RF Electronic Millivoltmeter
TF 2603

Code Nos. 52603-304P
-305X

CONTENTS

PRELIMINARIES

CHAPTERS

Note ...

Each page bears the date of the original issue or the code number and date of the latest amendment (Am. 1, Am. 2 etc.). New or amended material of technical importance introduced by the latest amendment is indicated by triangles positioned thus ▶ ..... ◀ to show the extent of the change. When a chapter is reissued the triangles do not appear.

Any changes subsequent to the latest amendment state of the manual are included on inserted sheets coded C1, C2 etc.

NOTES AND CAUTIONS

ELECTRICAL SAFETY PRECAUTIONS

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

Defects and abnormal stresses

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

Removal of covers

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

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

Mains plug

The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action shall not be negated by the use of an extension lead without protective conductor. Any interruption of the protective conductor inside or outside the equipment is likely to make the equipment dangerous. Before fitting a non-soldered plug to the mains lead, cut off the tinned ends of the mains lead. Otherwise cold flowing of the solder could cause intermittent connections.

Fuses

Note that the supply fuse is connected in series with the brown (live) wire of the supply lead. If the equipment is connected to the supply via a two-pin plug, it will be possible for the fuse to become connected to the neutral side depending upon the orientation of the plug in its socket. In these circumstances certain parts of the instrument could remain at supply potential even after the fuse has ruptured.

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

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

► RADIO FREQUENCY INTERFERENCE

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

► *CAUTION :* STATIC SENSITIVE COMPONENTS

Components identified with the symbol ⚠ on the circuit diagrams and/or parts lists are static sensitive devices. The presence of such devices is also indicated in the equipment by orange discs, flags or labels bearing the same symbol. Certain handling precautions must be observed to prevent these components being permanently damaged by static charges or fast surges.

(1) If a printed board containing static sensitive components (as indicated by a warning disc or flag) is removed, it must be temporarily stored in a conductive plastic bag.

(2) If a static sensitive component is to be removed or replaced the following anti-static equipment must be used.

A work bench with an earthed conductive surface.

Metallic tools earthed either permanently or by repeated discharges.

A low-voltage earthed soldering iron.

An earthed wrist strap and a conductive earthed seat cover for the operator, whose outer clothing must not be of man-made fibre.

(3) As a general precaution, avoid touching the leads of a static sensitive component. When handling a new one, leave it in its conducting mount until it is required for use.

MOUNTING ARRANGEMENTS

Excessive temperatures may affect the instrument's performance; therefore, completely remove the plastic cover, if one is supplied over the case, and avoid standing the instrument on or close to other equipment that is hot.

SAFETY TESTING

Where safety tests on the mains input circuit are required, the following procedures can be applied. These comply with BS 4743 and IEC Publication 348. Tests are to be carried out as follows and in the order given, under ambient conditions, to ensure that mains input circuit components and wiring (including earthing) are safe.

(1) Earth lead continuity test from any part of the metal frame to the bared end of the flexible lead for the earth pin of the user's mains plug. Preferably a heavy current (about 25 A) should be applied for not more than 5 seconds.

Test limit : not greater than 0.5 Ω.

(2) 500 V d.c. insulation test from the mains circuit to earth. ◄

Test limit : not less than 2 MΩ.

Chapter 1

GENERAL INFORMATION

CONTENTS

INTRODUCTION

1. The TF 2603 is a highly sensitive, general purpose millivoltmeter, covering the frequency range 50 kHz to 1500 MHz; eight ranges, giving full-scale deflections from 1 mV to 3 V, enable voltages down to 300 μV to be measured.

2. Meter readings are very close to true r.m.s. values up to 30 mV, or 3 V when using the 100:1 multiplier; above this value the response gradually changes, and approaches a peak-to-peak reading (calibrated in r.m.s. value of a sine wave) on the higher ranges. The meter is also calibrated in decibels giving an effective range of 0 to 71 dB with respect to 3.162 V. Full wave detection of the input signal by the probe minimizes errors associated with single diode probes.

3. The voltmeter may be operated from mains or battery supplies. Two versions of the voltmeter are available, differing only in the range of accessories supplied.

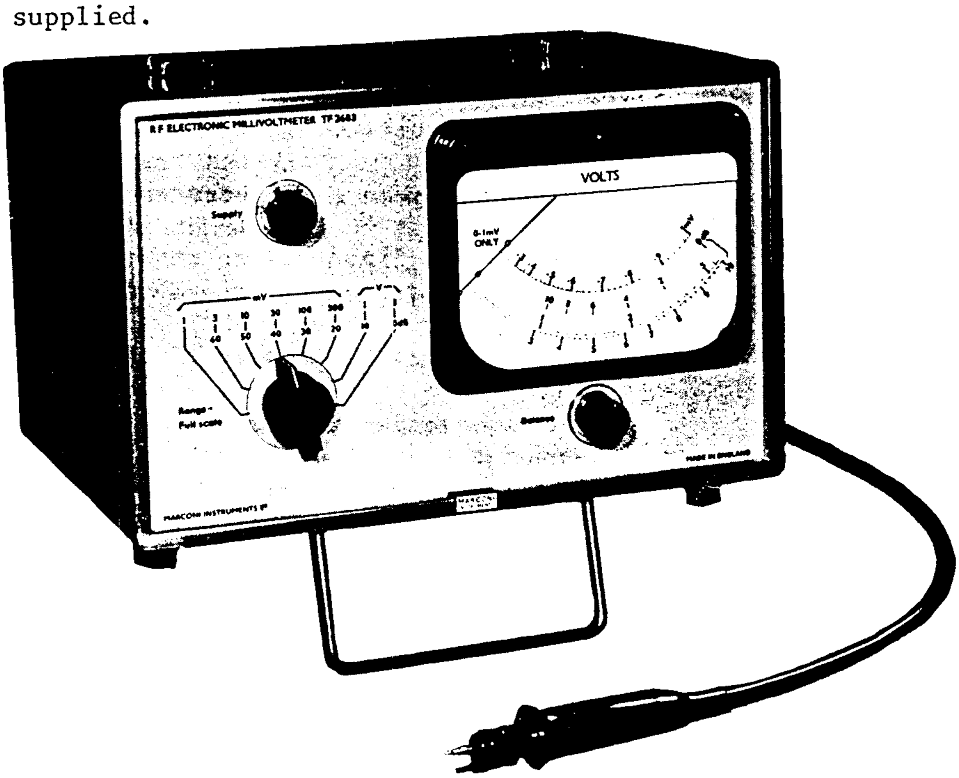


Fig. 1 RF Electronic Millivoltmeter TF 2603

PERFORMANCE DATA

4.	Voltage range	1 mV r.m.s. full-scale deflection, to 3 V r.m.s. full-scale deflection in 8 ranges. Maximum input, 8 V r.m.s. Probe will withstand up to 300 V d.c.
5.	Frequency range	50 kHz to 1500 MHz.
6.	Accuracy (from 18°C to 28°C)	10 mV and higher ranges : ±3% of full-scale. 3 mV range : ±5% of full-scale. 1 mV range : ±5% of full-scale. 200 kHz to 50 MHz.
7.	Frequency response (When fitted with coaxial T Connector TM 7948 and terminated with 50 Ω)	With respect to 200 kHz. 50 kHz to 200 kHz : +0, -0.4 dB. 50 MHz to 200 MHz : ±0.4 dB. 200 MHz to 500 MHz : ±1.0 dB 500 MHz to 900 MHz : ±2.0 dB. 900 MHz to 1500 MHz : ±3.0 dB.

Notes...

(1) The instrument will usually be operated in the frequency range 200 kHz to 50 MHz, and the error over this range is shown against Accuracy.

(2) When using the instrument at other frequencies, the Frequency response error must be added to the appropriate Accuracy figure to obtain the overall accuracy.

(3) Chapter 2, Fig. 3 shows in detail the typical spread of the probe frequency response limits.

8.	Meter scales	0 to 3.162, and 0 to 10 virtually linear. Calibrated in the r.m.s. value of a sine wave. Special scale for 1 mV range. Decibel scale 0 to 11 dB, 0 dB at full-scale. Range switch in 10 dB steps. The dB scale is not applicable to the 1 mV range.
9.	Input impedance	Input capacitance : less than 2.5 pF at 1 MHz and 1 V r.m.s. Input resistance : greater than 125 kΩ at 1 MHz and 1 V r.m.s. Chapter 2, Fig. 4 shows in detail the typical variation of input resistance with frequency.
10.	Probe	Uses two crystal diodes in a full wave detecting circuit which minimizes errors when measuring non-sinusoidal waveforms. A built-in heater ensures that ambient temperature variations have minimum effect. Response is very close to true r.m.s. with inputs of 30 mV or less.
11.	Power requirements	
	AC supply	45 Hz to 500 Hz : 190 V to 265 V or 95 V to 132 V (also 500 Hz to 1000 Hz at ±10% on 230 V).
	Power consumption	5.4 VA.

Battery supply	20 V to 32 V floating;	142 mA (heater on), 67 mA (heater off).

12. Dimensions and weight

Height	Width	Depth	Weight
204 mm (8 in)	292 mm ($11\frac{1}{2}$ in)	280 mm (11 in)	9.8 kg (22 lb)

ACCESSORIES

13. With version 52603-304P, items (1) to (7) are supplied and items (8)to (11) are optional. With version 52603-305X items (1) to (11) are all supplied.

(1) Mains lead — MI code : 43129-071D.

(2) Earth prod, TM 7936 — MI code : 44314-602L. A spring loaded earthing prod which clips on to the probe body.

(3) Earthing sleeve — MI code : 33631-901J. Provides earthing of the probe at the higher frequencies.

(4) Earth spring clip — MI code : 22328-013N. Allows the use of a flexible earth connection.

(5) Printed wiring plug — MI code : 23421-031K. Connects with test point sockets on printed boards.

(6) Multiplier, TM 7947 — MI code : 44416-050G.

100:1 capacitive divider for voltages up to 316.2 V over the frequency range 500 kHz to 500 MHz.

Accuracy (with respect to exact 100:1 ratio):

0.5 to 20 MHz	±0.1 dB
20 to 100 MHz	±0.3 dB
100 to 300 MHz	±0.7 dB
300 to 500 MHz	±1.5 dB

Input impedance :

Resistance, greater than 20 MΩ at 1 MHz,
greater than 1 MΩ at 50 MHz,
greater than 150 kΩ at 300 MHz.

Capacitance, less than 2.5 pF.

