TF 2500

TF 2500

A.F. Power Meter

INSTRUCTION MANUAL

mi

MARCONI INSTRUMENTS

Instruction Manual
No. EB 2500
for

A.F. Power Meter
TF 2500

mi Technical Publications

MARCONI INSTRUMENTS LIMITED
ST. ALBANS HERTFORDSHIRE ENGLAND

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General information

1.1 INTRODUCTION

A.F. Power Meter type TF 2500 is a battery-operated audio wattmeter/voltmeter for measuring power in the range of 10 μW to 25 W from 20 Hz to 20 kHz and voltage up to 150 V from 10 Hz to 1 MHz.

The instrument is basically an amplifier-rectifier voltmeter calibrated in watts, dBm and volts. For power measurement the amplifier is preceded by a switched input transformer and attenuators, providing seven power ranges for balanced and unbalanced measurement at any one of 40 input impedances. For voltage measurement the input is applied directly to the amplifier, giving nine voltage ranges at high impedance. As an additional facility the meter can be switched to indicate the state of the internal batteries.

Two sockets at the rear of the instrument provide a balanced d.c. output of 94·4 mV (at full-scale deflection) for use with a chart recorder.

A power supply of 18 V to drive the instrument is derived from two 9 V internal batteries.

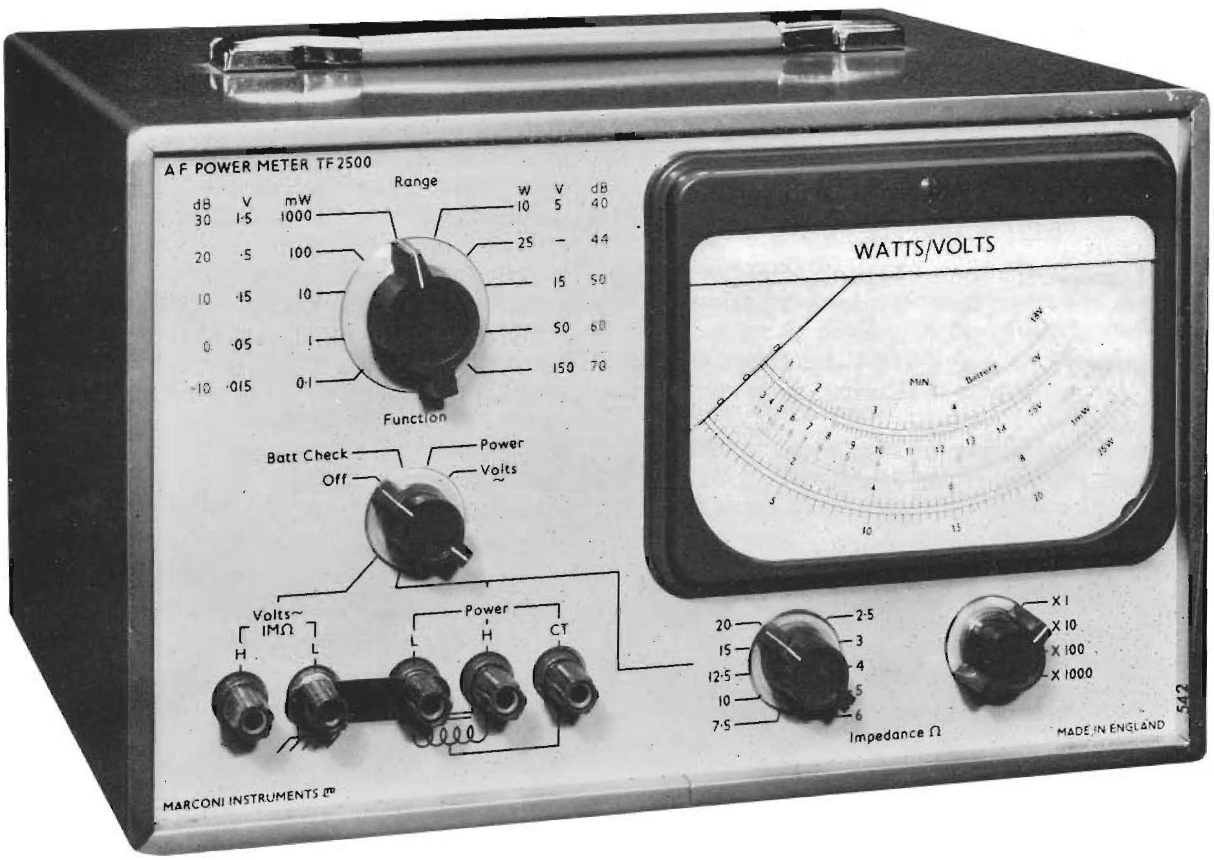


Fig. 1.1 A.F. Power Meter TF 2500

1.2 DATA SUMMARY

Power measurement

Range:	7 ranges with full-scale deflections of: 100 μW. 1, 10 and 100 mW. 1, 10 and 25 W.
Accuracy at 1 kHz:	±2·5% of full-scale.
Frequency response relative to 1 kHz:	10 mW and below: ±0·5 dB from 40 Hz to 20 kHz. 100 mW and 1 W: ±0·5 dB from 20 Hz to 20 kHz. 10 W, ±0·5 dB from 40 Hz to 20 kHz. 25 W, ±0·5 dB from 60 Hz to 20 kHz. Usable up to 35 kHz with reduced accuracy.
Input impedance:	40 values from 2·5 Ω to 20 kΩ as follows: 2·5, 3, 4, 5, 6, 7·5, 10, 12·5, 15 and 20 Ω with multipliers of ×1, ×10, ×100 and ×1 000. Accuracy at 1 kHz: ±4%. Impedances of one-quarter the above—extending the range down to 0·625 Ω—can be obtained using the input centre tap.

Voltage measurement

Range:	9 ranges with full-scale deflections of: 15, 50, 150 and 500 mV, 1·5, 5, 15, 50 and 150 V.
Accuracy including frequency response:	±2% of full-scale from 20 Hz to 200 kHz: ±3% of full-scale from 20 Hz to 1 MHz: Typically ±4·0% of full-scale at 10 Hz.
Input Impedance:	Typically 1 MΩ with 25 pF in shunt on 0·5 V and above. Typically 1 MΩ with 35 pF in shunt on 150 V and below.
Power supply:	18 V d.c. from 2 internal DT9 batteries. Current drain approximately 18 mA average.

Dimensions and weight:	*Height*	*Width*	*Depth*	*Weight*
	8 in	11½ in	10¾ in	23 lb
	(203 mm)	(292 mm)	(273 mm)	(10·5 kg)

Temperature range:	10 to 35°C.

1.3 ACCESSORIES SUPPLIED

Two 9 V dry batteries type DT9.
Two shorting links. One fitted across BAL D.C. OUTPUT terminals and the other across the VOLTS L and POWER L terminals.
One shielded adapter, providing BNC socket outlet from terminals; type TB 39868, Greenpar type GE 51002.

Chapter **2**

Operation

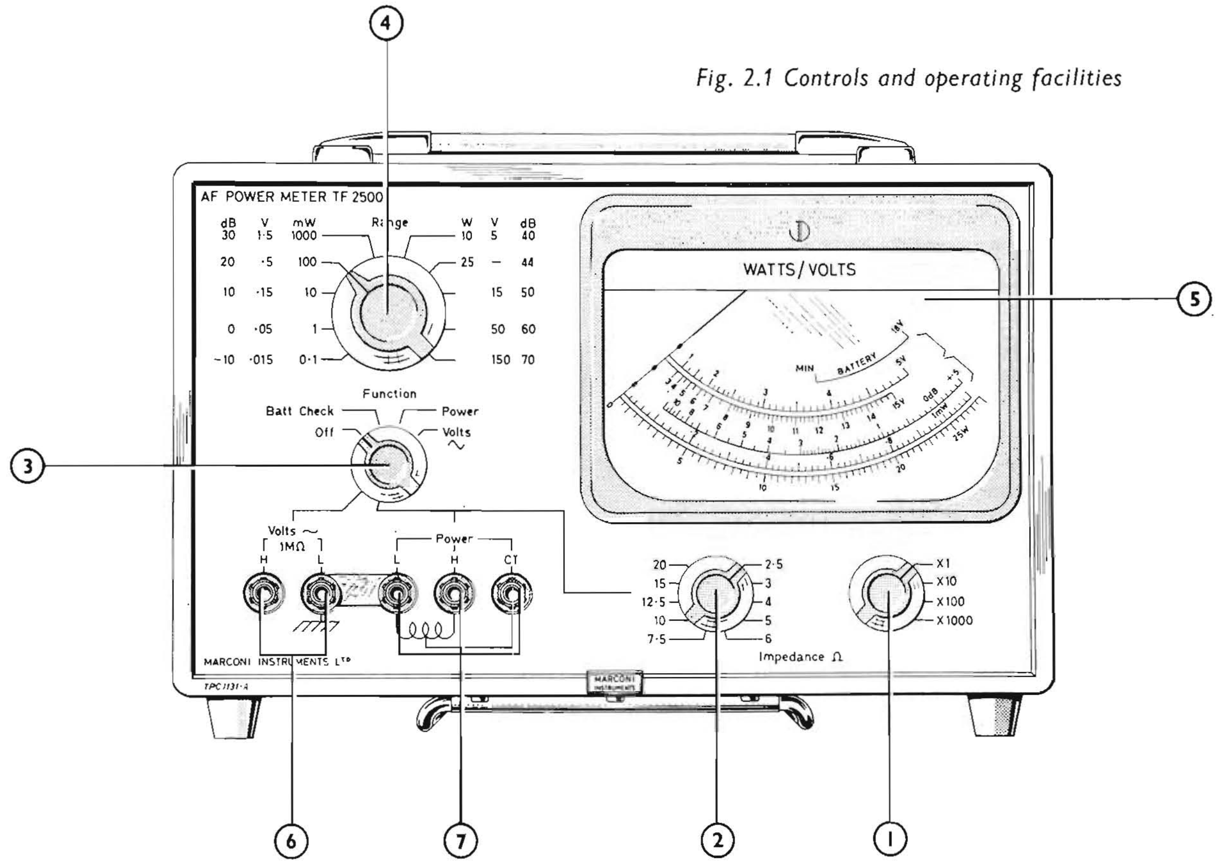


Fig. 2.1 Controls and operating facilities

2.1 GENERAL

The meter measures the power delivered by an audio frequency source into a load provided by the instrument itself. The wide power, impedance and frequency ranges of the instrument are due primarily to two important features of design. These are (a) the use of switched resistive loads for impedance selection and (b) the decade multiplication of the input impedance values by means of a specially designed auto matching transformer having a tapped primary winding and a small tertiary winding. The instrument can also be used, if required, for signal/noise measurements because of its sensitive power ranges.

2.2 CONTROLS

The functions of controls on the front panel are summarized below and shown in Fig. 2.1.

1. Impedance multiplier

Changes the input impedance, in four decade steps, by switching the effective turns ratio of the transformer.

2. Impedance selector

Together with the IMPEDANCE MULTIPLIER selects the impedance presented at the input terminals for power measurement.

3. Function switch

Selects power or voltage measurement and, in addition, enables a check to be made on the internal batteries.

4. Range control

Selects the power or voltage range and indicates the number of decibels to be added to the meter dBm scale reading.

5. Watts/volts meter

A 100 Ω moving-coil meter with six scales: two for voltage, two for power, one for dB relative to 1 mW at the selected input impedance and one for battery check.

6. Volts terminals (H and L)

For a.c. voltage measurements.

7. Power terminals (H, L and CT)

For power measurements.

BAL d.c. output terminals

On rear panel. For use with chart recorder. A link LK2 is fitted across the terminals to complete the meter circuit and must remain in position for all measurements not involving the use of the terminals.

2.3 POWER MEASUREMENT

CAUTION

Before measuring power, it is advisable to set the RANGE control to the 25 W position to avoid the possibility of overloading the meter. Take particular care that, on any range, the input power does not exceed the full-scale value at frequencies below the lower frequency limit for the range (see Sect. 1.2 data summary).

Unbalanced measurements

For measurements on unbalanced sources:

(1) Set the RANGE control to 25 W and the FUNCTION switch to POWER.
(2) Set the IMPEDANCE controls to give the required input load impedance.
(3) Connect the audio source under test to the POWER H and L terminals: the L terminal is the earthy end for any condition.
(4) Adjust the RANGE control to give a convenient meter deflection and read the power indicated directly on the meter.

Balanced measurements

For measurements on balanced sources:

Connect the audio source to the POWER H and L terminals. The centre tap may be referred to true earth, by connecting an earth wire to the POWER CT terminal. Measurements may then be carried out as for unbalanced outputs.

Measurement at low impedance

To obtain impedances at one-quarter the value indicated at any setting of the IMPEDANCE controls, the power source should be connected between the POWER CT and L terminals.

2.4 VOLTAGE MEASUREMENT

CAUTION

Before measuring voltage, it is advisable to set the RANGE control to the 150 V position to avoid the possibility of overloading the meter.

For normal voltage measurements:

(1) Set the FUNCTION switch to the VOLTS position.
(2) Adjust the RANGE control to give a convenient deflection and read the voltage directly on the appropriate scale on the meter.

