE 45°
ADJ TRACE STRAIGHT LINE 20Hz
ADJ Y INPUT AT 10kHz
HUM BUCKER
BALANCE TRACE
375V HT (RES)
Fig. 6.3
V5 DH3-91
TM8521
TM8522
tuned output to meter
Fig. 6.5
BALANCE RESISTANCE
TUNE
TWIN T NETWORK
FREQUENCY Hz
340V HT
Fig. 6.3
part of TM8522
MODE
SA MODE
DISTORTION CHECK
PRELIM CRT BALANCE
MEASURE INDUCTOR
VOLTS OR AMPS
METER BALANCE
TUNE
SB COARSE SENSITIVITY
all components to be prefixed 5
2TPE 878


VOLTAGE
RATIO-ARM
Fig. 6.1
Hi
Lx
Lo
METER
CIRCUIT
Fig. 6.5
DETECTOR
Fig. 6.4
POWER
SUPPLY
Fig. 6.3
CURRENT
RATIO-ARM
Fig. 6.1
STANDARD
BRIDGE-ARM
Fig. 6.2

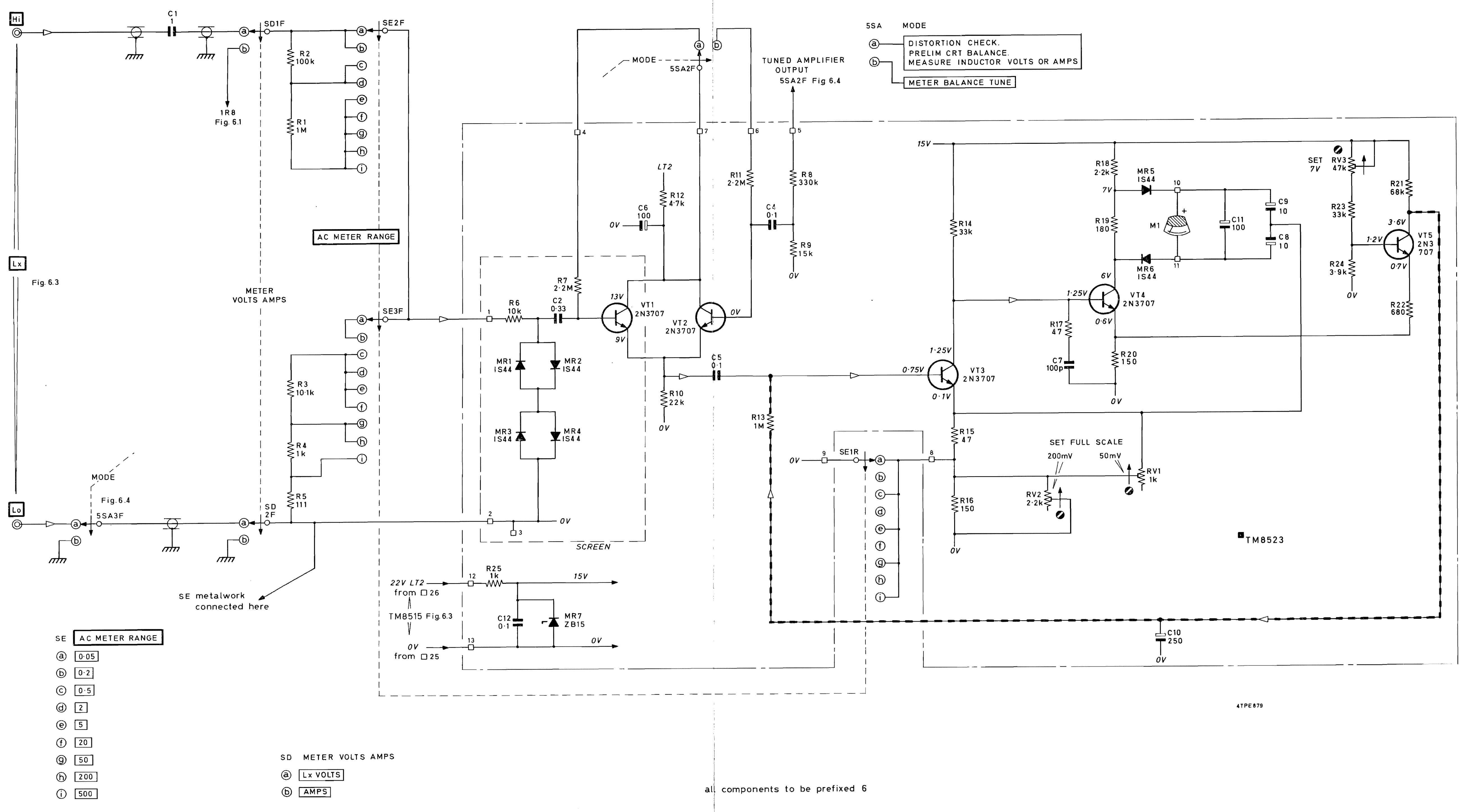
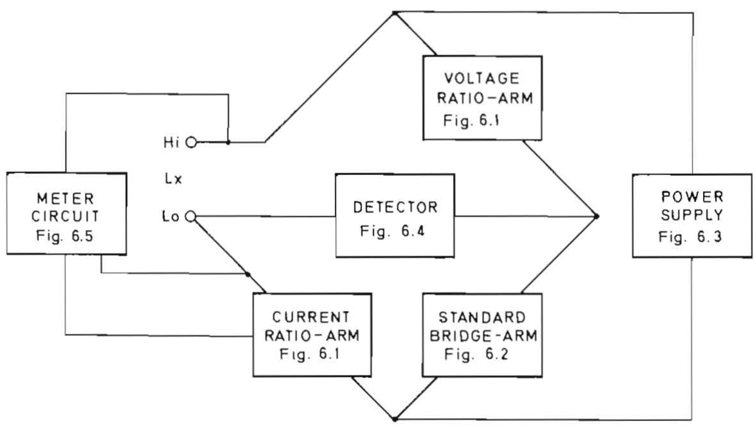