Maximum input :

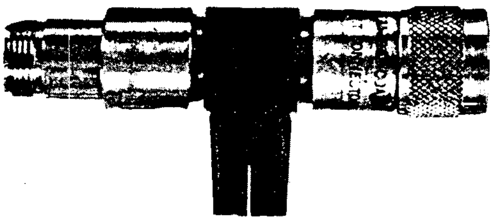
316.2 V up to 100 MHz.
Above 100 MHz maximum r.m.s. voltage =

$$\frac{3 \times 10^6}{f^2}$$

where f is in MHz.
V d.c. plus V a.c. peak must not exceed 1000 V.

(7) <u>Accessory case, TM 7960</u> MI code : 41673-015N.

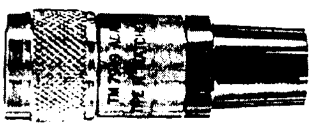
(8) <u>Coaxial T connector, TM 7948</u> MI code : 43167-007Z.



VSWR not greater than 1.2:1 at 1500 MHz when terminated in 50 Ω and voltmeter probe plugged in side entry.

Accuracy and Frequency response specification given in Performance Data applies to voltage across 50 Ω load.

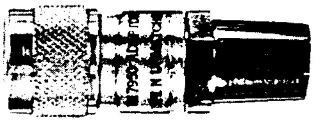
(9) <u>Adapter N terminated, TM 7949</u> MI code : 43168-011S.



Allows voltage measurement across load mounted in 50 Ω type N plug.
Maximum power input, 0.25 W.
VSWR when mounted on voltmeter probe:-

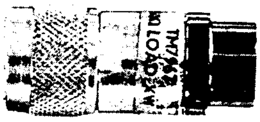
maximum 1.1:1, 50 kHz to 500 MHz,
maximum 1.2:1, 500 kHz to 900 MHz.

(10) Adapter N unterminated, TM 7950   MI code : 43168-010V.



50 Ω type N adapter with specification as terminated adapter but without 50 Ω load.

(11) 50 Ω Load, TM 7967   MI code : 44411-015N.



Load mounted in type N plug.
VSWR not greater than 1.05:1, d.c. to 1500 MHz.

Chapter 2

OPERATION

CONTENTS

CONTROLS AND CONNECTORS

1. The controls and connectors on the front panel of the voltmeter (Fig. 1) are as follows:-

(1) SUPPLY switch. For switching on/off the a.c. or battery supply. Red screening is visible when switched on.

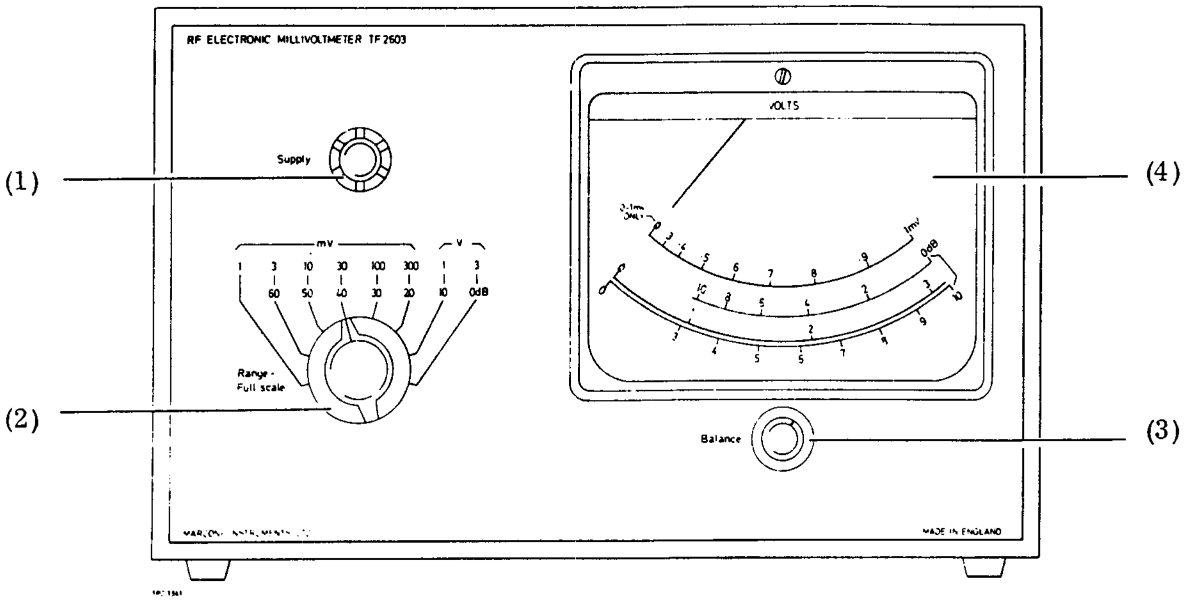


Fig. 1 Controls and connectors on front panel

(2) RANGE switch. For selecting the appropriate range for the voltage to be measured.

(3) BALANCE control. For adjusting meter to zero with zero input and probe warmed up.

(4) METER. For indicating on a scale calibrated in r.m.s. values and dB, the voltage detected by the probe.

2. The controls and connectors on the rear panel of the voltmeter (Fig. 2) are as follows:-

(5) MAINS/BATTERY switch. Set to position appropriate to supplies being used.

(6) BATTERY supply terminals.

(7) MAINS supply range switch. Selects a.c. voltage range.

(8) BLANKING plate. For securing the mains supply range switch in the selected position.

(9) AC FUSE. Value determined by a.c. supply voltage : 50 mA for 190 V to 265 V, 100 mA for 95 V to 132 V.

(10) MAINS supply plug. For connecting the a.c. supply by means of the mains lead.

(11) DC FUSE. 160 mA. Connected by mains/battery switch to battery supply or rectified a.c. supply line.

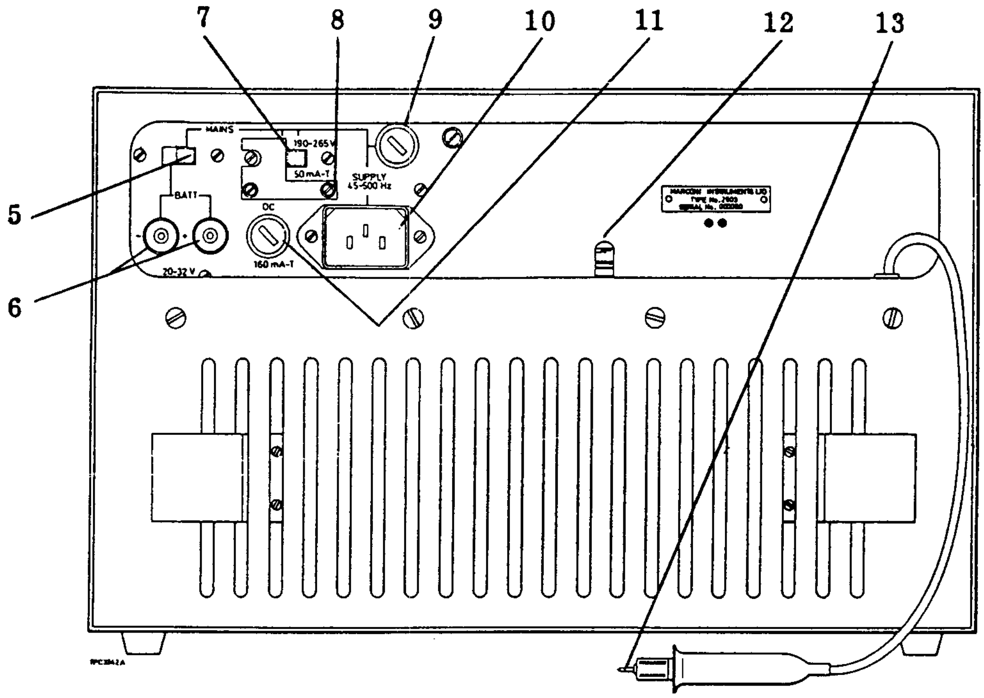


Fig. 2 Controls and connectors on rear panel

(12) PROBE clip. For retaining the voltmeter probe when not in use.

(13) PROBE. For connecting direct or via the accessories, to the voltage under test.

PREPARATION FOR USE

Meter location

3. The sensitivity of the meter is affected by its location in the front panel cut-out. As the meter has been calibrated when positioned at the bottom of the cut-out, it should be verified, on unpacking the instrument, that the meter has not moved.

AC power supply

4. The mains lead is a free cable fitted at one end with a cable mounted socket which connects with the instrument. When fitting a supply plug ensure that the conductors are connected as follows:-

Earth - Green/Yellow
Neutral - Blue
Live - Brown

5. Ensure that the front panel SUPPLY switch is in the off position and set the MAINS/BATTERY switch to the MAINS position.

6. Set the MAINS supply range switch to the correct position for the a.c. supply voltage to be used and secure the BLANKING plate.

7. Check that the AC FUSE rating is compatible with the a.c. supply voltage:-

50 mA for 190 V to 265 V,
100 mA for 95 V to 132 V.

Battery supply

8. Ensure that the front panel SUPPLY switch is in the off position and set the MAINS/BATTERY switch to the BATTERY position.

9. Connect the battery supply (20 V to 32 V) to the BATTERY terminals, ensuring that correct polarity is observed and that neither side of the supply is earthed.

Mechanical zero

10. Adjust the mechanical zero as follows:-

(1) Turn the adjustment screw to move the pointer up the scale, towards full-scale deflection and approach the zero mark from this side.

(2) Once the pointer is exactly on the mark, slightly turn back the adjustment screw so that it is free from the meter suspension.

SWITCHING ON

Warm-up period

11. If the probe is free (connected by wires or clips), the instrument will warm up sufficiently for most measurements 4 minutes after switching on. Maximum accuracy will be achieved after approximately 15 minutes.

12. With the probe connected to a large thermal mass (e.g. to a slotted line, via the coaxial T connector), the times stated in the previous paragraph should be amended to 15 minutes and 45 minutes.

13. The thermostat controlling the probe heater is mounted inside the oscillator box. The voltmeter should not be operated on top of any equipment etc. which may raise its internal temperature. To do so may introduce errors due to the thermostat prematurely switching off the probe heater.

Balance

14. After the correct warm-up period has elapsed, read the mean position of the meter pointer and adjust the BALANCE control to zero the meter. If the meter will not adjust to zero on the 1 mV range refer to para. 20 and Chap. 4, para. 47.