2.5 APPLICATIONS

Measurement of source impedance

To measure the internal impedance of a power source, set the RANGE control as necessary and the two IMPEDANCE controls to their maximum settings, i.e. the Ω control to 20 and the $\times$ control to $\times$ 1 000. Connect the power source and adjust the IMPEDANCE controls for maximum meter deflection. The impedance of the source is then approximately the same as that indicated by the settings of the IMPEDANCE controls.

Measurement of non-sinusoidal waveforms and random noise

(1) Switch the FUNCTION switch to POWER and set the IMPEDANCE controls (i.e., Multiplier and Selector) to the desired load impedance.
(2) Connect the power source to the POWER H and L terminals and adjust the RANGE control to give a convenient meter deflection and read the power indicated directly on the meter.
(3) The detection circuit is of the average reading type; therefore the reading should be corrected in accordance with the last column of Table 2.1.

For example, subtract 0·91 dB if measuring a square wave.

Table 2.1

Form factor table

Waveform	*Form factor*	*dB*	*Instrument indication*
Sine	$\frac{\pi\sqrt{2}}{4}$	0·91	Correct
Square	1	0	+0·91 dB
Triangular (Isosceles)	$\frac{2}{\sqrt{3}}$	1·214	−0·304 dB
Gaussian noise (Wide band)	$\sqrt{\frac{2}{\pi}}$	1·96	−1·05 dB
Rayleigh noise (Narrow band)	$\frac{2}{\sqrt{\pi}}$	1·048	−0·138 dB

The correction factor is derived by subtracting the form factor for a sinewave, which (expressed in dB) is 0·91 dB, from the form factor (in dB) of the signal being measured.

Note: *The same correction factors may be used for the measurement of voltage.*

Measurement of power with a d.c. component

(1) Switch the FUNCTION switch to POWER and set the IMPEDANCE controls (i.e., Multiplier and Selector) to the impedance of the generator.
(2) Connect the power source to the POWER H and L terminals and adjust the RANGE control to give a convenient meter deflection and read the power indicated directly on the meter.

Owing to the use of inductive coupling to provide the desired load value, the power meter can be used during the design of a.f. output stages, to

Table 2.2

Table of d.c. currents (mA) which will reduce power accuracy by approximately an additional 5%

Z	20 Hz		40 Hz			60 Hz				100 Hz				200 Hz				400 Hz				*Maximum total current (A)*
Ω	100 µW	1 W	100 µW	1 W	10 W	100 µW	1 W	10 W	25 W	100 µW	1 W	10 W	25 W	100 µW	1 W	10 W	25 W	100 µW	1 W	10 W	25 W	a.c. + d.c.
2·5	100	160	150	200	400	250	300	500	>1A	600	800	>1A	>1A		>1A				>1A			3·2
6	40	80	60	80	160	150	200	400	600	150	250	400	600	700	>1A				>1A			3·2
7·5	45	80	60	100	250	100	150	300	400	200	250	450	500	700	>1A				>1A			1·8
20	20	40	30	50	150	40	60	100	250	60	100	200	300	100	200	350	400	700	900	900	900	1·8
25	30	45	40	60	150	45	80	150	300	50	100	200	300	350	>500				>500			0·95
60	20	30	30	40	100	40	50	100	180	40	80	150	250	50	100	150	200	350	500	>500		0·95
75	15	20	25	30	100	30	40	150	200	140	160	200	250	300	400	500	600	500	>600			0·77
200	6	10	20	25	60	25	30	80	120	30	50	80	100	30	60	150	160	200	300	>400		0·77
250	6	10	10	15	50	15	20	70	70	70	80	100	120	150	200	250	>250		>250			0·28
600	3	8	8	15	25	12	15	40	60	15	25	40	50	18	30	60	70	100	150	>250		0·28
750	4	6	6	10	30	10	14	40	45	30	40	50	50	100	150	>150			>150			0·2
2k	3	5	5	10	16	8	10	25	35	10	16	30	35	12	20	45	50		>50			0·2
2·5k	2	3	3	5	15	5	7	15	20	15	20	25	25	50	70	100	>100		>100			0·14
6k	2	2	3	5	8	4	5	12	15	8	10	15	18	10	15	25	30	30	40	50	60	0·14
7·5k	2	2	3	4	8	4	5	10	15	10	15	20	25	30	50	>50			>50			0·085
20k	2	2	3	4	8	3	4	8	10	8	10	15	18	7	10	15	20	20	25	40	45	0·085

determine the most suitable load line for the active elements. The d.c. component reduces the accuracy a little at low frequencies but mostly this will not be greater than 5%. At a frequency of 1 kHz the full rating of the particular winding can be approached without any significant reduction in the overall accuracy.

For example, the output stage of a push-pull amplifier can be connected across the POWER H and L terminals with the CT terminal connected to h.t. to determine the desired load line.

Table 2.2 shows the approximate amount of direct current which can be applied to the whole of the core i.e., unidirectional current that will cause an error not greater than 5%; with a push-pull arrangement, the error will usually be less.

As the frequency falls less d.c. is acceptable before an additional power error of 5% is incurred. For example, at 20 Hz, with the impedance selector set to 20 kΩ, not more than 2 mA d.c. may be passed.

If power with a d.c. component is applied, then you have to choose the a.c. and d.c. currents so that the total r.m.s. value does not exceed the figure given in the extreme right-hand side of Table 2.2, otherwise the current rating of a particular winding will be exceeded.

Measurement of power by use of the voltmeter section

As the power meter only reads power at frequencies from 20 Hz to 20 kHz, the voltmeter section can be used, if required, to measure power in the range of 10 Hz up to 1 MHz. The circuit used is shown in Fig. 2.2.

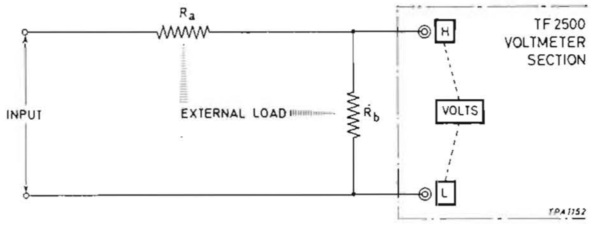


Fig. 2.2 Circuit used for power measurement

For example, if an external load of 2·5 Ω is connected to the VOLTS H and L terminals and with the FUNCTION control switched to VOLTS, the power scale will read correctly when the voltmeter is used to measure the voltage across it. For any other load value it is necessary to provide a composite load consisting of two resistors, the series value of which is the desired load value—the relative values having the relationship

$$R_b = \sqrt{2{\cdot}5(R_a + R_b)} = \sqrt{2{\cdot}5 \times R_L}$$

The load impedances and the corresponding values of R_a and R_b are given in Table 2.3.

When it is required to measure power on the final 25 W range, the shorting link between pin 19 on switch wafer SC3F and pin 18 on SC3B has to be temporarily removed (refer to Fig. 7.2). This link is provided to prevent false readings from being obtained when the instrument is measuring volts in the normal way since the 25 W position is not a 10 dB step.

Using a chart recorder

If required, a d.c. chart recorder can be coupled to the two terminals located at the rear of the instrument after removing the shorting link. (With a high impedance recorder a 100 Ω external load should be used.) An output of 94·4 mV or 0·944 mA d.c. at full-scale (0 dB) deflection is available from these terminals at any position of the RANGE control. It should be noted that the system is balanced and on no account must an earth connection be used. The chart recorder scale should, however, be changed for each power range.

Since a linear voltage chart recorder plots a non-linear graph when used to monitor power, the power must be calculated by the following procedure.

Note the recorder reading, V_F, corresponding to full-scale (0 dB) deflection, P_F, on the power meter. The power, P_I, corresponding to any other reading, V_I, on the recorder is then given by

$$P_I = P_F \left(\frac{V_I}{V_F}\right)^2$$

For example, if the recorder reads 94·4 mV when the power meter is at 1 W full-scale, the power input corresponding to a recorder reading of 80 mV is

$$P_I = 1\ \text{W} \left(\frac{80}{94{\cdot}4}\right)^2 = 0{\cdot}72\ \text{W}$$

Table 2.3

Resistor values for external loads

Z (Ω)	R_a ($R_L - R_b = R_a$) (Ω)	R_b ($\sqrt{2{\cdot}5\ R_L} = R_b$) (Ω)
2·5	0	2·5000
3	0·26140	2·7386
4	0·83770	3·1623
5	1·4645	3·5355
6	2·1270	3·8730
7·5	3·1699	4·3301
10	5·0000	5·0000
12·5	6·9100	5·5902
15	8·8760	6·1237
20	12·929	7·0711
25	17·094	7·9057
30	21·340	8·6603
40	30·000	10·000
50	38·820	11·180
60	47·753	12·247
75	61·307	13·693
100	84·190	15·811
125	107·32	17·678
150	130·63	19·365
200	177·64	22·361
250	225·00	25·000
300	272·61	27·386
400	368·38	31·623
500	464·64	35·355
600	561·27	38·730
750	706·70	43·301
1k	950·00	50·000
1·25k	1194·1	55·902
1·5k	1438·8	61·237
2k	1929·3	70·711
2·5k	2420·9	79·057
3k	2913·4	86·603
4k	3900·0	100·00
5k	4888·0	111·80
6k	5877·5	122·47
7·5k	7363·0	136·93
10k	9841·9	158·11
12·5k	12323	176·78
15k	14806	193·65
20k	19776	223·61

Decibel conversion table

Ratio Down			Ratio Up	
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER
1·0	1·0	·0	1·0	1·0
·9886	·9772	·1	1·012	1·023
·9772	·9550	·2	1·023	1·047
·9661	·9333	·3	1·035	1·072
·9550	·9120	·4	1·047	1·096
·9441	·8913	·5	1·059	1·122
·9333	·8710	·6	1·072	1·148
·9226	·8511	·7	1·084	1·175
·9120	·8318	·8	1·096	1·202
·9016	·8128	·9	1·109	1·230
·8913	·7943	1·0	1·122	1·259
·8710	·7586	1·2	1·148	1·318
·8511	·7244	1·4	1·175	1·380
·8318	·6918	1·6	1·202	1·445
·8128	·6607	1·8	1·230	1·514
·7943	·6310	2·0	1·259	1·585
·7762	·6026	2·2	1·288	1·660
·7586	·5754	2·4	1·318	1·738
·7413	·5495	2·6	1·349	1·820
·7244	·5248	2·8	1·380	1·905
·7079	·5012	3·0	1·413	1·995
·6683	·4467	3·5	1·496	2·239
·6310	·3981	4·0	1·585	2·512
·5957	·3548	4·5	1·679	2·818
·5623	·3162	5·0	1·778	3·162
·5309	·2818	5·5	1·884	3·548
·5012	·2512	6	1·995	3·981
·4467	·1995	7	2·239	5·012
·3981	·1585	8	2·512	6·310
·3548	·1259	9	2·818	7·943
·3162	·1000	10	3·162	10·000
·2818	·07943	11	3·548	12·59
·2512	·06310	12	3·981	15·85
·2239	·05012	13	4·467	19·95
·1995	·03981	14	5·012	25·12
·1778	·03162	15	5·623	31·62

Decibel conversion table *(continued)*

Ratio Down VOLTAGE	*Ratio Down* POWER	DECIBELS	*Ratio Up* VOLTAGE	*Ratio Up* POWER
·1585	·02512	**16**	6·310	39·81
·1413	·01995	**17**	7·079	50·12
·1259	·01585	**18**	7·943	63·10
·1122	·01259	**19**	8·913	79·43
·1000	·01000	**20**	10·000	100·00
·07943	6·310 x 10^{-3}	**22**	12·59	158·5
·06310	3·981 x 10^{-3}	**24**	15·85	251·2
·05012	2·512 x 10^{-3}	**26**	19·95	398·1
·03981	1·585 x 10^{-3}	**28**	25·12	631·0
·03162	1·000 x 10^{-3}	**30**	31·62	1,000
·02512	6·310 x 10^{-4}	**32**	39·81	1·585 x 10^{3}
·01995	3·981 x 10^{-4}	**34**	50·12	2·512 x 10^{3}
·01585	2·512 x 10^{-4}	**36**	63·10	3·981 x 10^{3}
·01259	1·585 x 10^{-4}	**38**	79·43	6·310 x 10^{3}
·01000	1·000 x 10^{-4}	**40**	100·00	1·000 x 10^{4}
7·943 x 10^{-3}	6.310 x 10^{-5}	**42**	125·9	1·585 x 10^{4}
6·310 x 10^{-3}	3·981 x 10^{-5}	**44**	158·5	2·512 x 10^{4}
5·012 x 10^{-3}	2·512 x 10^{-5}	**46**	199·5	3·981 x 10^{4}
3·981 x 10^{-3}	1·585 x 10^{-5}	**48**	251·2	6·310 x 10^{4}
3·162 x 10^{-3}	1·000 x 10^{-5}	**50**	316·2	1·000 x 10^{4}
2·512 x 10^{-3}	6·310 x 10^{-6}	**52**	398·1	1·585 x 10^{5}
1·995 x 10^{-3}	3·981 x 10^{-6}	**54**	501·2	2·512 x 10^{5}
1·585 x 10^{-3}	2·512 x 10^{-6}	**56**	631·0	3·981 x 10^{5}
1·259 x 10^{-3}	1·585 x 10^{-6}	**58**	794·3	6·310 x 10^{5}
1·000 x 10^{-3}	1·000 x 10^{-6}	**60**	1,000	1·000 x 10^{6}
5·623 x 10^{-4}	3·162 x 10^{-7}	**65**	1·778 x 10^{3}	3·162 x 10^{6}
3·162 x 10^{-4}	1·000 x 10^{-7}	**70**	3·162 x 10^{3}	1·000 x 10^{7}
1·778 x 10^{-4}	3·162 x 10^{-8}	**75**	5·623 x 10^{3}	3·162 x 10^{7}
1·000 x 10^{-4}	1·000 x 10^{-8}	**80**	1·000 x 10^{4}	1·000 x 10^{8}
5·623 x 10^{-5}	3·162 x 10^{-9}	**85**	1·778 x 10^{4}	3·162 x 10^{8}
3·162 x 10^{-5}	1·000 x 10^{-9}	**90**	3·162 x 10^{4}	1·000 x 10^{9}
1·000 x 10^{-5}	1·000 x 10^{-10}	**100**	1·000 x 10^{5}	1·000 x 10^{10}
3·162 x 10^{-6}	1·000 x 10^{-11}	**110**	3·162 x 10^{5}	1·000 x 10^{11}
1·000 x 10^{-6}	1·000 x 10^{-12}	**120**	1·000 x 10^{6}	1·000 x 10^{12}
3·162 x 10^{-7}	1·000 x 10^{-13}	**130**	3·162 x 10^{6}	1·000 x 10^{13}
1·000 x 10^{-7}	1·000 x 10^{-14}	**140**	1·000 x 10^{7}	1·000 x 10^{14}