Fig. 6.5 Meter circuit


VOLTAGE RATIO-ARM Fig. 6.1
Hi
Lx
Lo
METER CIRCUIT Fig. 6.5
DETECTOR Fig. 6.4
POWER SUPPLY Fig. 6.3
CURRENT RATIO-ARM Fig. 6.1
STANDARD BRIDGE-ARM Fig. 6.2

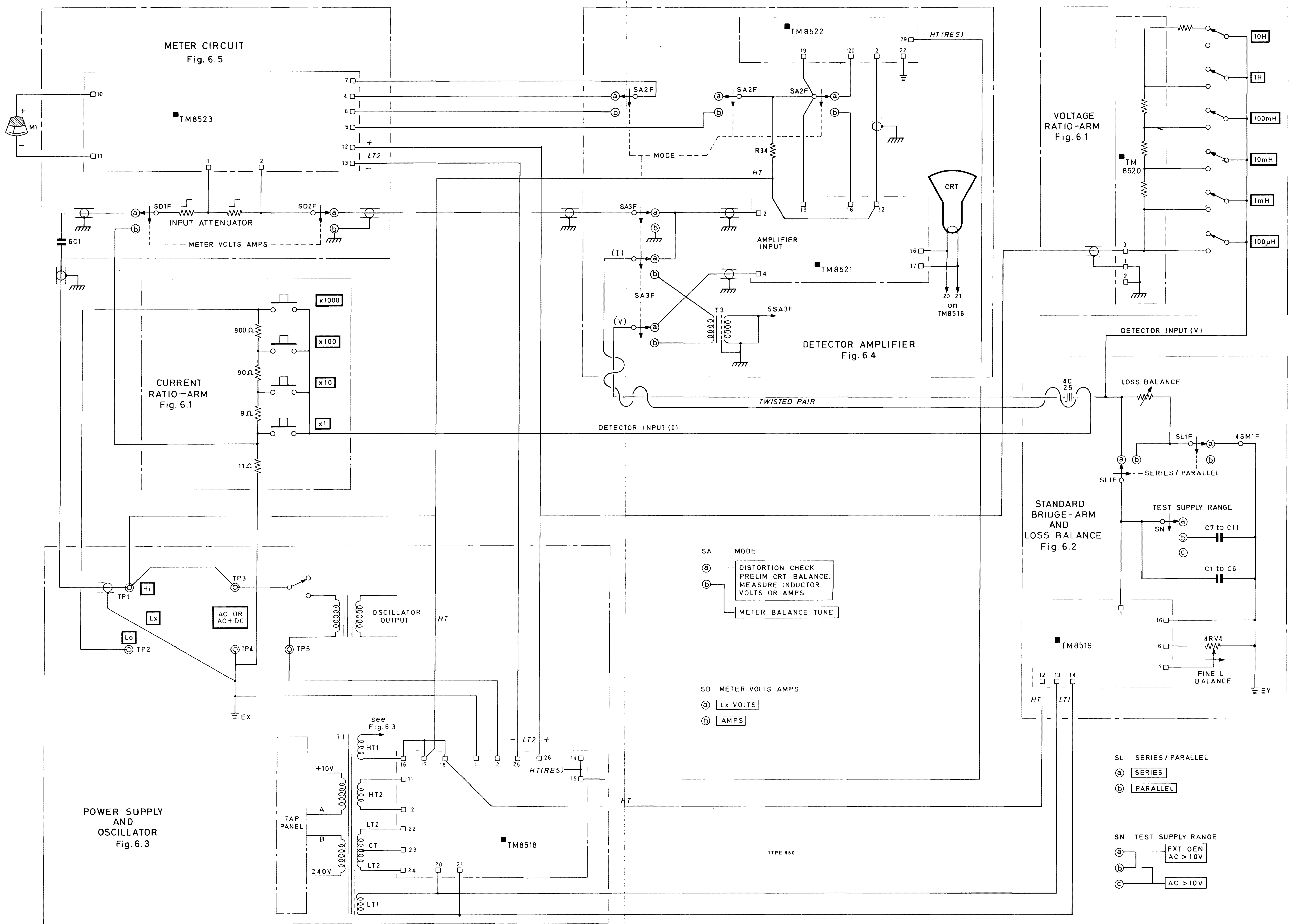