15. The BALANCE control requires no adjustment when voltages above 30 mV are to be measured.

16. For measurements at frequencies below approximately 20 MHz it is sufficient just to earth the probe tip. Above this frequency the tip must be screened from external interference in order that the meter can be adjusted to zero.

17. The BALANCE control injects a small d.c. voltage into the probe circuit

to balance out the diodes pn potential and any thermal voltages which develop in the associated input circuits. To check that the noise voltage level is normal proceed as follows:-

(1) See the RANGE switch to the 1 mV position.

(2) Ensure that there is no input to the probe.

(3) Adjust the BALANCE control for a reading between 0.3 and 0.4 mV.

(4) Check that the peak-to-peak pointer movement does not exceed 0.06 mV (3 small scale divisions).

(5) After confirming that the noise level is normal, reset the zero (para. 14).

Screening

18. The voltmeter has characteristics similar to a wide band, medium sensitivity, untuned receiver and care should be taken not to operate the set near high intensity fields.

19. If it is not possible to switch off the source of any such field during the voltmeter tests, ensure that the probe is screened sufficiently to eliminate any pick-up errors.

20. To check if any pick-up error exists, proceed as follows:-

(1) Switch off any field generating device.

(2) Set the voltmeter zero (para. 14).

(3) Switch on the field generating device and note any increase in meter reading.

(4) Reduce this reading to a minimum by screening.

OPERATING PROCEDURE

Voltage limitations

21. Maximum r.m.s. input should not exceed 8 V, but this may be superimposed on 300 V d.c. This restriction is governed by the peak inverse voltage limitation on the probe diodes.

22. Voltages in excess of 8 V may be measured using the 100:1 Multiplier TM 7947.

Probe input impedance

23. The probe presents to the source under test a capacitance of less than 2.5 pF and a shunt resistance which varies with frequency and voltage. Fig. 4 shows typical resistance variation with frequency and voltage.

Range selection

24. Set the RANGE switch to the nearest full scale above the expected voltage level. If the level is not known select the 3 V range.

25. When making a measurement on the 1 mV range read the mean position of the meter pointer.

Range switching

26. When a measurement is to be made on one of the lower ranges immediately after using the voltmeter on a higher range, the following procedure should be used to switch to the new position:-

(1) Hold the RANGE switch in a position between the required range (e.g. 1 mV) and the range immediately above it (e.g. 3 mV).

(2) Hold the switch in this position for at least 10 seconds.

(3) Switch to the required range (e.g. 1 mV).

27. This procedure allows time for switch SA3F to discharge the input circuit capacitors. An alternative but less satisfactory method is to very slowly turn the RANGE switch to the new position.

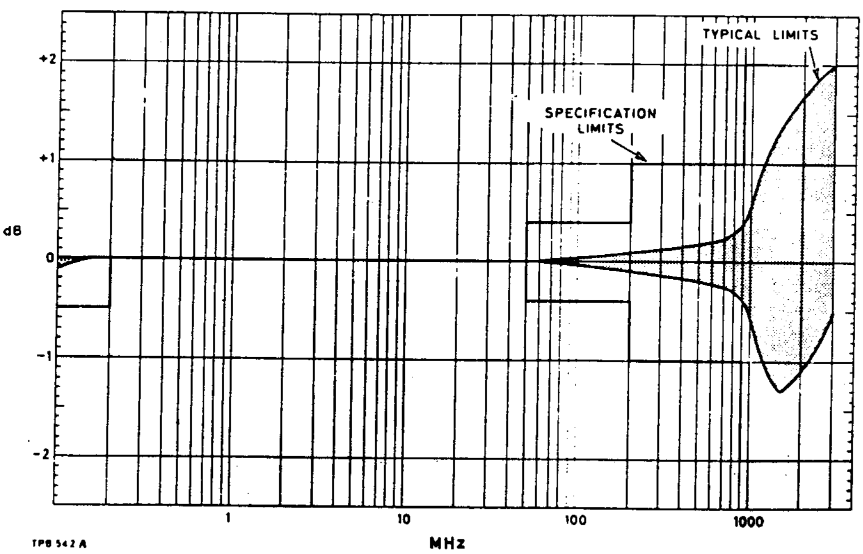


Fig. 3 Voltmeter frequency response limits

Accessory selection

28. The Accuracy and Frequency response specification given in Chapter 1 will only apply if the probe spike makes direct contact with the live point under test, and the earth connection between probe case and circuit earth has negligible inductance and resistance.

29. The earth connection can be a 150 mm length of 16/0.2 mm wire, or its equivalent for measurement frequencies up to 20 MHz. The wire is attached to the spring clip which clamps on to the probe body.

30. The telescopic earth prod (TM 7936) clamped to the probe body can be used up to 100 MHz or up to 300 MHz if an additional 2.5% error can be tolerated.

31. Above 100 MHz the probe body must make direct contact with a good earth point on the system under test. Alternatively, accessories TM 7947, TM 7948, TM 7949 or TM 7950 can be used.

32. Above 900 MHz in order to achieve a suitably low impedance earth connection it is essential in most measurements to use the coaxial T connector TM 7948.

33. The four accessories TM 7947, TM 7948, TM 7949 and TM 7950 can prove useful at frequencies below 100 MHz where their screening properties enable measurements to be made in the presence of stray fields.

34. Table 1 will assist in selecting the correct accessory for particular measurements.

Use of accessories

35. The use of the telescopic earth prod and the earth clip with lead is not satisfactory for high accuracy measurements at frequencies above approximately 250 MHz.

Earthing sleeve

36. This allows a direct connection to be made to the voltage source under test. Use as follows:-

(1) Bolt the sleeve to the chassis of the equipment under test using the three tapped 6BA holes in the base of the sleeve. The sleeve should be mounted so that it is concentric with the live point to be measured.

(2) Push the probe into the earthing sleeve until contact is made with the live point. The probe tip may be unscrewed before connecting the probe.

Multiplier TM 7947

37. Insert the probe into the multiplier ensuring that the probe point engages in the mating socket and push home.

38. The multiplier can be used to measure voltages up to 300 V r.m.s. at a frequency up to 100 MHz. Above 100 MHz the maximum r.m.s. voltage is given by the expression:-

$$V = \frac{3 \times 10^6}{f^2}$$

where f is in MHz.

TABLE 1 FREQUENCY RANGE OF ACCESSORIES

Frequency	Earth prod TM7936	Earth spring clip	Earth sleeve	100:1 Multi-plier TM7947	Coaxial T con-nector TM7948	Termi-nated Adapter TM7949	Unter-minated Adapter TM7950	Dummy 50 ohm Load TM7967
50kHz-20MHz	B	BW	X	C	X	X	X	X
20 -100MHz	B	-	X	X	X	X	X	X
100 -300MHz	AE	-	X	X	X	X	A	X
300 -500MHz	E	-	X	X	X	X	-	X
500 -900MHz	E	-	X	-	X	X	-	X
900 -1500MHz	T	-	X	-	X	-	-	X
1500 -3000MHz	T	-	X	-	D	-	-	F

X Usable in frequency range stated.

\- Does not meet the specification at these frequencies but may be used provided the additional errors can be tolerated.

A Usable up to 300 MHz provided an error of up to 2.5% in addition to specification can be tolerated.

B Assumes that the live probe spike makes direct contact with the measurement point.

C Cannot be used below 500 kHz.

D May be used up to 3000 MHz with good results. VSWR may deteriorate but indication of voltage across load remains reasonably accurate.

E At these frequencies the probe body should be held (or clamped) firmly against a good earth point on the system under test. Alternatively use other accessories.

F VSWR may deteriorate above 1500 MHz.

T Use coaxial T connector TM 7948.

W With 150 mm of 16/0.2 mm wire, attached to the clip as an earth connection.

Note ...

Wires should never be soldered directly to the probe tip. If this type of connection is required, solder the wire to an earth tag. Unscrew the probe tip and then clamp the tag to the probe with the tip.

39. When measuring a.c. voltages superimposed on d.c., the peak value of the a.c. voltage plus the standing d.c. or mean voltage must not exceed 1000 V.

40. Multiplier errors (Chap. 1) are generally of opposite sign to those of the probe. Total error therefore will probably not exceed that shown in Chapter 1 under Accuracy and Frequency response.

41. Fig. 4 shows typical variations of input resistance when using Multiplier TM 7947.

Coaxial T Connector TM 7948

42. Plug the probe directly into the T connector ensuring that the probe point engages in the mating socket.

43. The series arms of the T connector are fitted with type N connectors. An arrow on the connector body points towards the arm which should be terminated with a 50 ohm load. The voltmeter indicates the voltage across the load when the test voltage is connected to the remaining arm.

44. Fig. 5 shows the typical insertion loss for the T connector plus the probe.

Terminated Adapter TM 7949

45. The probe plugs directly into the adapter which provides a matched 50 ohm coaxial termination. The 50 ohm load is fitted into the type N connector and the voltmeter indicates the voltage across this termination.

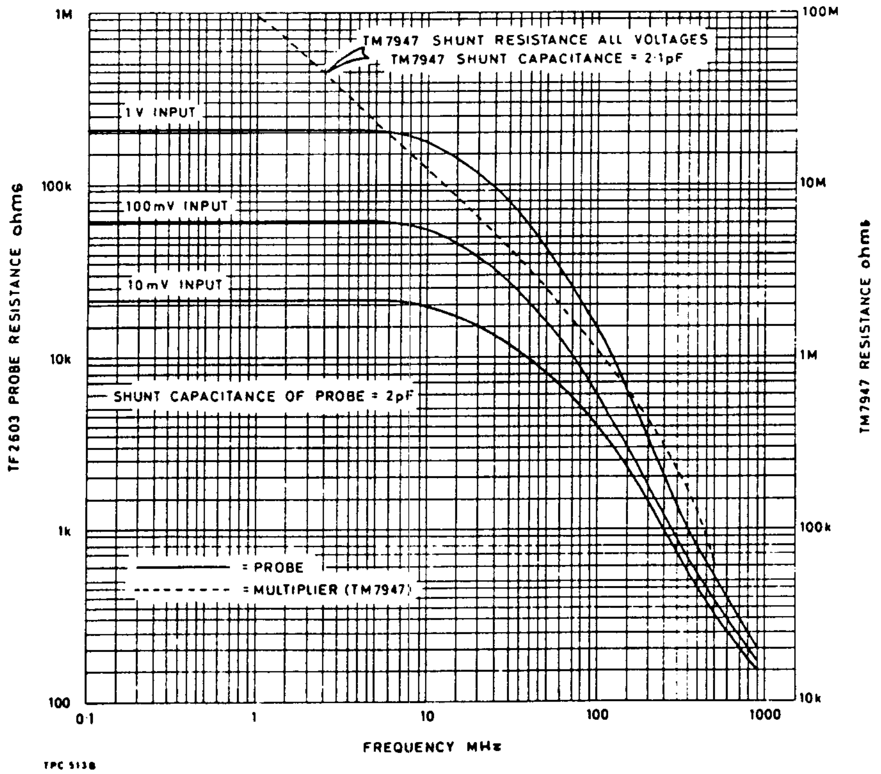


Fig. 4 Probe and multiplier input resistance (typical)