Chapter 3

Technical description

3.1 GENERAL

Functionally the A.F. Power Meter TF 2500 provides 40 load values by the use of an auto-transformer, switched by a Selector control and a Multiplier control designated IMPEDANCE. The output is applied to a voltmeter calibrated in terms of power. A simplified functional diagram is given in Fig. 3.1.

The instrument consists of two separate circuits—(a) the power section and (b) the voltmeter section which can be seen in schematic form in Fig. 3.2 and Fig. 3.3 respectively.

The power section comprises the auto-transformer with its load and copper compensation resistors, voltage correction for impedance change and coupling compensation while the voltmeter section consists of the input (coarse) and inter-stage (fine) attenuators, amplifiers and indication: these two sections are given in circuit diagrams Fig. 7.1 and Fig. 7.2 respectively.

It is intended that the description given in the circuit summary below should be read in conjunction with the schematic diagrams and reference should be made to the overall circuit diagrams at the back of the manual when reading the more detailed information in the subsequent sections.

3.2 CIRCUIT ANALYSIS

Impedance selection is effected by means of an auto-transformer, T1, which is connected to the input terminals via a 10-position switch SB1B and SB2B. The transformer taps act as a range multiplier with a series of resistors to give the various impedance values and correct level response to feed the voltmeter over so wide a frequency range.

The transformer is isolated from the case and is provided with a centre-tap for push-pull working and balanced measurements. This centre-tap also allows impedances down to 0·625 Ω to be obtained, but with some falling off in performance. A thermistor, TH1, located on the transformer assembly, is employed to compensate for ambient temperature over the range of $+10°C$ to $+35°C$.

The audio signal arriving at the input to the voltmeter section is passed, via the input (coarse) attenuator, to a bootstrap amplifier consisting of transistors, VT1 to VT4, whose output is switched by the inter-stage (fine) attenuator. Further amplification is provided by the transistors, VT5 to VT8 and the output taken from the junction of VT7 and VT8 to the meter indication consisting of a full wave bridge detector, MR4 to MR7, and the meter, M1.

3.3 POWER SECTION

The audio source under test is connected to the POWER H and L input terminals as shown in Fig. 3.2 which are connected via the two IMPEDANCE controls to the windings of the auto-transformer, T1. Impedance selection is effected by T1 whose windings are divided into two groups, each of

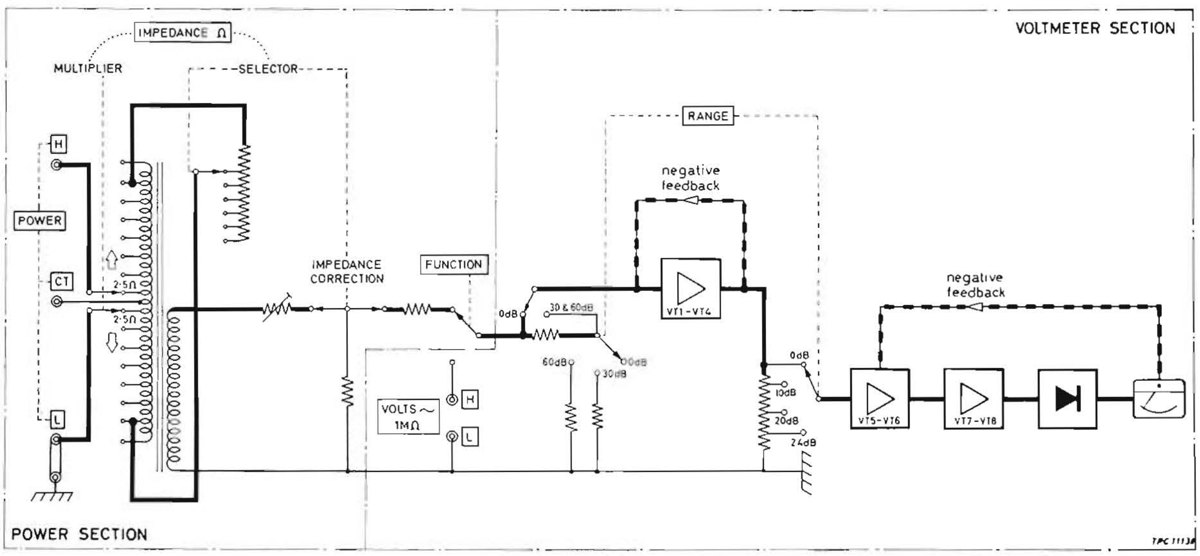


Fig. 3.1 Functional diagram

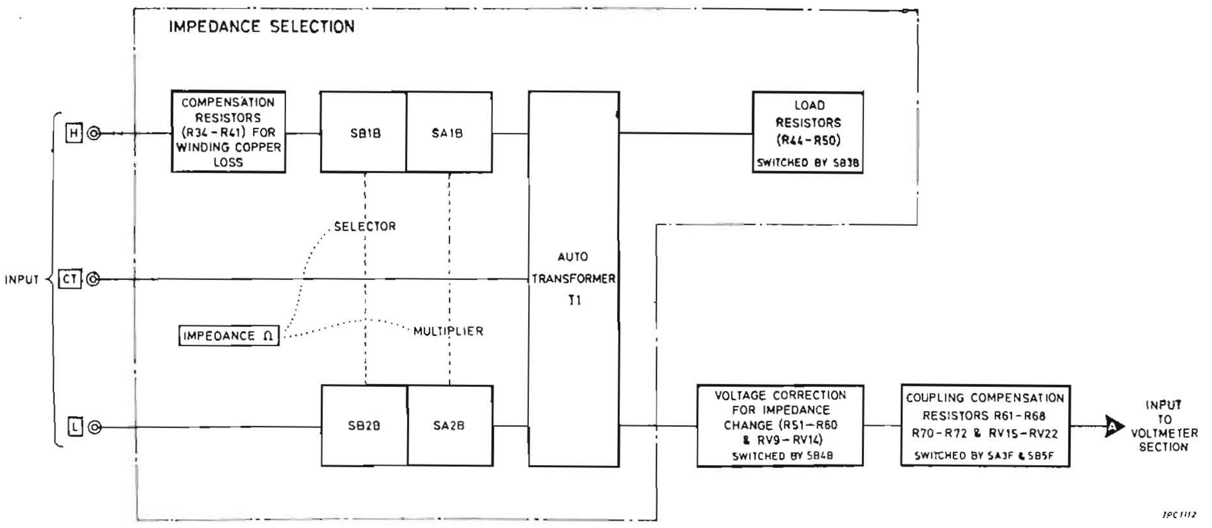


Fig. 3.2 Block diagram of power section

eight taps (and with one centre-tap, CT) and switched by the wafers SA1B/SB1B and SA2B/SB2B.

The first group of impedances, 2·5 to 6 Ω, are obtained by selecting the load resistors R44 to R48, the second group of impedances, 7·5 to 20 Ω, are obtained by selecting the resistors R45 to R50 and so on up to 20 kΩ.

Resistors R34 to R41 compensate for copper losses in the transformer while resistors R44 to R50, switched by SB3B, change the load on the transformer. A voltage is provided by a tertiary winding and correction factors are applied for the impedance in use and the transformer coupling.

Potentiometers RV9 together with RV10 to RV14 and the resistors R51 to R63 form the impedance correction attenuator which also compensates for copper losses in the transformer. This configuration produces the same voltage for a given power at any impedance setting.

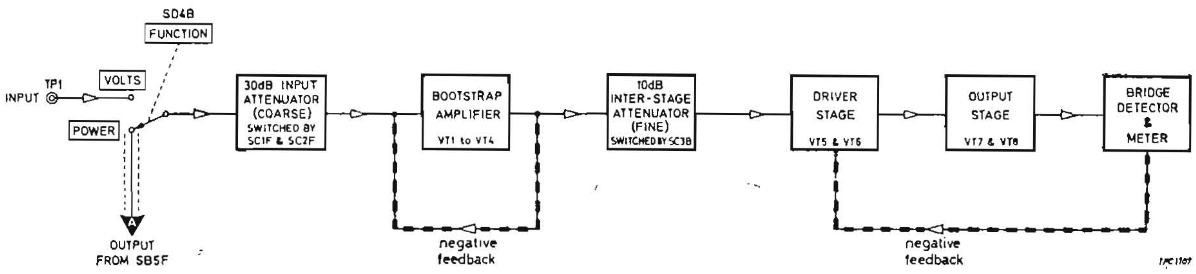
Coupling and frequency compensation is effected by the variable potentiometers RV15 to RV22, the resistors R64 to R68, R70 to R72 and the capacitors C29 and C32, these being switched by the wafers SA3F and SB5F. C26 compensates at low frequency (20 Hz to 35 Hz).

The thermistor TH1 provides ambient temperature correction over the range of +10°C to +35°C, the degree of compensation being governed by the resistor R62.

The voltage appearing on the switch wafer SB5F is taken to the voltmeter section.

3.4 VOLTMETER SECTION

The 60 dB input attenuator is a three-stage attenuator switched by the switch wafers SC1F and SC2F as shown in Fig. 3.3. The front end (coarse) attenuator is capacitance compensated and operates in three steps, giving a total attenuation of 60 dB. In the first three positions of the switch no attenuation is obtained, the next four positions provide 30 dB attenuation and the final three positions provide the 60 dB.



Front end attenuator

Positions	*dB*
1, 2 and 3	0
4, 5, 6 and 7	30
7, 8, 9 and 10	30

Inter-stage attenuator

Positions	*dB*
1, 4 and 8	0
2, 5 and 9	10
3, 6 and 10	20
7	24 (approx.)

Fig. 3.3 Block diagram of voltmeter section

The input resistors, R3 to R5 are switched in to obtain the desired attenuation: R2 maintains the input impedance in the first three positions.

The audio input, arriving at the TP1 terminal on the front panel, is passed via the coarse attenuator and capacitor C5 to a bootstrap amplifier consisting of VT1 to VT4. The d.c. voltage levels throughout the amplifier are determined by the resistor network R9 and R6.

VT1 is directly coupled to VT2 and VT3 which are arranged as a long-tailed pair amplifier. Negative feedback is applied to the base of VT3 to maintain constant the gain and frequency response. MR1 and MR2 are protection diodes to protect VT1, VT2 and VT3.

The output from the emitter follower, VT2, is fed to a further amplifier, VT4, whose output is switched by the inter-stage (fine) attenuator comprising switch wafer SC3B and the resistor network R16 to R19, and R21 and the variable potentiometers RV3 to RV7. The long-tailed pair, VT2 and VT3, together with VT4, form the first three stages of amplification.

The inter-stage (fine) attenuator operates in steps of 10 dB, except on position 7 (i.e., the 25 W position of the RANGE control) where an attenuation of approximately 24 dB is obtained. Positions 1, 4 and 8 provide straight through connections and consequently, no attenuation is obtained. On positions 2 and 3, steps of 10 dB and 20 dB are obtained; this sequence is repeated on positions 5, 6, 9 and 10 respectively.

The output from the long-tailed pair, VT5 and VT6, is taken to a pnp-npn stage, VT7 and VT8: VT5 and VT6 acting as a driver stage, VT7 as the output stage and VT8 as a load. The junction of the collectors of VT7 and VT8 serves as the output to feed the bridge detector consisting of the diodes MR4 to MR7 and the meter, M1. The meter is included in the negative feedback line to the base of VT6.

An h.t. supply of 18 V, derived from two separate 9 V internal batteries, BT1 and BT2, is used to power the instrument.