Fig. 6.6 Interconnecting diagram

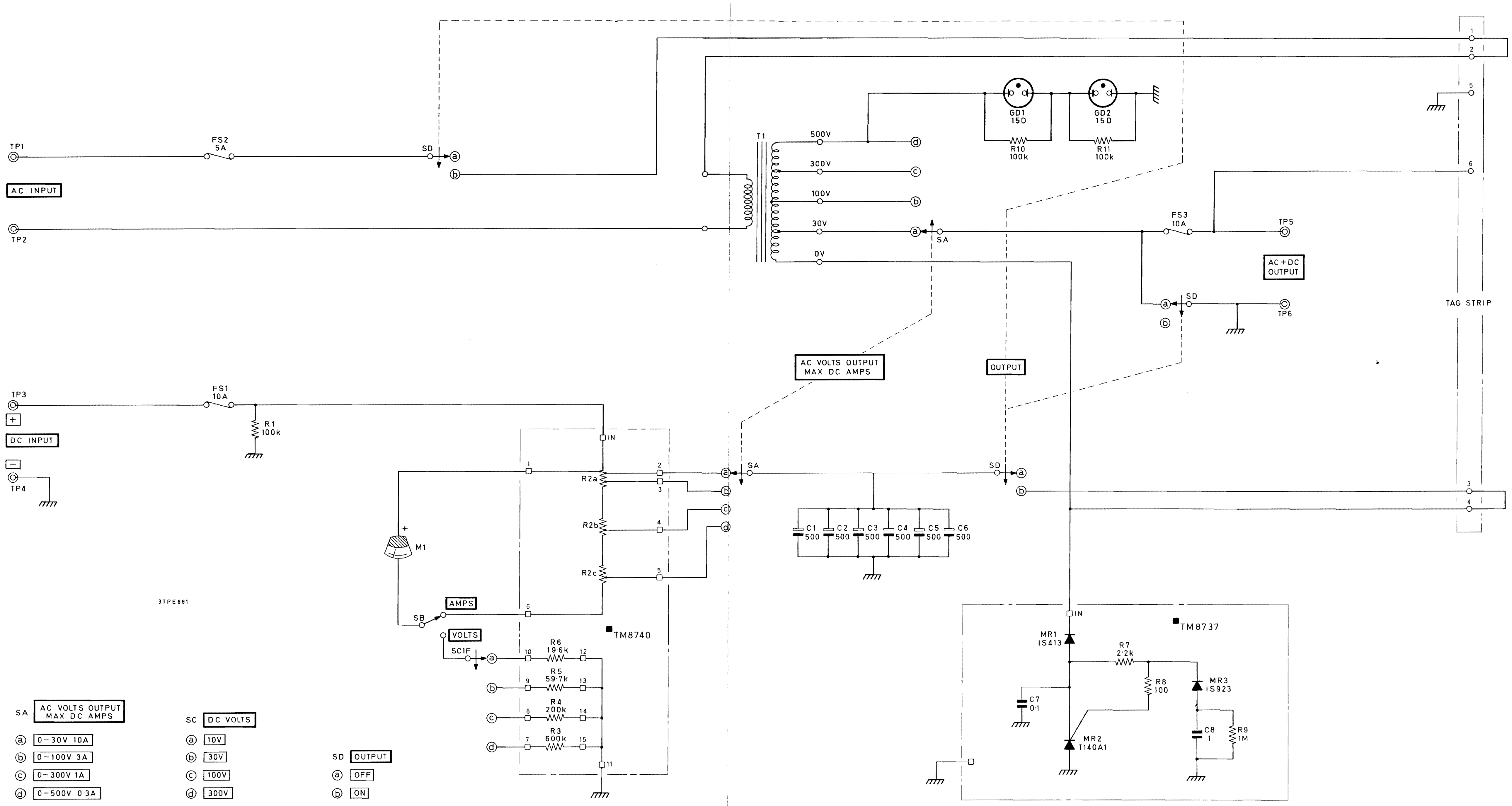


Fig. 6.7 A.C. + D.C. Mixer Unit [illegible]

TF 2702

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