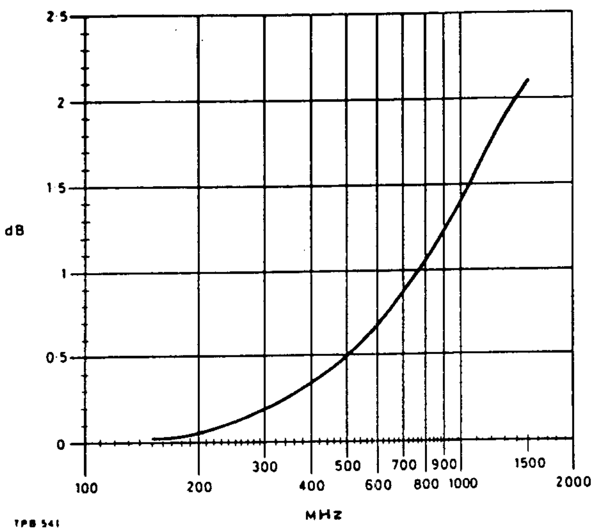


Fig. 5 Insertion loss curve for T connector and probe (typical)

46. Maximum power input is 0.25 W.

Unterminated adapter

47. Conditions of use are the same as for the terminated adapter but the load is omitted.

50 ohm Load TM 7967

48. The 50 ohm load is fitted into a type N connector and provides a matched coaxial termination for use with the T connector.

dB measurements

49. The decibel ranges are in 10 dB steps from 0 dB to 60 dB and are marked on the voltmeter front panel under the voltage figures. When making a measurement, add the reading on the meter decibel scale to the range reading to obtain the total decibel value.

50. The meter decibel scale is of particular value when relative levels in successive measurements are required, e.g. for instance when determining amplifier or filter response characteristics.

APPLICATIONS

51. The following applications are typical of the many that can only be made by this type of voltmeter:

(1) Measurements of low level signals in semi-conductor circuits - especially transistors and tunnel diodes.

(2) Measurement of transistor parameters - for instance, fT in the 500 MHz to 1500 MHz range.

(3) Voltage measurement on strip-line circuits.

(4) Measurements on battery operated equipment at locations remote from mains supplies.

(5) In conditions where accurate voltage measurement is difficult due to circuit earth loops, errors can often be eliminated by using a battery energized TF 2603.

(6) Because of the good r.m.s. response up to 30 mV, noise measurements can be made. If the 100:1 Multiplier (TM 7947) is used the measurement range is increased to 3 V.

(7) Distortion measurements are possible over a wide frequency range.

$$\text{Total distortion } \% = 100 \frac{V1}{V2}$$

where V1 = voltage due to harmonics,
and V2 = voltage due to harmonics plus fundamental.

V1 should be measured by connecting the TF 2603 to the output terminals of a network (e.g., a bridged T) capable of suppressing the fundamental, and using the r.m.s. region of the instrument.

(8) Used in conjunction with a Q meter, e.g., TF 1245, measurements can be carried out at low voltage levels; the TF 2603 is connected across the test circuit capacitor. This method is extremely useful with most transistors or circuits containing them. To make direct measurements of Q at low levels, the ΔC method should be used in order to avoid errors due to the shunting effect of TF 2603 probe. If required, a much higher resistance can be obtained by also using the 100:1 Multiplier (TM 7947) if the voltage across the Q meter capacitor is 30 mV or more.

(9) Despite all precautions regarding layout, feedback and inclusion of 'stopper' resistors, a wide band video multi-stage amplifier may develop spurious oscillation of frequency between 1 MHz and 1000 MHz. A loop connected to the TF 2603 probe can be held near each part of the circuit in turn to ascertain if unwanted oscillations are present.

(10) The tuning of narrow band amplifiers and filters, and other cases where a multiplicity of tuned circuits require adjustment, is made easy by use of the more sensitive ranges of TF 2603. The probe spike can be held close to circuit conductors and the preceding circuit tuned for a maximum voltage reading. Because of the loose coupling used, removal of the probe will have negligible effect, and little if any tuning correction will be required.

(11) Testing of filter frequency response, particularly in the stop band, can be achieved without excessive voltage requirements from the signal generator. For example, 50 dB attenuation can be measured using a generator capable of delivering 0.1 V to the filter input terminals.

(12) In wide band r.f. bridge measurements TF 2603 can be used as a null detector in place of several radio receivers, provided sufficient source voltage is available. If necessary, a simple resonant step-up circuit can be inserted between the bridge and TF 2603.

Chapter 3

TECHNICAL DESCRIPTION

CONTENTS

CIRCUIT SUMMARY

1. The simplified block diagram (Fig. 1) shows how the various stages are functionally interconnected and the waveforms at the key stages.

2. The probe diodes, associated filters and attenuators are balanced about earth. This assists in maintaining a low inherent noise level. Positive d.c. is fed via the input network, to one input of the chopper and negative d.c. to the other. The chopper operates at 87 Hz driven by the control oscillator. The signal from it passes to an impedance converter and on to the amplifiers.

3. After amplification and via an 87 Hz filter the signal is fed to the detector. The detector is synchronized with the chopper by the control oscillator and the detected low noise output is passed to the meter.

4. The linearity control system achieves a linear meter scale even though the probe output ranges from a square law response with small inputs, to a virtually linear law on the 1 V and 3 V ranges.

Note ...

Transistors are referenced TR in this chapter and VT in chapters 6 and 7.

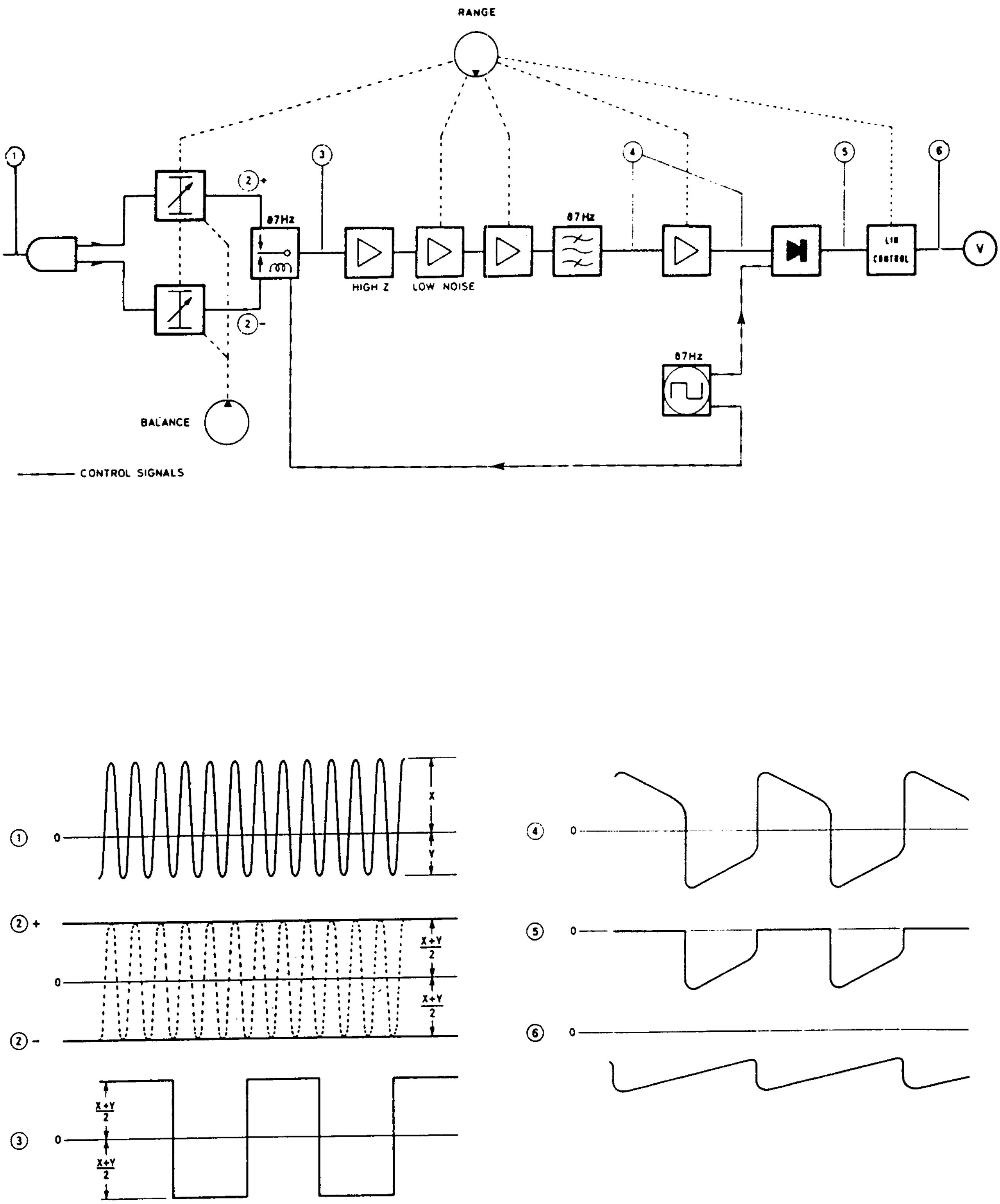


Fig. 1   Block diagram with waveforms

INPUT CIRCUITS

5. The input circuits consist of the probe, balance and smoothing networks and the balanced attenuator.

6. Input signals are full-wave rectified by D1 and D2. The positive part of the cycle, smoothed by R2 and C12, is fed via the attenuator (SA1F) to one input of the chopper. When switched to the 1 mV, 3 mV or 10 mV range, further smoothing and hum attenuation is provided by R54 and C4. This process is duplicated for the negative part of the cycle which is then fed to the other chopper input. The output from the chopper is passed to the impedance converter.