A simple stabilizer circuit, consisting of VT9 as series control transistor with the reference voltage being provided by MR8, maintains the supply line to amplifier circuits constant. VT10 is connected as a diode to provide protection against polarity reversal.

The FUNCTION switch, SD, has four positions which enables the instrument to be switched for measuring either (a) POWER, (b) VOLTS or (c) BATTERY CHECK; the fourth position switches the instrument OFF. In position 2, switch wafer SD2F changes over the meter to check the battery. SD3F switches the resistor R74 across the amplifier output when the meter is out of circuit. When the FUNCTION control is switched to the VOLTS position and the RANGE control is switched to the 25 W position, SD1F and SC3F short out the signal path and prevent voltage indication from being obtained on the meter. MR8 provides protection from reversal of battery polarity.

Two test points, TP1 and TP2, are provided on the Amplifier Board, TM 9348 (i.e., in the voltmeter section, refer to Fig. 7.2). They are used when calibrating the instrument, initially, during the setting-up period but their main function is to check the stability of the instrument.

Two terminals are provided at the rear of the instrument to enable a d.c. chart recorder to be coupled after removing the shorting link LK2, connecting TP6 and TP7: this link is in series with the meter (refer to Chap. 2).

Chapter 4

Maintenance

4.1 GENERAL

This chapter is intended as a general guide to the maintenance and repair of the instrument. In case of difficulties, please contact our Service Division at the address on the back cover or your nearest Marconi Instruments representative.

Screw fasteners

Screw threads used on this instrument are of the following sizes: 2BA, 4BA and 6BA.

4.2 POWER SUPPLY

Two 9 volt self-contained internal dry batteries, type DT9 are used to power the instrument: current drain is less than 18 mA average. These batteries are mounted on a tray, inside the battery container, at the rear of the chassis and can be easily withdrawn for replacement.

When connecting the batteries, make sure that the positive and negative sides are connected to the correct terminals.

4.3 SAFETY PRECAUTIONS

This instrument uses semiconductor devices which, although having inherent long-term reliability and mechanical ruggedness, are susceptible to damage by overloading, reversed polarity and excessive heat or radiation. Avoid hazards such as reversal of batteries, prolonged soldering, strong r.f. fields or other forms of radiation, use of insula-

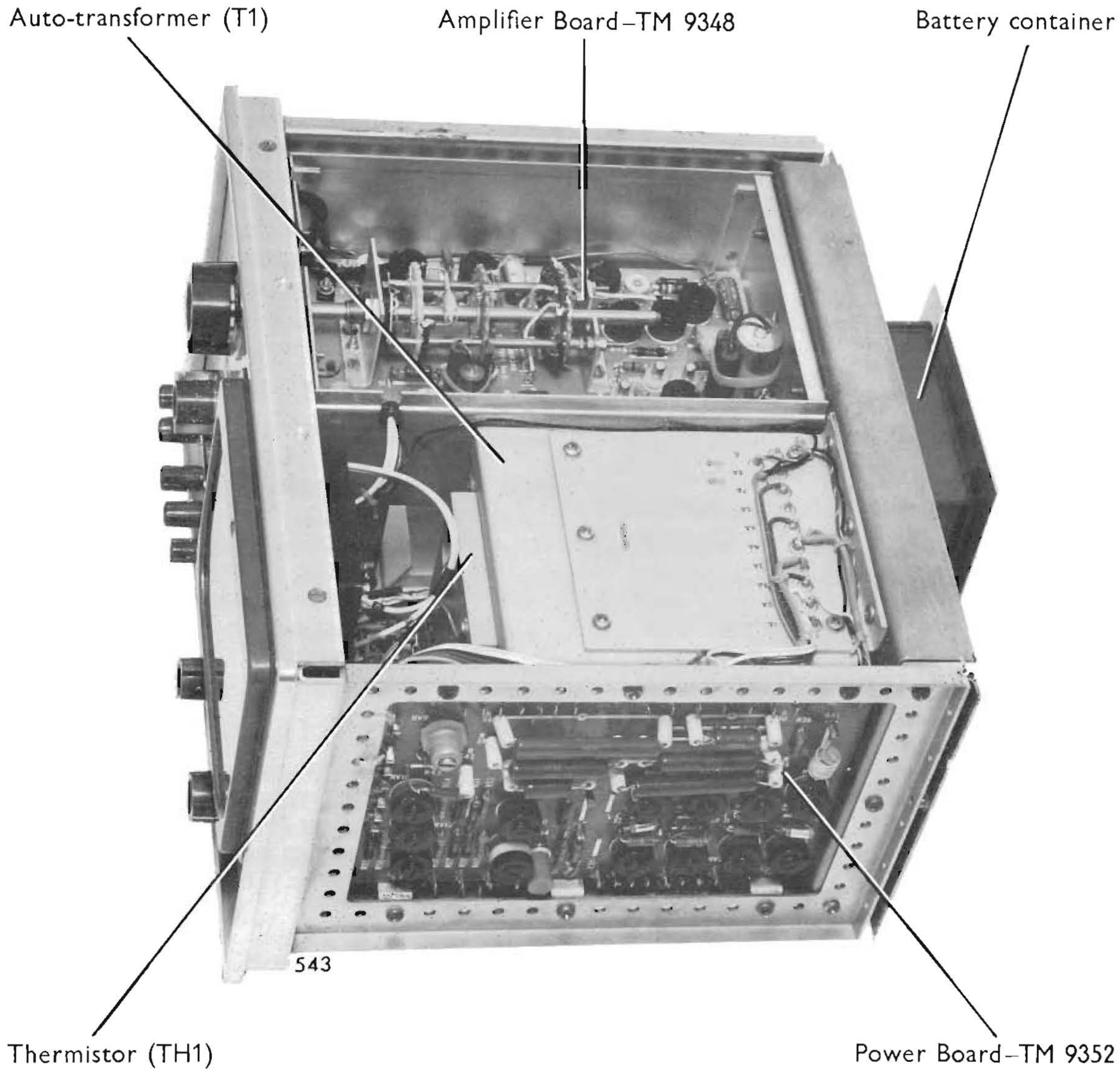


Fig. 4.1 Location of sub-assemblies

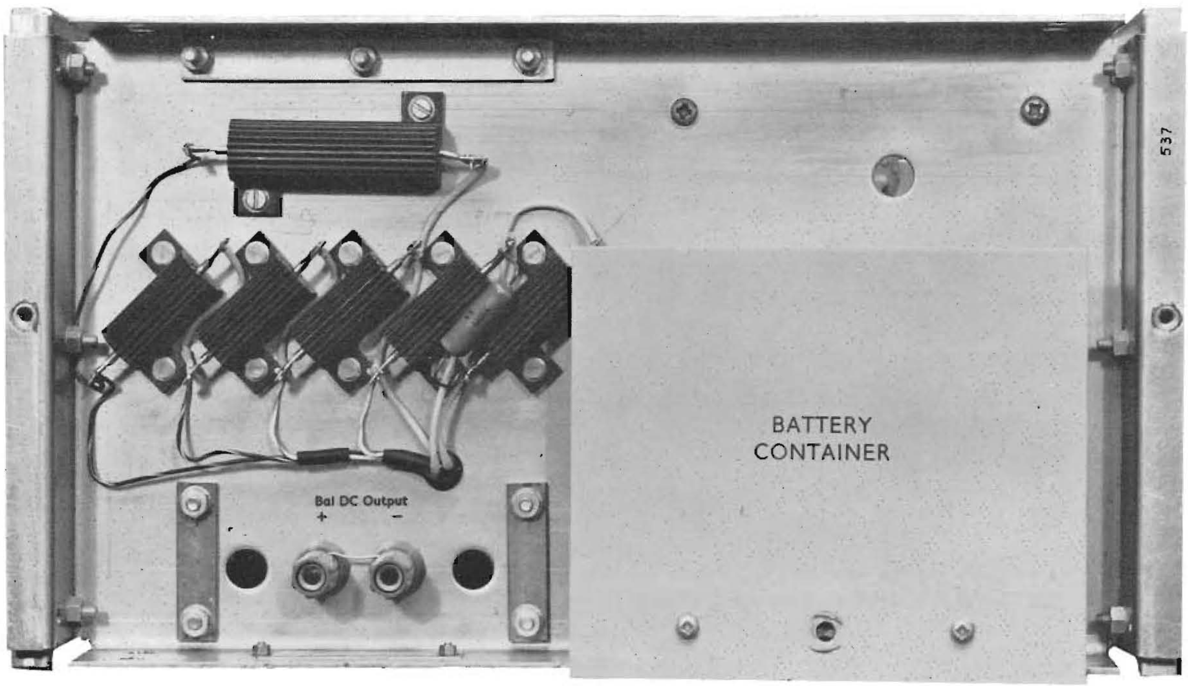


Fig. 4.2 Location of power absorbtion resistors on rear panel

tion testers, or accidentally applied short-circuits. Even the leakage current from an unearthed soldering iron could cause trouble. Before shorting or breaking any circuit, refer to the circuit diagrams to establish the effect on bias arrangement on the transistors.

Power

Before measuring power, it is advisable to set the RANGE control to the 25 WATT position to avoid the possibility of overloading the meter.

Voltage

Before measuring voltage, it is advisable to set RANGE control to the 150 VOLT position to avoid the possibility of overloading the meter.

4.4 ACCESS AND LAYOUT

4.4.1 Mechanical construction

The instrument is housed in a standard $\frac{2}{3}$ module case and has no conventional chassis. The framework takes a rectangular design consisting of a front panel, on which are mounted the various controls, input terminals and the meter; a rear chassis (or panel) on which are mounted the power absorption resistors and the balanced d.c. output terminals; and the two side panels (or brackets). A cut-out in the rear panel houses the battery container.

The amplifier printed board is located inside its own amplifier box, which is mounted on the inside face of the rear panel, and has a top plate. The auto-transformer is also mounted on the inside face of the same panel while the power printed board is supported on small brackets attached to one of the side panels.

The instrument case fits over the whole framework to make up the complete unit.

The general location of these sub-assemblies is shown in Fig. 4.1 and 4.2.

4.4.2 Removal of instrument case

(1) Place the instrument upside down on its front panel.
(2) Release the knurled captive screw from the battery container, slide out the container from the runners with the batteries still in situ and remove the battery connectors.
(3) Take out the two 4BA screws retaining the case, remove the back cover and then lift off the case from the instrument.

4.4.3 Removal of batteries

Take out the knurled captive screw from the battery container, and whilst partially sliding out the container from the runners, unclip the battery connectors and then completely slide out the container. The batteries can now be removed.

4.4.4 Removal of amplifier printed board—TM 9348

(1) Remove the top lid from the amplifier box.
(2) Slacken the grub screw retaining the RANGE

control and skirt from the spindle of the switch assembly.
(3) Take out the four 6BA screws securing the printed board onto the main chassis.
(4) Take out the four 6BA screws securing the switch assembly onto the printed board.
(5) Lift off the printed board.

4.4.5 Removal of RANGE switch assembly with amplifier printed board in situ

(1) Slacken the grub screw securing the RANGE control and skirt from the spindle of the switch assembly.
(2) Unsolder all the connections to the switch assembly and take out the two 6BA nuts and washers securing the switch assembly to the small rear bracket.
(3) Remove the brass hexagon nut from the switch shaft and lift off the switch assembly.

4.4.6 Removal of power board—TM 9352

(1) Unsolder all connections to the printed board.

CAUTION

All wiring to this printed board has been specifically made as short as practical, hence great care must be taken not to damage the insulation during unsoldering.

(2) Take out the six 6BA screws securing the printed board onto the main chassis.
(3) Lift off the printed board.

4.4.7 Removal of thermistor assembly (TH1)

(1) Remove the two leads from the back of the front panel meter and take out the two 4BA screws securing the meter to the front panel. Withdraw the meter from the front of the panel.
(2) Unsolder the two connections to the thermistor assembly block.
(3) Take out the four 4BA screws securing the block to the transformer assembly and remove this block together with retaining spring (the spring is located between the metal block and the face of the insulator block on which the thermistor is wired).
(4) Unsolder the wires securing the thermistor and remove thermistor.

4.4.8 Removal of auto-transformer (T1)

(1) Remove the front panel meter; refer to 4.4.7(1).
(2) Unsolder the two connections to the thermistor assembly block.
(3) Remove the top lid from the amplifier box.
(4) Remove the rubber grommet, securing the cableform, out of the slot and push cableform well clear of the transformer e.g., towards and into the amplifier box.
(5) Unsolder all connections to the terminals of the transformer.
(6) Place the instrument upside down with the front panel pointing away from you.
(7) Take out the seven 4BA nuts, washers and screws together with the metal strips securing the transformer onto the rear panel.
(8) Remove the transformer away from the main framework.

To replace the transformer, reverse the above procedure ensuring that the metal strips are in position.

4.5 TEST POINT LOCATION AND DATA

Two test points, 1 and 2 are provided on the Amplifier Board, TM 9348. These test points are used for checking the stability of the instruments. If the stability is suspected, the two sections of the amplifier can be checked by applying a 5 kHz 15 mV square wave into terminal TP1 and observing the waveform at test points 1 and 2 (refer to Chap. 5).