7. The probe heater moves the working range of the diodes into a part of the characteristic where the sensitivity is less affected by ambient temperature changes. The heater thermostat is located inside the oscillator box and switches the heater on when the temperature in the box falls below 33°C.

8. Thermal voltages which may develop in the input circuitry, and pn potentials developed by the probe diodes are balanced out by applying positive correction voltages. The relative amplitudes of the two voltages are controlled by RV1 (BALANCE) in conjunction with R49/R51 and R52/R53. The voltage to RV1 is taken from the pre-amplifier circuit (TR103).

IMPEDANCE CONVERTER

9. This circuit (TR101) presents a high impedance (approximately 10 to 15 Mohms) to the chopper. The low impedance point at TR101 emitter, supplies the signal to the pre-amplifier.

10. The 87 Hz square wave output from the chopper is a.c. coupled into TR101. This transistor, together with TR102, forms a composite transistor circuit with a high input impedance. R112 is bootstrapped to a higher effective value by applying positive feedback to its junction with R110 and R113 thus maintaining the high input impedance.

PRE-AMPLIFIER

11. The pre-amplifier (TR103) is a low noise circuit primarily intended to amplify the small signals encountered when using the 1 mV full-scale range.

12. The input from the impedance converter is fed to the two transistor amplifier TR103/TR104. This is a conventional amplifier stage in which the amount of feedback from the collector of TR104 to the emitter of TR103 is controlled by connecting C111 and R17 or R18 (selected by the RANGE switch) across R126.

13. Output from this amplifier is a.c. coupled into a similar stage, TR105 and TR106. Preset potentiometers (RV2 to RV9 inclusive) are selected by the RANGE switch and used to adjust the gain of the amplifier. The output, taken from the collector of VT106, drives the main amplifier.

MAIN AMPLIFIER AND 87 Hz FILTER

14. This circuit comprises two stages of amplification and a filter.

15. Both amplifying stages TR107/TR108 and TR109/TR110 are similar to those in the pre-amplifier.

16. Output of the main amplifier is passed through the 87 Hz band-pass filter to a further stage of amplification.

AMPLIFIER AND DETECTOR

17. The signal from the filter is amplified and passed to the detector circuit. The detector output is synchronized with the chopper output by a control signal from the 87 Hz oscillator.

18. Output from the filter is fed into emitter follower TR111 which is a.c. coupled to amplifier TR112/TR113. This amplifier is of the same configuration as those in the pre-amplifier.

19. The amplifier output is a.c. coupled to a common emitter stage TR114. This employs current feedback to provide a high resistance feed to the detector TR115.

20. TR115 detector is controlled by an 87 Hz switching signal from the same oscillator that drives the chopper. Only that portion of the signal from TR114 which is in phase with the oscillator signal is passed to the meter. This achieves good noise discrimination and polarity sense is retained.

LINEARITY CONTROL AND METER CIRCUIT

21. The detector output follows a square or linear law dependent on the low or high test voltage applied to the probe. The linearity control circuit network applies corrections, when necessary, to provide the required linear meter scale.

22. Because of the probe response, the detector output follows a square law with probe inputs of less than 30 mV, a linear law on the 1 V and 3 V ranges, and falls between these two conditions on the other ranges. Inverse square law correction is applied as necessary via D4 and one of the associated preset resistors RV10 to RV14 inclusive.

23. These resistors are shunted across the detector output on the 3 to 300 mV ranges, the resistance increasing as the range gets higher and needs less correction. On the 1 V and 3 V ranges, D4 and the resistors are switched out. D5 network provides a small series correction on the 3 V range only. No correction is required on the 1 mV range because of the special meter scale used.

24. The thermistor network is included on the 3 to 300 mV ranges to compensate for temperature errors occurring in D4.

25. Smoothing of the signal into the meter is effected by C8 and R42, the meter responding to the average value of the smoothed signal over the input range 30 mV to 1 V. Because of the probe characteristic the meter reading is proportional to the peak to peak value of the probe input on the higher ranges and the r.m.s. value on the lower ranges.

OSCILLATOR

26. The 87 Hz oscillator circuit provides a control signal to the detector and drive to the chopper.

27. The oscillator is a free running, emitter coupled multivibrator TR301/TR302. Frequency is controlled by capacitors C302, C303 and the resistor chain R303, RV301 and RV302.

28. TR303 feeds the 87 Hz oscillator output to the amplifier TR305 and to the emitter follower TR304. The amplified signal is fed to TR401 which provides the drive to the chopper through IC401. TR304 provides the switching control signal to the detector.

POWER SUPPLY

29. The power supply circuit has a mains transformer, full-wave rectifier circuit and a conventional series regulator circuit which provides a stabilized +15 V rail.

30. On the mains transformer T1 are two primary windings which can be linked in series or parallel to permit operation from a.c. supplies giving between 190 V and 265 V or between 95 V and 132 V respectively.

31. Resistor chain R206, RV201 and R205 senses variations in the output voltage and feeds a small correcting voltage back through amplifier TR201 and emitter follower TR202, to the regulator TR1. The emitter voltage of TR201 is stabilized by Zener diode D203, which is fed from the +15 V rail.

32. Terminals and switch SB on the rear panel allow the input of the regulating circuit to be fed from an external battery. Series diode D3 protects the instrument against the application of the wrong polarity.

DRIVER BOARD

33. Input to the driver board is an 87 Hz square wave voltage from the oscillator unit. TR401 and TR402 provide the negative supply voltage for integrated circuit IC401 which produces two anti-phase negative-going square wave voltages to drive the FET chopper.

34. TR401 and TR402 with C401 form a charge-pump circuit for C402 which operates as follows. When the oscillator input goes negative TR401 conducts, charging C401 to approx. +15 V through D402. When input goes positive TR401 holds C401 -ve at approx. -15 V which charges reservoir capacitor C402 through D401. R405 and C404 provide smoothing with Zener diode D403 stabilizing the supply to IC401 at approx. -6.8 V.

35. Quad NAND gate IC401 has a single square wave input. This is derived from the oscillator input by a.c. coupling through C403 and amplitude limiting by means of diodes D404 and D405 connected to the 0 V and -6.8 V supply rails.

36. IC401 outputs at pins 10 and 11 are antiphase negative-going square waves which control the gates of the FET switches in the chopper assembly. IC401 logic is such that the chopper has a make-before-break action to minimize spurious transients on the chopper output waveform.

37. Chopper offset voltage which can be due to unequal FET inter-electrode capacitance and unequal mark/space driving waveform is minimized by adjustment of RV401.

Chapter 4

MAINTENANCE

CONTENTS

Note ...

Transistors are referenced TR in this chapter and VT in chapters 6 and 7.

SERVICING GUIDE

1. This chapter contains information for maintaining the instrument in good operational condition and details adjustment procedures that may be necessary after replacement of components.

2. Before attempting any maintenance the information given should be read with reference to the preceding Technical Description chapter.

CAUTION...

Semiconductor devices are used throughout 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.

FUSES

3. The circuits of the voltmeter are protected by two time lag fuses. AC FUSE FS1 is in series with one supply input connection to the mains transformer. DC FUSE FS2 is in series with the rectified mains supply to the regulator circuit or, in series with the negative input from the battery to the regulator circuit; depending on the setting of the BATTERY/MAINS switch SB.

4. Both fuse holders are mounted on the rear panel. FS1 is marked AC and the correct fuse rating together with the appropriate voltage range is disclosed by the mains BLANKING plate. The two ratings are 50 mA for the 190 to 265 V range and 100 mA for the 95 to 132 V range. FS2 is marked DC 160 mA. Both fuses can be replaced without removing the instrument from its case.

MAINS TRANSFORMER CONNECTIONS

5. Transformer connections require changing only when the a.c. supply voltage is changed from the 190 to 265 V range, to the 95 to 132 V range, and vice versa.

6. To change the connections, ensure that the front panel SUPPLY switch is in the off position, then remove the BLANKING plate which secures the MAINS supply range switch (Chap. 2, Fig. 2). Move the switch to the required setting, reverse the BLANKING plate and replace it. Change FS1 (para. 4) to the correct rating.

BATTERY AND CONNECTIONS

7. Any battery supplying a voltage in the range 20 to 32 V may be used. For example, five PP8 batteries will give 120 hours at 4 hours per day rate, or 135 hours at 2 hours per day rate. In both cases the initial 30 V discharges to 20 V.

8. Before connecting the batteries ensure that the front panel SUPPLY switch is in the off position. Observe the correct polarity of the connections with neither side earthed. Set the MAINS/BATTERY switch to BATTERY.

ACCESS TO PRINTED CIRCUIT BOARDS AND COMPONENTS

9. Access to the main instrument and then to the printed circuit boards and components may be gained by removing the case assembly and the internal covers as described in the following paragraphs. All component references are marked on the board and chassis.

Removal of case

10. The case assembly is in two sections. The rear case clamps the main case to the front panel frame of the voltmeter.

11. To remove the case assembly proceed as follows:-

(1) Unscrew the four centrally located coin-slotted screws on the rear cover (Chap. 2, Fig. 2).

(2) Withdraw the mains lead socket from the plug on the rear panel.

(3) Pushing on the rear panel, slide the instrument forward out of the case, at the same time taking care while the probe and lead feed through the rear case cut-out.

An alternative method for (3) is to place the voltmeter front panel face down on a soft surface and lift the case assembly off.

Amplifier

12. The amplifier board is mounted on the under side of the chassis. To gain access proceed as follows:-

(1) Remove the bottom cover by unscrewing the two 2BA screws in the rear of the instrument.

(2) Remove the two screws holding the board to the support pillars (at right side when viewed from rear).

(3) Hinge the board back to show all components on the board.

13. With the amplifier board hinged back, access is also gained to the RANGE switch (Fig. 1), chopper base, RV2 to RV14, BALANCE control, C8, D4 and D5.

Oscillator

14. The oscillator board is mounted on the top right side of the chassis (viewed from rear). To gain access proceed as follows:-

(1) Remove the top cover by unscrewing the two 2BA screws.

(2) Remove the three screws located near right-hand edge of board.

(3) Hinge the board upwards to show all components on the board.

15. With the oscillator board hinged upwards, access is also gained to the oscillator drive board, probe heater thermostat and TR1. These components are mounted inside the oscillator box.

Power supply

16. The power supply board is mounted, on its edge, on the top left side of the chassis viewed from the rear. To gain access proceed as follows:-

(1) Slacken the two long screws, one in each pillar at the ends of the board.

(2) Hinge the board downwards to show all the components on the board.