4.6 OVERALL TESTS AND ADJUSTMENTS

The tests in this chapter may be used as a routine maintenance procedure to verify the main performance parameters of the instrument. Most of the tests can be completed without removing the case, except where some internal readjustment is indicated; refer to Chap. 5 for these additional tests.

4.6.1 Test equipment required

(a) Standard d.c. power supply giving an output voltage of 13 V to 18 V.
(b) Wide range oscillator, e.g. **mi** type TF 1370A.
(c) Wide band sensitive valve voltmeter having an accuracy of ±0·25% with a frequency range of 10 Hz to 1 MHz.
(d) Differential a.c. and d.c. voltmeter having an accuracy of ±0·1%.
(e) Universal bridge measuring resistance at 1 kHz e.g. **mi** type TF 2700.
(f) 50 W a.f. amplifier, 0·1% distortion at 1 kHz, output impedance 5 Ω to 40 kΩ.
(g) Series load box consisting of 1% wire wound resistors and potentiometers, switched in various series combinations to give 2·5, 3, 4, 5, 6, 7·5, 8, 10, 12·5, 15 or 20 Ω; ×1, ×10, ×100 and ×1 000. Standardizing resistors and potentiometers are connected to each main resistor to give an accuracy of ±0·1% with maximum power input of 25 W.

(h) A.F. oscillator, e.g. **mi** type TF 2100.
(i) Response load box giving nominal resistance values of 2·5, 20, 25, 200 and 250 Ω, 2 kΩ, 2·5 kΩ and 20 kΩ to dissipate 100 mW.
(j) Voltage divider consisting of a series resistor of 414 kΩ ± 0·1 % shunted by a preset capacitor of 40 pF for use with **(d)** to extend voltage range to 1414·2 V.

4.6.2 Battery check and standing reading

Test equipment: a

(1) Set the mechanical zero on meter. Substitute the external power supply and switch the FUNCTION control on the power meter to BATT CHECK position.
(2) Set the external power supply to 13 V, switch on and check that the meter reads at the MIN mark. Set the external power supply to 18 V and check that the meter reads at the 18 V mark.
(3) Reset both the sensitive valve voltmeter and the power meter to the 500 mV range, set the power supply to 13 V and 18 V in turn and note that the reading does not change by more than 1·5 mV.

4.6.3 Voltmeter scale shape

Test equipment: a, c and d.

Apply a power supply of 14 V to the power meter and check the scale voltage on each of the nine voltage ranges using a 1 kHz signal. By comparison check the readings obtained on the power meter against the differential voltmeter. In addition check the cardinal points of the voltage scales.

Using the sensitive valve voltmeter, the frequency response of the voltmeter section can be checked. At frequencies below 50 Hz use the differential voltmeter instead of the sensitive valve voltmeter.

4.6.4 Power meter impedance check

Test equipment: e measuring R at 1 kHz.

(1) Connect the test equipment as shown in Fig. 4.3.

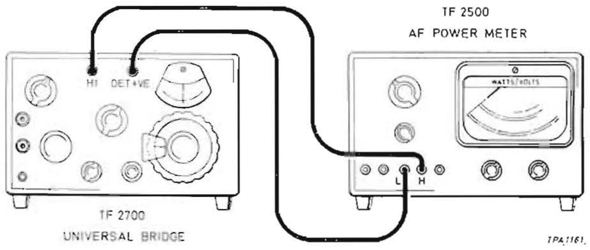


Fig. 4.3 Power meter impedance check

(2) Set the Power Meter Function switch to the OFF position and the IMPEDANCE controls to 2·5 and ×1.
(3) Measure impedance at 1 kHz.

Note: *The impedance must be within ±4%.*

(4) Repeat the above operations for all the impedance ranges.

4.6.5 Voltmeter accuracy

Test equipment: a and d.

Check voltage readings on each of the nine voltage ranges against the differential voltmeter. If a significant error is recorded, refer to Chap. 5.

4.6.6 Power accuracy

Test equipment: a, d, f, g and h.

(1) Connect the test equipment as shown in Fig. 4.4. The series load must equal the impedance setting of the power meter.
(2) The reading of the differential voltmeter (Vo) must be within $\pm 2\frac{1}{2}\%$ of the values given in

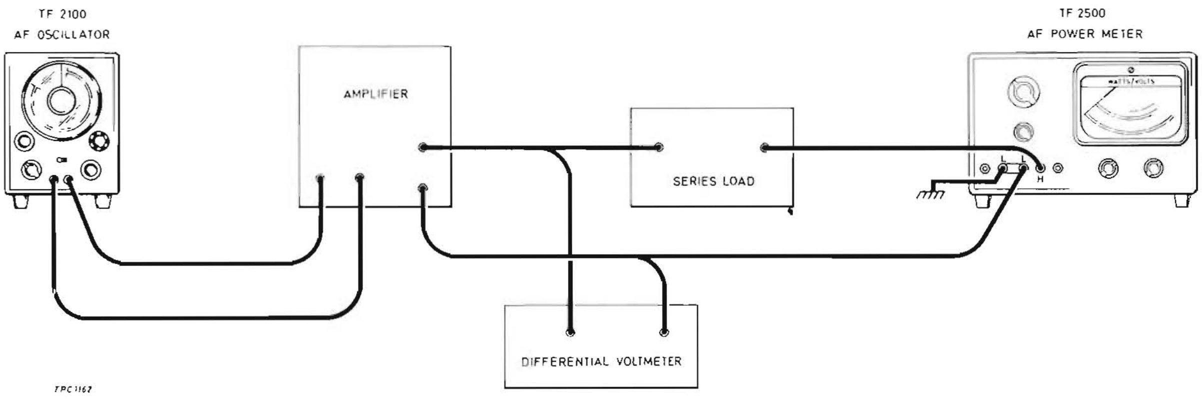


Fig. 4.4 Test gear to check power accuracy

Table 4.1

Impedance (Ω)	*Voltage required (Vo)* *100 μW*	*1 mW*	*10 mW*	*10 W*	*25 W**
2·5	31·623 mV	100·00 mV	316·23 mV	10·000 V	15·811 V
20	89·440 mV	282·84 mV			44·721 V
2·5 × 10	100·00 mV	316·23 mV			50·000 V
20 × 10	282·84 mV	894·40 mV			141·42 V
2·5 × 100	316·23 mV	1·0000 V			158·11 V
20 × 100	894·40 mV	2·8280 V			447·21 V
2·5 × 1000	1·0000 V	3·1623 V			500·00 V
20 × 1000	2·8280 V	8·9440 V			1414·2 V

* *If any 25 W ranges are inaccurate re-adjust RV7 (Refer to Chap. 5)*

Table 4.1 at the impedance settings given, with full scale deflection of the power meter on power ranges 100 μW, 1 mW, 10 mW, 10 W and 25 W.

Note: *Caution must be taken at the higher voltages and the amplifier gain reduced to zero when changing ranges on the power meter, amplifier and the load box.*

For voltages above 1000 V, connect the voltage divider between the voltmeter (or a.c./d.c. converter) and amplifier with the voltmeter connected to 1000 and amplifier to pair of terminals corresponding to voltage to be measured.

To check the accuracy at other impedances use the same method but calculate the differential voltmeter reading, Vo, from the expression $Vo = 2\sqrt{PR}$,

where P = power range
and R = impedance setting of power meter and series load.

For example, with the power meter (and series load) set to 5Ω × 10 on the 25 W range, the differential voltmeter reading should be $2\sqrt{25 \times 50} = 70{\cdot}7$ V.

4.6.7 Power meter frequency response

Test equipment: a, d, f, h and i.

(1) Set the amplifier GAIN to zero.
(2) Replace the switched load box by the response load box (limited to 350 mW).
(3) Set the Power Meter RANGE control to 1 mW and the IMPEDANCE controls to 2·5 Ω and ×1.
(4) Swing the a.f. oscillator frequency down to 20 Hz and then sweep up to 20 kHz pausing at 30 Hz to 60 Hz and noting the response, adjusting the GAIN of the amplifier as necessary to keep the differential voltmeter to zero: the response must be within ±0·5 dB from 20 Hz to 20 kHz.
(5) Repeat the above operation at 20 Ω and multiples of 2·5 and 20 Ω, resetting gain load box and voltmeter as necessary.
(6) Reset the amplifier gain to zero and set the power meter RANGE control to 100 μW.
(7) Set up for 0 dB at 1 kHz (31·623 mV approximately) and 20 kΩ, the response must be within ±0·5 dB from 40 Hz to 20 kHz and ±1·0 dB between 20 and 40 Hz.

4.7 CLEANING AND LUBRICATING

Switch contacts

If it is necessary to clean the contacts of the rotary switches, this should be done as follows:

(1) The contacts on the plastic wafer on the RANGE switch should be cleaned with denatured ethyl alcohol. If this is not available Genklene or Arklone (both I.C.I. products) may be used. Do not use any lubricant.
(2) The other switch wafers should be cleaned with white spirit (not carbon tetrachloride) and the contacts wiped afterwards with a suitable lubricant such as a 5% solution of petroleum jelly in white spirit.

Chapter 5

Repair

5.1 GENERAL PRECAUTIONS

The instrument uses semiconductor devices which, although having inherent long-term reliability and mechanical ruggedness, are susceptible to damage by overloading, reversed polarity, and excessive heat or radiation. Avoid hazards such as reversal of batteries, prolonged soldering, strong r.f. fields or other forms of radiation, use of insulation testers, or accidentally applied short-circuits.

Before measuring power, it is advisable to set the RANGE control to the 25 W position to avoid the possibility of overloading the meter.

Before measuring voltage, it is advisable to set the RANGE control to the 150 V position to avoid the possibility of overloading the meter.

To maintain the performance of the instrument at high humidity, the copper track side of the Amplifier Board TM 9348 is covered with an anti-tracking coating. This will not hinder removal or replacement of components but, as the action of soldering will destroy the coating locally, it should be replaced by brushing with DP 2621 which is available from Midland Silicones Ltd. The whole of capacitor C3 is treated similarly and, if replaced, it must be dipped in the same material before fitting.

5.2 FAULT LOCATION

Before attempting to locate a fault you should be familiar with the circuit functions as described in Chap. 3, and with the operating procedure so that all controls are at their correct setting.

The general procedure in fault location is first to trace the trouble to a particular section, bearing in mind that the a.f. power meter is a combined audio wattmeter and a voltmeter; the overall circuit diagrams, Fig. 7.1 and 7.2, will be found useful for this purpose.

Having identified the faulty section, first look for obvious signs of failure such as damaged components or printed boards, burnt-out resistors and other overheating symptoms or flash over marks.

Check for intermittent contact in joints or switches by noting the changes in performance caused by gently tapping the joints with an insulated prod. The remedy for most of these defects is obvious but it is important to determine the cause of heat damaged parts before replacing them, in order to prevent further damage.

More systematic fault location can be performed by checking the voltages given in Table 5.1 or by carrying out the appropriate parts of the test procedure given in this chapter.

5.3 CIRCUIT VOLTAGES

The following voltages measured with respect to chassis, using a 20 kΩ/V meter are those which may be expected on a typical A.F. Power Meter type TF 2500, using two 9 V dry batteries, type DT9.

Table 5.1

Transistor terminals

Transistor	*Emitter (V)*	*Base (V)*	*Collector (V)*
VT1	—	—	11·0
VT2	5·4	—	10·2
VT3	5·4	6·0	11·0
VT4	11·0	10·2	6·0
VT5	5·5	6·0	10·2
VT6	5·5	6·0	11·0
VT7	11·0	10·2	6·5
VT8	2·6	3·2	6·5
VT9	0	−0·5	−1·6 to −6·7
VT10	13 to 18	12·7 to17·5	12·7 to 17·5

5.4 ADJUSTMENT AND CALIBRATION

During factory calibration, certain of the performance characteristics of the power meter are brought within close limits by means of preset components.

Following replacement in certain parts of the circuit, it is essential, if the performance is not to be impaired, to repeat the calibration procedure by which the preset components were adjusted.

Refer to Section 4.6.1 for the list of test equipment used.

5.4.1 Voltmeter calibration

Test equipment: a, b and d.

(1) Set the power supply to 14 V and connect the oscillator and differential voltmeter to the VOLTS H and L terminals on the power meter.
(2) Set the power meter FUNCTION switch to VOLTS and the RANGE control to 0·015 V. Set the oscillator to 1 kHz to give 15·81 mV as indicated on the differential voltmeter.
(3) Adjust RV8 for a meter reading of 1 mW on the power scale. (Setting up against the voltmeter scales may impair the power measuring accuracy, which is the principal function of the instrument.)
(4) Set the RANGE control to 0·05 V and, with an input of 5 mV, adjust RV4 for a meter reading of 1 mW.
(5) Repeat the procedure on the remaining ranges

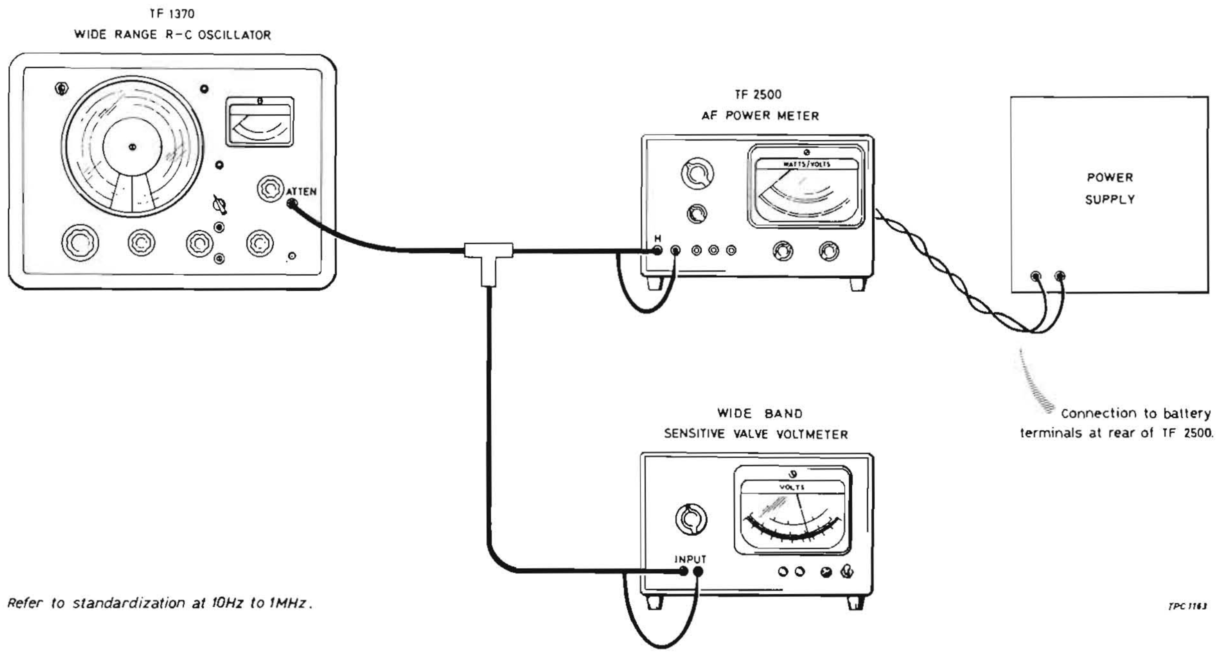


Fig. 5.1 Test gear for voltmeter frequency response

using the following inputs and adjusting each potentiometer for a meter reading of 1 mW. Note that no adjustment is provided on the last two ranges—check that the reading is accurate to within about ±1%.

Range	*Input*	*Adjust*
0·15 V	158·1 mV	RV6
0·5 V	0·5 V	RV1
1·5 V	1·581 V	RV3
5 V	5 V	RV5
15 V	15·81 V	RV2
50 V	50 V	—
150 V	158·1 V	—

5.4.2 Voltmeter frequency response

Test equipment: a, b and c.

(1) Connect the test equipment as shown in Fig. 5.1.

(2) Set the power meter FUNCTION switch to VOLTS and the RANGE control to 0·015 V.

(3) Set the wide range oscillator to 1 kHz and its output volts selector to 30 mV range. Adjust the oscillator output for a reading of 15 mV on the power meter. Note reading on the sensitive valve voltmeter.

(4) Swing the frequency continuously through the bands 10 Hz to 1 MHz noting any changes of reading on the power meter and checking, via the sensitive valve voltmeter, that the level of the wide range oscillator output does not change with frequency, compensating with SET OUTPUT if necessary.

(5) Set C22 to mid-travel and with the input frequency at 1 MHz adjust C11 for full-scale reading on the 15 mV range. If in step 4 there was a dip in the frequency response, recheck the point at which it occurred and, if the response has not been sufficiently flattened, readjust C22 to the position that gives the best compromise to the frequency response. The overall frequency response must be within ±2% of f.s.d. from 20 Hz to 200 kHz, ±3% from 20 Hz to 1 MHz and typically ±4·0% at 10 Hz.

(6) Set the power meter to 50 mV range, reset the wide range oscillator to 1 kHz and adjust output for a reading of 50 mV on the power meter. Sweep through the frequency range as before. Adjust C13 at 1 MHz on the 150 mV range, if necessary, and recheck the 50 mV range.

(7) Repeat for the 15 V range, setting C1 and checking the 50 and 150 V ranges.

(8) Set C3 for the 500 mV range.

(9) Check the 1·5 V and 5 V range and reset C3, if necessary, to compensate for errors.

5.4.3 Power meter impedance check

Before power calibration can be carried out, the input impedance should be checked as given in Chap. 4.

5.4.4 Power calibration

Test equipment: a, d, f, g, h and j.

(1) Connect the test equipment as shown in Fig. 5.2.

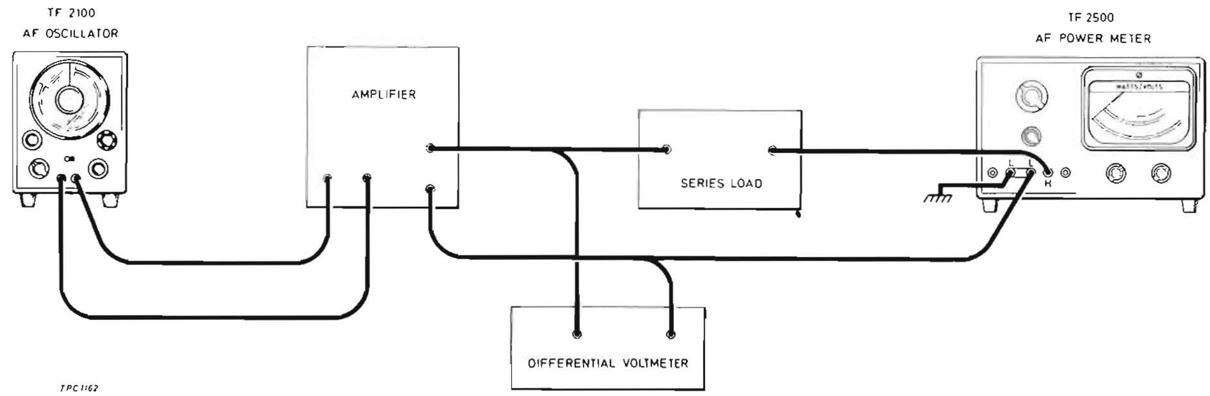


Fig. 5.2 Test gear for power calibration

(2) Switch amplifier on, set GAIN to minimum, set switched load box to 2·5 and × 1000, set power meter FUNCTION switch to POWER, IMPEDANCE switches to 2·5 and × 1000, set the oscillator to give 1 kHz and 1 V output and set Impedance range on amplifier to the required position.
(3) Adjust amplifier GAIN for a reading of 100 V on the differential voltmeter and set all power setting potentiometers, RV7, RV9 to RV21, to mid-travel.
(4) The following adjustments are made at 1 W and the h.t. switch on the amplifier must be turned off before making any impedance change.
(5) Set to 2·5 kΩ and apply 100 V: set R22 for maximum.
(6) Set to 2·5 kΩ and apply 100 V: set RV9 to give −0·984 W.
(7) Set to 2·5 Ω and apply 3·1623 V: set RV19 to give +1·016 W.
(8) Set to 6 Ω and apply 4·899 V: set RV11 to give −0·984 W.
(9) Set to 6 kΩ and apply 154·92 V: check reading.

Note: *The figures 0·984 W and 1·016 W are approximate only and can thus be estimated directly by eye.*

(10) Set to 3 Ω and apply 3·464 V: set RV14 for f.s.d.
(11) Set to 4 Ω and apply 4·0 V: set RV13 for f.s.d.
(12) Set to 5 Ω and apply 4·472 V: set RV12 for f.s.d.
(13) Set to 12·5 Ω and apply 7·0711 V: set RV15 for f.s.d. + 1%.
(14) Set to 20 Ω and apply 8·944 V: set RV15 for f.s.d.
(15) Set to 40 Ω and apply 12·649 V: set RV20 for f.s.d.
(16) Set to 125 Ω and apply 22·361 V: set RV16 for f.s.d. + 1%.
(17) Set to 400 Ω and apply 40 V: set RV21 for f.s.d.
(18) Set to 1·25 kΩ and apply 70·711 V: set RV17 for f.s.d. + 1%.
(19) Set to 12·5 kΩ and apply 223·61 V: set RV18 for f.s.d. + 1%.
(20) Set to 2·5 Ω and apply 15·811 V: set RV7 for + 1·016 W at 25 W.
(21) Reset to 3Ω and adjust RV14 to give a reading of +1%, i.e. 1·01 W.
(22) Reset to 5Ω and adjust RV12 to give a reading of −1%, i.e. 0·99 W.

Note: *In operations (11) to (19) inclusive, full scale means deflection to the 0 dB mark.*

5.5 FAULT DIAGNOSIS

General procedure

The following checks are a general guide on fault diagnosis in the voltmeter section and power section listing in sequential order, the method to be used and the likely components to suspect.

Voltmeter section

Check for gain

The gain can be checked by applying a 1 kHz, 15 mV sinewave, at the input terminal TP1 and with the RANGE control set to 0·015 (fully counter-clockwise), to measure the volts required at f.s.d. at test point 2 which should be of the order of less than 100 mV.

This method of checking gain tests both sections of the amplifier since 15 mV is normally required at the input terminal, TP1.

Check for waveform distortion

The waveform distortion can be checked by applying a 1 kHz, 15 mV sinewave, at the input terminal, TP1, and monitoring the output of each test point, TP1 and TP2 respectively.

If distortion is noticeable, check such components as transistors, leaky electrolytic capacitors, biasing resistors and emitter/collector resistors.

Check for stability

The stability can be checked by applying a 5 kHz, 15 mV square waveform, at the input

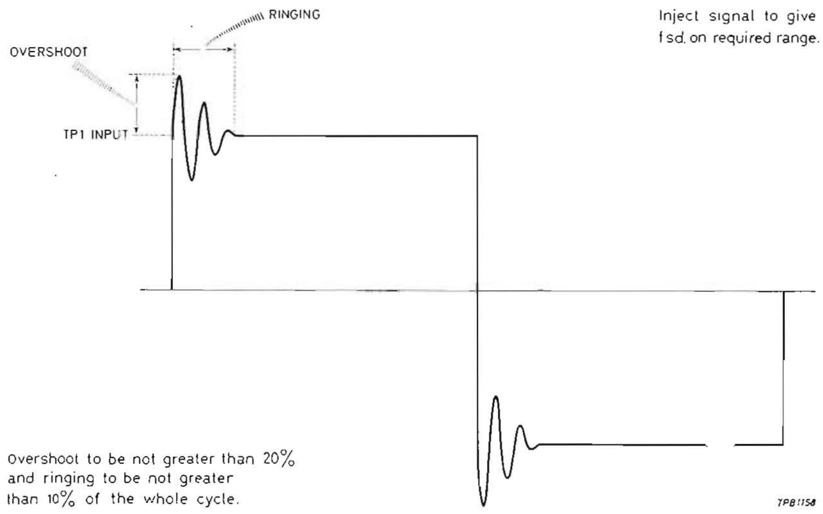


Fig. 5.3
5 kHz, 15 mV square waveform showing overshoot and ringing

terminal, TP1, and with the RANGE control set to 0·015 (fully counter-clockwise), and monitoring the output at test point TP2 by means of a double trace oscilloscope for example, an **mi** type TF 2200A oscilloscope set (Nato Stock Number 6625-99-955-0876) with a dual trace unit TM 6456. The output waveform is shown in Fig. 5.3.

Note: *A suitable signal can be conveniently obtained from the Bright-up terminal and the capacitance of the oscilloscope probe must not exceed 7 pF.*

Adjust the oscilloscope controls so that the output waveform is the same size, and coincides in shape with the input waveform. Check that the overshoot is not greater than 20% and that ringing is not greater than 10% of the whole cycle.

This method of checking stability tests both sections of the amplifier.

If instability still occurs, check the first half section of the amplifier by unsoldering the lead on pin 6 i.e., the lead which connects to pin 20 of switch wafer SC3B and apply a 5 kHz, 15 mV square waveform at the input terminal, TP1, monitoring the output waveform at pin 6.

Check for overshoot and ringing and if these are within limits, the instability can be said to occur in the second section of the amplifier.

The second section of the amplifier can be checked by connecting the lead which had been unsoldered from pin 6 and re-connecting this lead to the junction of a biasing resistor network made up to 51 kΩ and 82 kΩ: the free end of the 82 kΩ resistor being connected to chassis while the other end of the 51 kΩ resistor to a suitable h.t. point on the amplifier.

Apply a 5 kHz, 15 mV square waveform at test point TP1 and monitor the output waveform at test point TP2. If instability is still noticeable, check such components as transistors, capacitor C22 for value and insulation (in the case of the first section, C7), and also the decoupling capacitors.

Check for frequency response

The frequency response can be checked by applying a 1 kHz, 15 mV sinewave, at the input terminal, TP1 and checking that the 15 mV setting is correct at 1 kHz.

Swing the frequency of the wide range oscillator down to 10 Hz and then up to 20 Hz, 200 kHz and 1 MHz keeping the input at the same reference level as at 1 kHz.