SELECTED COMPONENTS

17. Certain components are selected to meet a given specification to ensure correct functioning of the voltmeter. These components are denoted on the circuit diagrams by an asterisk. So that replacement components may be correctly selected, the following list details the circuit references and specifications.

TABLE 1 SELECTED COMPONENTS AND SPECIFICATIONS

Component circuit reference	Specification
C104	Leakage not greater than 0.22 μA when 4.5 V ±10% is applied. (Test at 20°C)
D1 and D2	Selected to MI 44529-009
TR101	Spot noise figure less than 2 dB. With conditions:- V_{ce} = 5 V, I_c = 10 μA, f = 1 kHz, R_g = 10 kohm
THT1	Setting : Break on rise at 33°C ±2°C. Differential : 3° to 5°C

EARTH CONNECTIONS

18. To eliminate earth-loop currents the system is connected to chassis at one point only. That is tag 101 on the Amplifier board TM 7668. When servicing the voltmeter, reconnect earth wires to their original positions.

19. When capacitors C4, C5, C11 or C12 require replacements ensure that the outer foil is connected to earth so that pick-up effects are reduced to a minimum.

PERFORMANCE TESTS AND ADJUSTMENTS

20. The tests in this section are simplified and of restricted range compared with those which would be needed to demonstrate complete compliance with the specification. They should be regarded only as providing a check procedure for use during routine maintenance, to determine whether adjustment or repair is necessary.

21. The performance limits quoted are for guidance and should not be taken as guaranteed performance specifications unless they are also quoted in the Performance Data in Chap. 1.

22. When making tests to verify that the instrument meets the stated performance limits, allowance must always be made for the uncertainty of the test equipment used.

Test equipment

23. The recommended test equipment is as follows:-

(1) Multimeter. Selectest.

(2) Oscilloscope, general purpose type.
Frequency range 20 Hz to 10 MHz.
Amplitude measurement 0 to 25 V.

(3) Frequency Counter.

(4) Signal Generator. MI TF 144H/6S.
Distortion less than 1% at 200 kHz.

(5) AC Voltmeter. MI TF 2600.
Error less than 0.3%.

Probe unit

24. Check that the probe is functioning correctly as follows:-

(1) Diodes forward resistance.
Connect the negative lead of the multimeter to the junction of R49 and R50, and the positive lead to the junction of R53 and R54. The resistance reading should be approximately 50 kohms.

(2) Diodes reverse resistance.
Reverse the multimeter connections to the probe wires described in (1), after disconnecting the wires from the board pins. The resistance reading should be between 5 Mohms and 15 Mohms.

(3) Heater.
Disconnect the lead from the thermostat to the heater and check that the resistance between this lead and pin 302 is 180 ohms ±2%.

25. When a faulty probe unit is replaced check the voltmeter as described in the following paragraphs.

Adjustment of preset controls

26. Preset potentiometers should normally need no readjustment but this may become necessary if component changes are made. Tests and adjustments should be carried out in a screened room in which the ambient temperature is maintained between 20°C and 23°C.

27. Adjust presets in the order given in the following instructions. Where no adjustments are necessary check the stage, before proceeding to the next stage. Carry out the preliminary procedures described in Chap. 2 before resetting any of the presets.

Power supply RV201

28. Connect multimeter between terminal 208 or 209 (positive lead) and terminal 207 (negative lead) of the power supply. Adjust RV201 to obtain a +15 V reading on the multimeter.

Oscillator RV301, RV302

29. Monitor with the oscilloscope on test point TP1 on Amplifier board TM 7668.

30. Select the 3 mV range on the instrument RANGE switch and connect the probe to the output of the signal generator set for an output signal of 200 kHz at 3 mV.

31. Adjust RV301 and RV302 on Oscillator board TM 7667 so that the displayed waveform is as shown in Fig. 2, Test Point 1, with 'A' equal to 'B'.

32. Check that at full-scale deflection on each range, any fast edge (A or B) of TP1 waveform is at least 5% of the total peak-to-peak waveform amplitude.

33. Connect the frequency counter to terminal 303 on Oscillator board TM 7667. Check that the oscillator frequency indicated is 87 Hz ±13 Hz.

34. Fig. 3 shows the waveforms displayed at various test points in the oscillator circuits.

Amplifier gain : RV2 to RV9
Meter linearity : RV10 to RV14

35. With the instrument case removed, access to RV2 and RV3 may be gained from the top. RV4 to RV14 inclusive are accessible at the side, after the preset cover plate (held by two screws) is removed.

36. (1) Before switching on the instrument check that the meter needle is correctly positioned at zero, if not adjust the meter mechanical zero control as detailed in Chapter 2.

(2) Switch on the instrument, select the RANGE switch to 1 mV and place the BALANCE control to the mid-position. Short circuit the probe and adjust RV401 on the Driver board to achieve a meter reading of zero.

37. Connect the instrument probe to the output of the signal generator and monitor this output with the a.c. voltmeter (Coaxial T Connector TM 7948 may be used for this purpose). Set the signal generator to provide a 200 kHz signal at a level of 1 mV as monitored on the a.c. voltmeter.

38. Adjust RV2 to give full-scale deflection on the instrument.

Notes...

(1) In conditions of severe r.f. interference, check if the a.c. voltmeter is injecting this unwanted signal into the probe. This can be ascertained by disconnecting the a.c. voltmeter and if the interference is eliminated, leave disconnected after setting the 1 mV output level of the signal generator.

(2) The signal generator must be well screened and the supply leads filtered.

(3) Screening and filtering must be effective over the range 10 kHz to 3000 MHz, unless the local interference frequencies are known with certainty.

39. Select the 3 mV range and with the input signal still at 1 mV, adjust RV3 for 1 mV indication on the instrument.

40. Set the output level of the signal generator to 3 mV as monitored on the a.c. voltmeter and adjust RV10 for an indication of 3 mV on the instrument.

41. Repeat paras. 39 and 40 adjusting if necessary for the best compromise between extremes of the range and also the middle (2 mV marking).

42. Check the accuracy throughout the scale. This should be within limits stated in Table 2, if not, readjust RV3 and RV10 to achieve this accuracy.

43. Refer to Table 2 and similarly adjust the 10 mV to 3 V ranges in turn. When adjusting for accuracy at the centre of the 10 mV, 100 mV and 1 V scales, check at the '6' marking (lower scale).

TABLE 2 LINEARITY AND GAIN CONTROLS AND ACCURACY

Scale	Preset control		Accuracy (% of full-scale)
	Linearity	Gain	
1 mV	-	RV2	±2.5%
3 mV	RV10	RV3	±2.0%
10 mV	RV11	RV4	±1.5%
30 mV	RV12	RV5	±1.5%
100 mV	RV13	RV6	±2.0%
300 mV	RV14	RV7	±2.0%
1 V	-	RV8	±2.0%
3 V	-	RV9	±2.0%

Notes...

(1) The gain preset controls have most effect at the lower end of the meter scale and the linearity presets at the higher end.

(2) Fig. 2 shows the waveforms displayed at test points in the amplifier circuits.

AVOIDANCE OF LEAKAGE

44. To avoid leakage effects, the following parts should be kept clean:-

(1) Switch wafers SA1, SA2 and SA3.

(2) Ceramic tag strips associated with the probe filter components.

(3) All connections, components and dielectrics between tag 105 and C105 (on Amplifier board TM 7668).

45. A cleanser recommended for this purpose is Gen Klene (ICI) or a less satisfactory alternative is carbon tetrachloride.

46. Cleaning is particularly important when the instrument is operating in conditions of high humidity.

47. If the instrument is operated or stored in conditions where severe condensation may occur, or large temperature or humidity variations, it may become impossible to set zero on the 1 mV range. To overcome this, dry out the instrument by applying warm dry air and then clean the parts listed in para. 44.

RANGE SWITCH

48. The RANGE switch (Fig. 1) contains three wafers, SA1, SA2 and SA3 (the three nearest to the control knob) made of thermoplastic material.

CAUTION...

When soldering the switch tags of these wafers use a low wattage soldering iron to prevent damage. (A 25 W soldering iron applied to a tag for more than 2 seconds will soften the wafer material.)

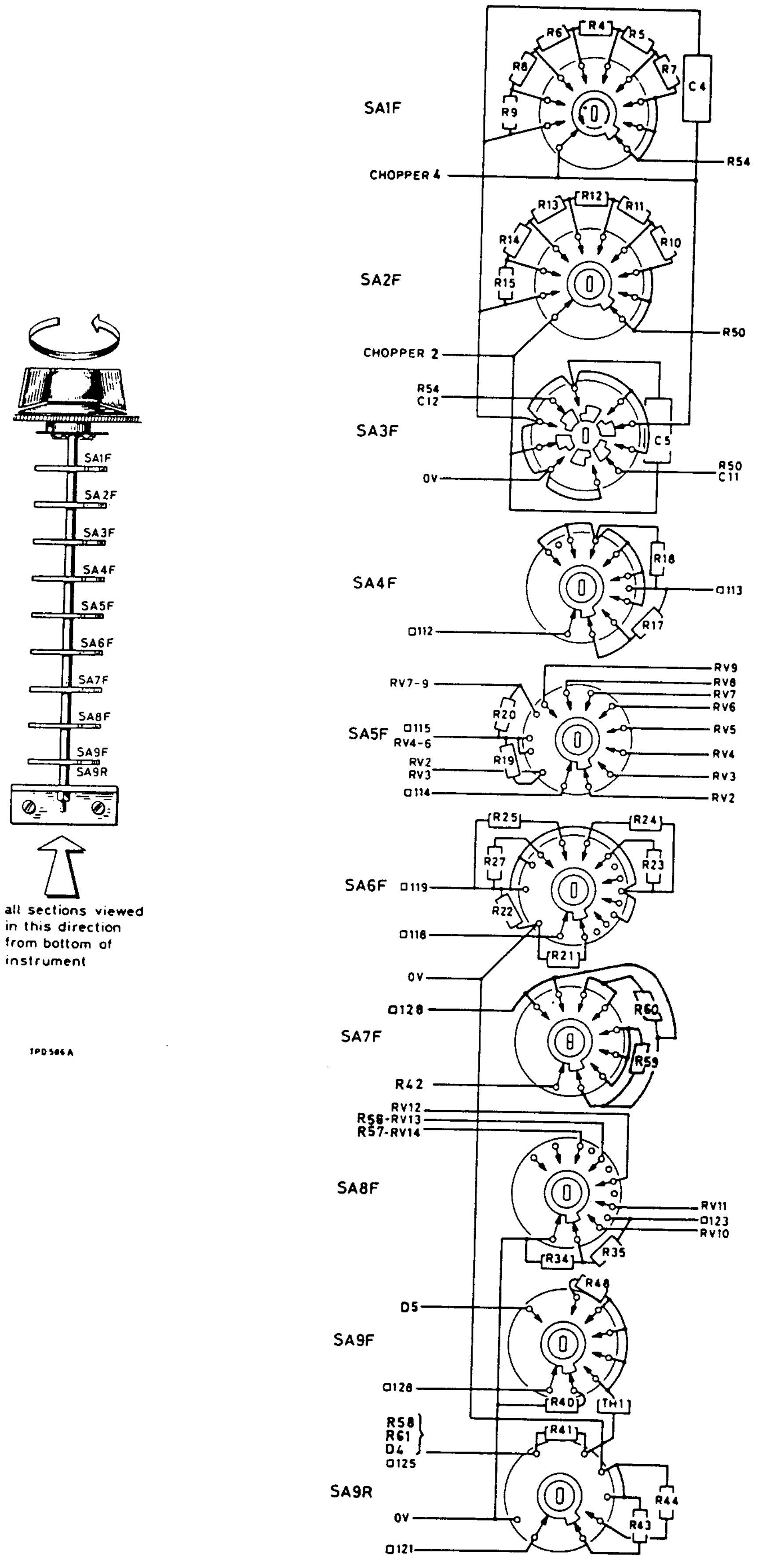
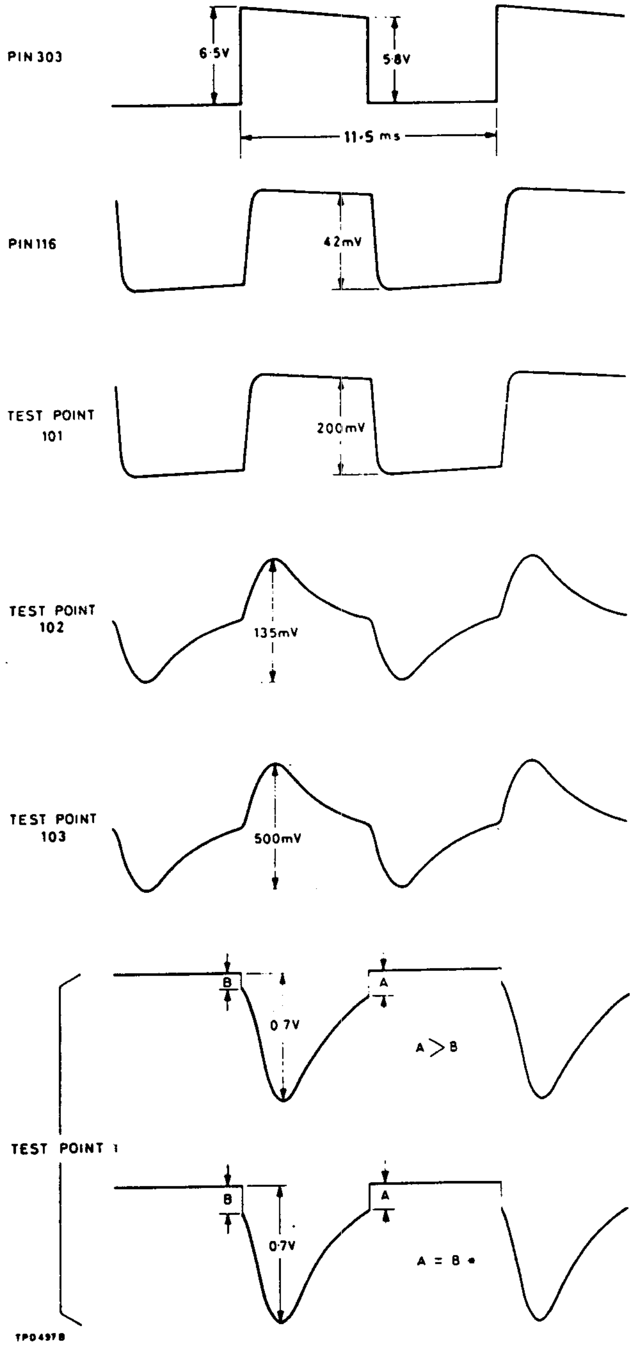


Fig. 1 Range switch component location.



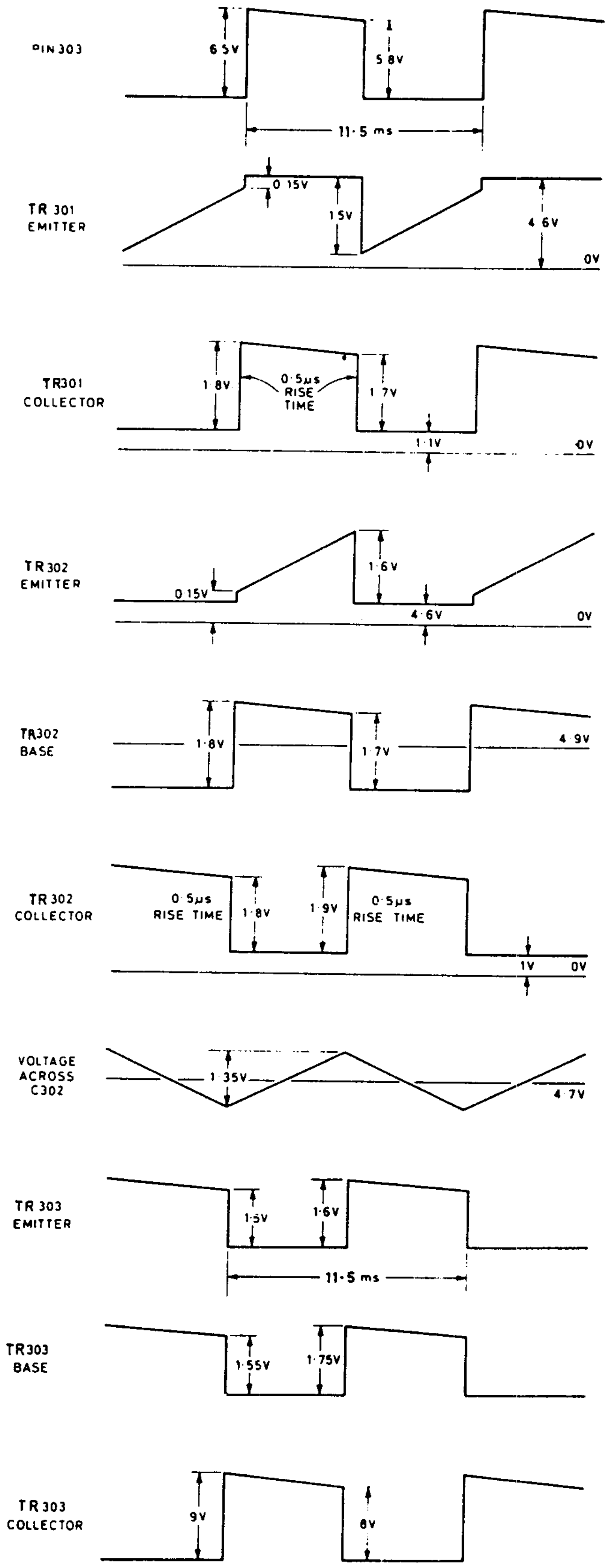
Notes ...

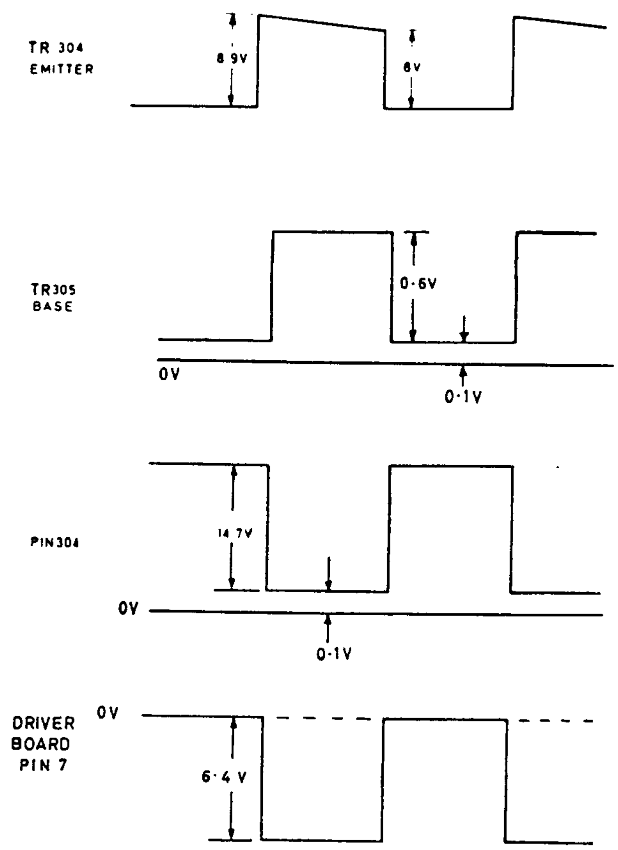
(1) Input to instrument 1 V at 200 kHz.

(2)* Input is 3 mV at 200 kHz.

(3) In general, mark/space ratio should be within 52:48 or 48:52.

Fig. 2 Amplifier waveforms.





Notes ...

(1) Input to instrument is 1 V at 200 kHz.

(2) In general, mark/space ratio should be within 52:48 or 48:52.

Fig. 3 Oscillator waveforms.

Chapter 6

REPLACEABLE PARTS

CONTENTS

INTRODUCTION

1. This section lists replaceable parts in alphabetical order of their circuit references, with miscellaneous parts at the end of the list. The following abbreviations are used :

C : capacitor
Carb : carbon
Cer : ceramic
Cerm : cermet
D or MR : semiconductor diode
Elec : electrolytic
FS : fuse
L : inductor
M : meter
Met : metal
Mic : mica
Ox : oxide
PL : plug
Plas : plastic
R : resistor
RV : variable resistor
S : switch
SKT : socket
T : transformer
TH : thermistor
THT : thermostat
TP : terminal or test point
TR or VT : transistor
WW : wirewound
† : value selected during test; nominal value listed
Ø : feed-through component
W : watts at 70°C
⚠ : Static sensitive device (see Notes and cautions)

COMPONENT VALUES

2. One or more of the components fitted in this instrument may differ from those listed in this chapter for any of the following reasons :

(1) Components indicated by † have their value selected during test to achieve particular performance limits.