Select C10, if necessary (normally 22 pF) and adjust C11 for flattest response. Verify that the response, relative to 1 kHz, is within ±5% for 10 Hz to 20 Hz, ±2% for 20 Hz to 200 kHz, ±3% for 200 kHz.

Repeat the above procedure on all ranges checking that the appropriate trimmer is effective in flattening response. The sequence of adjustment is given in 5.4.2 and in Table 5.2.

Table 5.2

Sequence of adjustment for frequency response

Position of switch	*Order of Adjustment*	*Trimmer*
1	1	C11
2	3	C13
3	2	C13
4	7	C3
5	8	C3
6	9	C3
8	4	C1
9	5	C1
10	6	C1

Position 9 and 10 should have the 1 kHz reference set at the highest level available at 1 MHz.

If the response is found to be poor at 10 Hz and 20 Hz, suspect electrolytic capacitors, particularly C23 and C24.

Compromise setting of the trimmers C1, C3 and C13 may be required.

Power section

For fault diagnosis, the power section can be conveniently divided into two groups (a) the power absorption system and (b) the monitoring system. Faults in the power absorption system are independent of the faults occurring in the monitoring system.

Power absorption system

The power absorption system comprises the auto-transformer, T1, together with the load resistors R44 to R50: these components provide the 40 load impedances which are measured by the use of the **mi** Universal Bridge type TF 2700.

Each impedance can be measured by connecting the universal bridge to the POWER H and L terminals, this checks the load selection switches, the continuity of the load resistors and the transformer.

Resistors R44 to R48 are used in positions 1, 2, 3, 4 and 5 of the Selector switch while resistors R45 to R50 are checked in positions 6, 7, 8, 9 and 10.

If any values of R44 to R48 are found to be incorrect, the load resistors in use for that particular impedance value must be checked for accuracy: also check the appropriate copper loss resistors as detailed below.

Impedance group (Ω)	*Multiplier control at*	*Resistor in circuit*
1 (2·5–6)	×1	None
2 (7·5–20)	×1	R41
3 (25–60)	×10	R40
4 (75–200)	×10	R39
5 (250–600)	×100	R38
6 (750–2k)	×100	R37
7 (2·5k–6k)	×1000	R35 & R36
8 (7·5k–20k)	×1000	R34

Monitoring system

If no output is obtained on the meter and the tests on the voltmeter section and the power section given above are found to be correct, proceed as follows:

Apply a power input of 1 mW at 1 KHz with the power meter set to 2·5 Ω, check for voltage at C1A terminal on the tertiary windings of the auto-transformer, T1, on pin 39 of the power printed board (this reading should be 100 mV) and on pin 6 of the switch wafer SB5F.

Note: *When measuring the voltage on pin 6 of SB5F, take care that the impedance of the voltmeter does not shunt the circuit.*

If the signal at pin 39 is absent at some positions of the Selector switch, SB, check the impedance correction networks R51 to R59. The coupling and frequency correction networks which are operated by SA, together with C25, provide compensation at the higher frequencies. The series capacitor, C26, compensates over the frequency range 20 Hz to 40 Hz.

The compensating networks mentioned above are brought into circuit with the following impedance groups:

Impedance group (Ω)	*Multiplier control at*	*Components in circuit*
1 (2·5–6)	×1	RV19, R68
2 (7·5–20)	×1	RV15, R64
3 (25–60)	×10	RV20, R70, C32
4 (75–200)	×10	RV16, R65
5 (250–600)	×100	RV21, R71
6 (750–2k)	×100	RV17, R66
7 (2·5k–6k)	×1000	RV22, R72
8 (7·5k–20k)	×1000	RV18, R67, C29

Check for temperature compensation

The thermistor, TH1, provides ambient temperature correction over the range of +10°C to +35°C, the degree of compensation being governed by the resistor, R62.

If the accuracy of the instrument is well out over this ambient temperature range and assuming that all the checks on power and volts have been proved, suspect and check the thermistor and resistor, R62.

Unsolder the thermistor wires from pins 39 and 40 on the power printed board and measure the resistance of TH1 by means of an ohmmeter; the resistance reading should be 270 Ω at 20°C.

Chapter 6 Replaceable parts

Introduction

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

BT	:	battery
C	:	capacitor
Carb	:	carbon
Cer	:	ceramic
CRT	:	cathode ray tube
Elec	:	electrolytic
FS	:	fuse
ILP	:	illumination lamp
JK	:	jack
L	:	inductor
Log	:	logarithmic law
M	:	meter
Met	:	metal
Min	:	minimum value
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	:	wirewound
X	:	ferrite bead
†	:	value selected during test; nominal value listed
ø	:	feed-through component
W	:	watts at 70°C
W*	:	watts at 55°C
W**	:	watts at 40°C
W°	:	watts at unspecified temperature

Ordering

When ordering replacement or spare parts, address the order to our Service Division (for address see rear cover) or nearest representative. Please specify the following information for each part required.

(1) Type and serial number of instrument (see rear data plate).

(2) Complete circuit reference (see Introduction).

(3) Description.

(4) M.I. code number.

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

Transistor Selection

Transistors that are mounted in holders may need to be selected for low noise if replaced.

Circuit reference	*Description*	*M.I. code*
BT1	Multi-cell DT9 9 V	23721–242
BT2	Multi-cell DT9 9 V	23721–242
C1	Plas 0·7–3·3 pF Trimmer	26872–104
C2	Plas 82 pF ±2 pF 500 V	26516–226
C3	Cer 10–40 pF Trimmer	26847–265
C4	Plas 0·004 μF ±2% 500 V	26516–631
C5	Paper 0·5 μF ±10% 150 V	26174–179
C6	Elec 10 μF −20 +50% 35 V	26414–121
C7	Cer 68 pF ±2% 750 V	26324–868
C8	Cer 47 pF ±2% 750 V	26324–833
C9	Elec 250 μF −20+100% 6 V	26417–162
C10	Cer 4·7 pF†±0·25 pF 750 V	26324–017
C11	Cer 10–40 pF Trimmer	26847–265
C12	Elec 100 μF −20 +100% 6 V	26417–154
C13	Cer 10–40 pF Trimmer	26847–265
C14	Not fitted	
C15	Paper 0·1 μF ±10% 150 V	26174–169
C16	Elec 250 μF −20 +100% 6 V	26417–162
C17	Paper 0·1 μF ±10% 150 V	26174–169
C18	Plas 33 pF ±2 pF 500 V	26516–130
C19	Elec 200 μF −20 +100% 6 V	26423–333
C20	Plas 10 pF†±1 pF 500 V	26516–013
C21	Elec 1000 μF −20 +100% 12 V	26417–403
C22	Var cer 3–10 pF	26847–212
C23	Paper 0·01 μF ±10% 200 V	26174–145
C24	Paper 0·01 μF ±10% 200 V	26174–145
C25	Not fitted	
C26	Elec 8 μF −20 +100% 6 V	26423–307
C27	Not fitted	
C28	Not fitted	
C29	Plas 820 pF† ±20% 500 V	26516–464
C30	Not fitted	
C31	Not fitted	
C32	Plas 1000 pF ±2% 500 V	26516–488
C33	Not fitted	

Circuit reference	*Description*	*M.I. code*
M1	1 mA	44561–409
MR1	200 V P.I.V. 1S 923	28356–018
MR2	200 V P.I.V. 1S 923	28356–018
MR3	200 V P.I.V. 1S 923	28356–018
MR4	40 V P.I.V. 1S 44	28357–548
MR5	40 V P.I.V. 1S 44	28357–548
MR6	40 V P.I.V. 1S 44	28357–548
MR7	40 V P.I.V. 1S 44	28357–548
MR8	Zener Z5B12	28372–143
R1	Met film 1 MΩ ±$\frac{1}{2}$% $\frac{1}{4}$ W	24635–901
R2	Met film 1 MΩ ±$\frac{1}{2}$% $\frac{1}{4}$ W	24635–901
R3	Met film 32·2 kΩ ±1% $\frac{1}{4}$ W	24637–558
R4	Carb 975 Ω ±1% $\frac{1}{4}$ W	24133–975
R5	Carb 56 Ω ±10% $\frac{1}{2}$ W	24342–040
R6	Met ox 82 kΩ ±7% TE $\frac{3}{8}$ W*	24552–133
R7	WW 4·7 kΩ ±5% 1$\frac{1}{2}$ W	25123–100
R8	Carb 470 kΩ ±10% $\frac{1}{2}$ W	24342–152
R9	Met ox 51 kΩ ±7% TE $\frac{3}{8}$ W*	24552–127
R10	Met ox 1 kΩ ±7% TE $\frac{3}{8}$ W*	24552–080
R11	Met ox 100 kΩ ±7% TE $\frac{3}{8}$ W*	24552–135
R12	Met ox 2·2 kΩ ±7% TE $\frac{3}{8}$ W*	24552–088
R13	Met film 1 kΩ ±1% $\frac{1}{4}$ W	24637–101
R14	Met film 1 kΩ ±1% $\frac{1}{4}$ W	24637–101
R15	Met film 3·9 kΩ ±1% $\frac{1}{4}$ W	24637–209
R16	Carb 7·56 kΩ ±1% $\frac{1}{4}$ W	24134–756
R17	Carb 2·28 kΩ ±1% $\frac{1}{4}$ W	24134–228
R18	Carb 375 Ω ±1% $\frac{1}{4}$ W	24133–375
R19	Carb 39 Ω ±10% $\frac{1}{2}$ W	24342–035
R20	Met ox 1 kΩ ±7% TE $\frac{3}{8}$ W*	24552–080
R21	Carb 698 Ω ±1% $\frac{1}{4}$ W	24133–698
R22	Carb 100 Ω ±10% $\frac{1}{2}$ W	24342–050
R23	Met ox 1 kΩ ±7% TE $\frac{3}{8}$ W*	24552–080
R24	Met ox 3·3 kΩ ±7% TE $\frac{3}{8}$ W*	24552–094
R25	Met ox 180 Ω ±7% TE $\frac{3}{8}$ W*	24552–056
R26	Met ox 150 Ω ±7% TE $\frac{3}{8}$ W*	24552–054

Circuit reference	*Description*	*M.I. code*
R27	Met ox 15 kΩ ±7% TE $\frac{3}{8}$ W*	24552–114
R28	Carb 10 Ω ±10% $\frac{1}{2}$ W	24342–020
R29	Met ox 470 Ω ±7% TE $\frac{3}{8}$ W*	24552–069
R30	Met ox 12 kΩ ±7% TE $\frac{3}{8}$ W*	24552–112
R31	Met ox 27 kΩ ±7% TE $\frac{3}{8}$ W*	24552–120
R32	Met ox 2·2 kΩ ±7% TE $\frac{3}{8}$ W*	24552–088
R33	Met ox 18 kΩ ±$\frac{1}{2}$% $\frac{1}{4}$ W	24635–505
R34	WW 900 Ω ±1% 12 W	25114–747
R35	WW 478 Ω ±1% 12 W	25114–741
R36	Met ox 3·3 kΩ ±7% TE $\frac{3}{8}$ W*	24552–094
R37	WW 75 Ω ±1% 9 W	25114–529
R38	WW 24 Ω ±1% 9 W	25114–520
R39	WW 4·86 Ω ±5% 6 W	25114–309
R40	WW 1·26 Ω ±5% 6 W	25114–302
R41	WW 0·37 Ω ±5%	44123–201
R42	Met ox 120 Ω ±7% TE $\frac{3}{8}$ W*	24552–052
R43	WW 270 Ω ±5% 2$\frac{1}{2}$ W	25123–061
R44	Alum finned 2060 Ω ±1% 50 W	25377–405
R45	Alum finned 516 Ω ±1% 25 W	25377–185
R46	Alum finned 1036 Ω ±1% 25 W	25377–195
R47	Alum finned 1036 Ω ±1% 25 W	25377–195
R48	Alum finned 1036 Ω ±1% 25 W	25377–195
R49	WW 220 Ω ±5% 2$\frac{1}{2}$ W	25125–624
R50	Alum finned 2115 Ω ±1% 25 W	25377–203
R51	Carb 5·6 kΩ ±1% $\frac{1}{4}$ W	24134–560
R52	Met ox 8·2 kΩ ±7% TE $\frac{3}{8}$ W*	24552–108
R53	Carb 3·9 kΩ ±1% $\frac{1}{4}$ W	24134–390
R54	Met ox 5·6 kΩ ±7% TE $\frac{3}{8}$ W*	24552–103
R55	Carb 3 kΩ ±1% $\frac{1}{4}$ W	24134–300
R56	Met ox 3·9 kΩ ±7% TE $\frac{3}{8}$ W*	24552–096
R57	Carb 1·8 kΩ ±1% $\frac{1}{4}$ W	24134–180
R58	Met ox 3 kΩ ±7% TE $\frac{3}{8}$W*	24552–093
R59	Carb 750 Ω ±1% $\frac{1}{4}$ W	24133–750
R60	Met ox 220 Ω ±7% TE $\frac{3}{8}$ W*	24552–058
R61	Carb 482 Ω ±1% $\frac{1}{4}$ W	24133–482
R62	Met ox 180 Ω ±7% TE $\frac{3}{8}$ W*	24552–056
R63	Metal 3 kΩ ±1% $\frac{1}{4}$ W	24637–204
R64	Met ox 7·5 kΩ ±7% TE $\frac{3}{8}$ W*	24552–107
R65	Met ox 8·2 kΩ ±7% TE $\frac{3}{8}$ W*	24552–108
R66	Met ox 7·5 kΩ ±7% TE $\frac{3}{8}$ W*	24552–107
R67	Met ox 8·2 kΩ ±7% TE $\frac{3}{8}$ W*	24552–108
R68	Met ox 10 kΩ ±7% TE $\frac{3}{8}$ W*	24552–110
R69	Carb 1·8 kΩ ±10% $\frac{1}{2}$ W	24342–086
R70	Met ox 9·11 kΩ ±7% TE $\frac{3}{8}$ W*	24552–109
R71	Met ox 7·5 kΩ ±7% TE $\frac{3}{8}$ W*	24552–107
R72	Met ox 7·5 kΩ ±7% TE $\frac{3}{8}$ W*	24552–107
R73	Met film 100 kΩ ±0·5% $\frac{1}{4}$ W	24635–705
R74	Carb 100 Ω ±10% $\frac{1}{2}$ W	24342–050
R75	Met ox 33 kΩ† ± 7% TE $\frac{1}{2}$ W*	24552–122

For symbols and abbreviations see introduction to this chapter

Circuit reference	*Description*	*M.I. code*
RV1	Carb 1 kΩ ±20% $\frac{1}{4}$ W	25611–014
RV2	Carb 100 Ω ±20% $\frac{1}{4}$ W	25611–002
RV3	Carb 470 Ω ±20% $\frac{1}{4}$ W	25611–010
RV4	Carb 470 Ω ±20% $\frac{1}{4}$ W	25611–010
RV5	Carb 100 Ω ±20% $\frac{1}{4}$ W	25611–002
RV6	Carb 100 Ω ±20% $\frac{1}{4}$ W	25611–002
RV7	Carb 100 Ω ±20% $\frac{1}{4}$ W	25611–002
RV8	Carb 100 Ω ±20% $\frac{1}{4}$ W	25611–002
RV9	WW 500 Ω ±10% 1 W	25815–147
RV10	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611–025
RV11	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611–025
RV12	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611–025
RV13	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611–025
RV14	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV15	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV16	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV17	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV18	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV19	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV20	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV21	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
RV22	Carb 4·7 kΩ ±20% $\frac{1}{4}$ W	25611–022
SA	IMPEDANCE multiplier	44323–507
SB	IMPEDANCE selector	44326–029
SC	RANGE switch	44326–028
SD	FUNCTION selector	44323–708
T1	TM 9342	43528–004
TH1	KB 221, 220 Ω ±20%	25683–485
TP1	VOLTS H	23235–176
TP2	VOLTS L	23235–177
TP3	POWER L	23235–176
TP4	POWER H	23235–176
TP5	POWER CT	23235–176
TP6	Bal d.c. output −	23235–176
TP7	Bal d.c. output +	23235–176

Circuit reference	*Description*	*M.I. code*
Test point 1		34461–712
Test point 2		34461–712
VT1	Silicon BC 109	28452–777
VT2	Silicon BC 108	28452–787
VT3	Silicon BC 108	28452–787
VT4	Silicon 2N 4058/E5025	44522–038
VT5	Silicon BC 108	28452–787
VT6	Silicon BC 108	28452–787
VT7	Silicon 2N 4058/E5025	44522–038
VT8	Silicon BC 108	28452–787
VT9	Silicon 2N 4058/E5025	44522–038
VT10	Germanium 2N 404	44522–004

Miscellaneous

Description	*M.I. code*
Battery container	37576–118
Battery connector	23721–881
1 in bar knob and skirt (IMPEDANCE controls)	41145–208
$1\frac{1}{2}$ in bar knob and skirt (RANGE control)	41145–206
1 in bar knob and skirt (FUNCTION control)	41145–239
Battery retaining clip	35451–409
Coaxial lead TM 4726/336 (on Amplifier board)	43121–047
Coaxial lead TM 4726/335 (on Selector-IMPEDANCE switch)	43121–048
Indicator ring (part of FUNCTION switch)	37437–510
Insulator (part of thermistor assembly)	37155–311
Shorting link (to be removed when chart recorder is in use)	34461–503
Shorting link (for use across VOLTS 'L' and POWER 'L' terminals)	34461–506
Printed board TM 9348 (Amplifier)	44645–105
Printed board TM 9352 (Power)	44688–608
Spring (retaining battery container)	35524–115
Spring (retaining thermistor block)	35434–108
Thermistor block	37527–311
Terminal TP2 (earthing)	23235–177
Transistor pad	28488–114
Capacitor strap (small)	23243–705
Capacitor strap (large)	23243–708

For symbols and abbreviations see introduction to this chapter

Chapter 7

Circuit diagrams

CIRCUIT NOTES

1. ARRANGEMENT
   The two circuit diagrams show all sub-assembly units in the equipment together with their reference code number.

2. COMPONENT VALUES
   Resistors: no suffix = ohms, k = kilohms, M = megohms.
   Capacitors: no suffix = microfarads, p = picofarads.
   Inductors: no suffix = henries, m = milihenries, μ = microhenries.
   S.I.C.: values selected during test; nominal value shown.

3. SYMBOLS
   printed board tag number.
   test point.
   main signal path.
   feedback, modulation or control signal path.

4. SWITCHES
   Switched sections are drawn viewed from the knob end with the knob fully counter-clockwise.

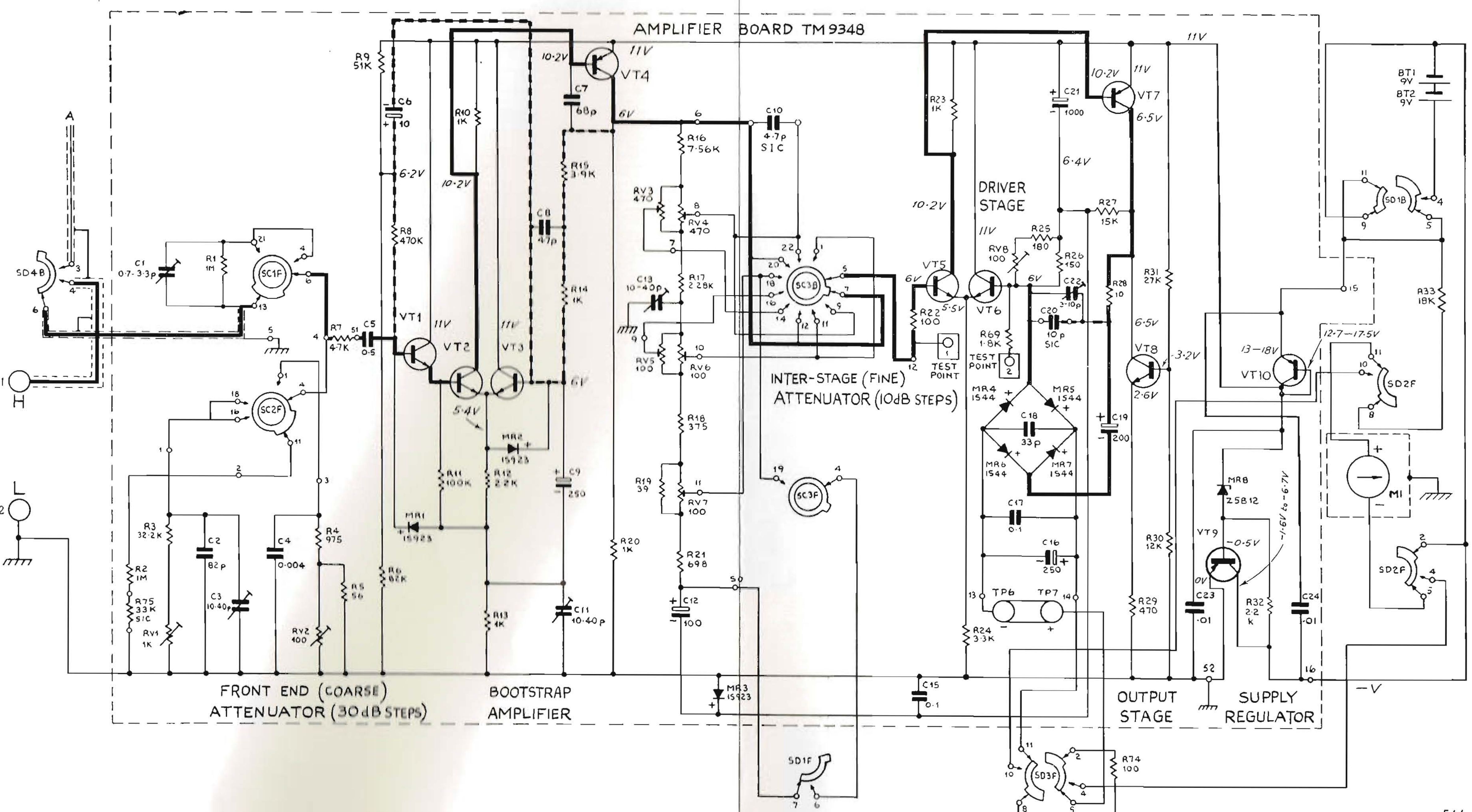


Fig. 7.2 Voltmeter section

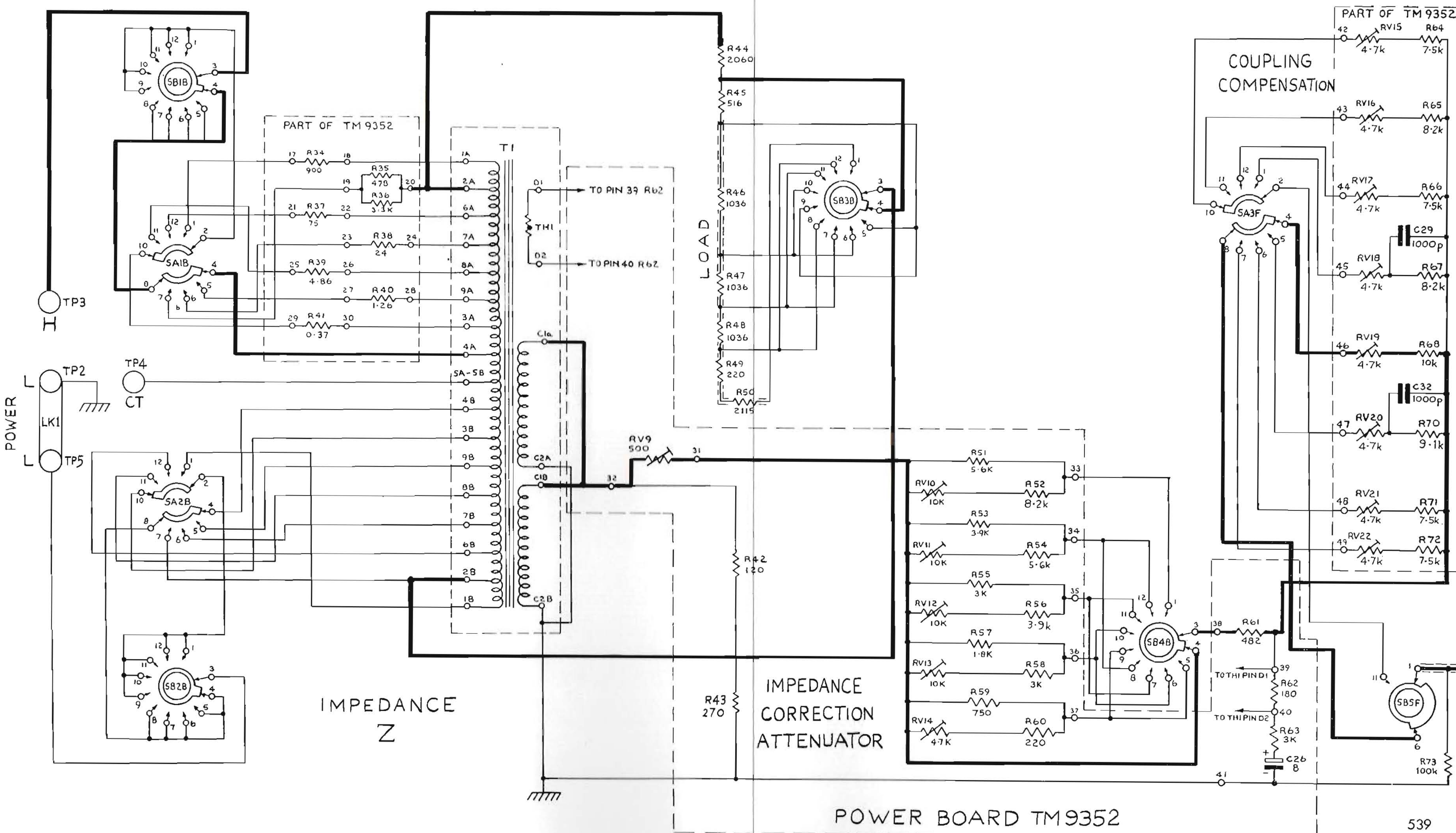


Fig. 7.1 Power section

TF 2500

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