(2) Owing to supply difficulties, components of different value or type may be substituted provided the overall performance of the instrument is maintained.

(3) As part of a policy of continuous development, components may be changed in value or type to obtain detail improvements in performance.

3. When there is a difference between the component fitted and the one listed, always use as a replacement the same type and value as found in the instrument.

ORDERING

4. When ordering replacement parts address the order to our Service Division. Specify the following information for each part required :

(1) Type* and serial number of instrument.

(2) Circuit reference.

(3) Description.

(4) MI code number.

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

Circuit ref.	*Description*	*MI code*
C1	Cer 0.001μF +80-20% 250V	26387-113T
C2	Cer 0.001μF ±20% 200V	26343-598Z
C3	Cer 0.001μF ±20% 200V	26343-598Z
C4	Plas 0.1μF 0.5% 125V	26516-841X
C5	Plas 0.1μF 0.5% 125V	26516-841X
C6	Elec 100μF +100-20% 25V	26415-813U
C7	Elec 100μF +100-20% 25V	26415-813U
C8	Elec 5μF +100-20% 15V	26414-113J
C9	Cer 0.0022μF +80-20% 250V	26383-439S
C10	Cer 0.0022μF +80-20% 250V	26383-439S
C11	Plas 0.1μF 0.5% 125V	26516-841X
C12	Plas 0.1μF 0.5% 125V	26516-841X
C13	Cer 470pF +40-20% 500V	26383-139M
C14	Cer 470pF +40-20% 500V	26383-139M
C15	Cer 470pF +40-20% 500V	26383-139M
C16	Cer 470pF +40-20% 500V	26383-139M
C17	Cer 0.001μF +80-20% 500V	26383-242P
C18	Cer 470pF +40-20% 500V	26383-139M
C19	Cer 470pF +40-20% 500V	26383-139M
C20	Cer 0.001μF +80-20% 500V	26383-242P
C21	Cer 0.001μF +80-20% 500V	26383-242P
C22	Plas 0.1μF 10% 250V	26512-228Y
C103	Plas 3000pF 2% 125V	26516-597M
C104†	Elec 100μF +100-20% 25V	26423-243M
C105	Plas 0.1μF 10% 125V	26516-843C
C106	Elec 100μF +100-20% 25V	26423-243M

Circuit ref.	*Description*	*MI code*
C107	Elec 100μF +100-20% 25V	26423-243M
C108	Elec 100μF +100-20% 25V	26423-243M
C109	Elec 22μF +100-20% 40V	26423-222E
C110	Elec 100μF +100-20% 25V	26423-243M
C111	Elec 220μF +100-20% 6V	26423-250K
C112	Elec 470μF +100-20% 40V	26415-823V
C113	Paper 0.001μF 10% 300V	26174-125H
C114	Elec 100μF +100-20% 25V	26423-243M
C115	Elec 22μF +100-20% 40V	26423-222E
C116	Elec 100μF +100-20% 25V	26423-243M
C117	Elec 470μF +100-20% 40V	26415-823V
C118	Elec 220μF +100-20% 6V	26423-250K
C119	Paper 0.001μF 10% 300V	26174-125H
C120	Elec 100μF +100-20% 25V	26423-243M
C121	Elec 22μF +100-20% 40V	26423-222E
C122	Elec 100μF +100-20% 25V	26423-243M
C123	Elec 100μF +100-20% 25V	26423-243M
C124	Elec 100μF +100-20% 25V	26423-243M
C125	Elec 470μF +100-20% 40V	26415-823V
C126	Elec 22μF +100-20% 40V	26423-222E
C127	Elec 100μF +100-20% 25V	26423-243M
C128	Elec 100μF +100-20% 25V	26423-243M
C129	Elec 470μF +100-20% 40V	26415-823V
C130	Plas 0.22μF 10% 250V	26512-245P
C131	Plas 0.22μF 10% 250V	26512-245P

Circuit ref.	Description	MI code
C132	Plas 0.22μF 10% 250V	26512-245P
C133	Plas 0.22μF 10% 250V	26512-245P
C134	Plas 0.22μF 10% 250V	26512-245P
C135	Plas 0.22μF 10% 250V	26512-245P
C136	Elec 22μF +100-20% 40V	26423-222E
C137	Elec 100μF +100-20% 25V	26423-243M
C139	Elec 100μF +100-20% 25V	26423-243M
C140	Elec 100μF +100-20% 25V	26423-243M
C141	Elec 470μF +100-20% 40V	26415-823V
C142†	Elec 100μF +100-20% 25V	26423-243M
C201	Elec 470μF +100-20% 40V	26415-823V
C202	Elec 47μF +100-20% 40V	26415-810Z
C203	Plas 0.047μF 10% 400V	26555-471X
C204	Elec 50μF +100-20% 25V	26417-152C
C205	Elec 470μF +100-20% 40V	26415-823V
C301	Elec 470μF +100-20% 25V	26427-823B
C302	Plas 2.2μF 10% 250V	26512-288Z
C303	Plas 2.2μF 10% 250V	26512-288Z
C304	Elec 100μF +100-20% 25 V	26423-243M
C305	Elec 100μF +100-20% 25V	26423-243M
C306	Elec 47μF +100-20% 25V	26423-231F
C307	Elec 100μF +100-20% 25V	26423-243M
C309	Elec 47μF +100-20% 25V	26423-231F
C311	Elec 470μF +100-20% 25V	26427-823B
C401	Tant 22μF 20% 16V	26486-230B

Circuit ref.	Description	MI code
C402	Tant 22μF 20% 16V	26486-230B
C403	Tant 2.2μF 20% 35V	26486-214V
C404	Tant 22μF 20% 16V	26486-230B
CH1	Chopper assy.	41700-322R
	(VT1 & VT2, 2N4416)	28459-018C
FS1	50 mA for 190-265V	23411-051S
	100 mA for 95-132 V	23411-052W
FS2	160 mA	23411-054T
	Holder for FS1 or FS2	23416-192R
	Cover for fuse holder	23416-198E
H1	Heater for probe	44734-002E
IC401 ⚠	4011	28466-340R
M1	100μA full scale	44553-406A
MR1†	CG91AH/1	28321-312F
MR2†	CG91AH/1	28321-312F
MR3	1N4004	28357-028K
MR4	AA143	28331-355M
MR5	AA143	28331-355M
MR201	1N540	28357-048W
MR202	1N540	28357-048W
MR203	BZX 79C10	28371-844U
MR401	1N4148	28336-676J
MR402	1N4148	28336-676J

Circuit ref.	Description	MI code
MR403	BZX 79C6V8	28371-550W
MR404	1N4148	28336-676J
MR405	1N4148	28336-676J
PL1	Mains plug, 3 pin	23423-159P
R1†	Met film 100Ω 2% 1/4W	24773-249J
R2	Met film 22kΩ 2% 1/4W	24773-305R
R3	Met film 22kΩ 2% 1/4W	24773-305R
R4	Met film 56kΩ 1% 1/4W	24637-602X
R5	Met film 390kΩ 1% 1/4W	24637-754N
R6	Met film 4.7kΩ 1% 1/4W	24637-208J
R7	Carb film 3.3MΩ 1% 1/2W	24765-578M
R8	Met film 1.3kΩ 1% 1/4W	24637-105L
R9	Met film 510Ω 1% 1/4W	24636-807J
R10	Carb film 3.3MΩ 1% 1/2W	24765-578M
R11	Met film 390kΩ 1% 1/4W	24637-754N
R12	Met film 56kΩ 1% 1/4W	24637-602X
R13	Met film 4.7kΩ 1% 1/4W	24637-208J
R14	Met film 1.3kΩ 1% 1/4W	24637-105L
R15	Met film 510Ω 1% 1/4W	24636-807J
R16	Met ox 33Ω 2% 1/2W	24573-037S
R17	Met ox 2kΩ 3% TE 1/2W	24512-387H
R18	Met ox 1kΩ 3% TE 1/2W	24512-380M
R19 †	Met ox 1.5kΩ 2% TE 1/2W	24573-077X
R20 †	Met ox 820Ω 2% 1/2W	24573-071V

Circuit ref.	Description	MI code
R21	Met ox 1.6kΩ 3% TE 1/2W	24512-385A
R22	Met ox 27kΩ 7% TE 1/2W	24552-120L
R23	Met ox 7.5kΩ 3% TE 1/2W	24512-407W
R24	Met ox 2.2kΩ 3% TE 1/2W	24512-388E
R25	Met ox 1.2kΩ 3% TE 1/2W	24512-382R
R26	Met ox 15Ω 2% 1/2W	24573-029L
R27	Met ox 820Ω 7% TE 1/2W	24512-378C
R34	Met ox 47kΩ 7% TE 1/2W	24552-126W
R35	Met ox 510Ω 3% TE 1/2W	24512-370V
R40	Met ox 510Ω 3% TE 1/2W	24512-370V
R41	Met ox 1.2kΩ 3% TE 1/2W	24512-382R
R42	Met ox 100Ω 2% 1/2W	24573-049B
R43	Met ox 1.3kΩ 3% TE 1/2W	24512-383B
R44	Met ox 2.2kΩ 3% TE 1/2W	24512-388E
R47	Met ox 20Ω 2% 1/2W	24573-032L
R48	Met ox 1.6kΩ 7% 1/2W	24552-085G
R49	Met ox 22MΩ 10% 1/2W	24323-989S
R50	Met film 330kΩ 1% 1/4W	24637-755L
R51†	Met ox 1kΩ 2% 1/2W	24573-073W
R52†	Met ox 1kΩ 2% 1/2W	24573-073W
R53	Met ox 22MΩ 10% 1/2W	24323-989S
R54	Met film 330kΩ 1% 1/4W	24637-755L
R55	Met ox 100Ω 2% 1/2W	24573-049B
R56	Met ox 330Ω 2% 1/2W	24573-061U
R57	Met ox 1.5kΩ 2% 1/2W	24573-077X

Circuit ref.	Description	MI code
R58	Met ox 910Ω 2% 1/2W	24573-072S
R59	Met ox 330Ω 2% 1/2W	24573-061U
R60	Met ox 680Ω 2% 1/2W	24573-069S
R61	Met ox 5.6kΩ 2% 1/2W	24573-091H
R62	Met ox 1kΩ 2% 1/2W	24573-073W
R63	Met ox 1kΩ 2% 1/2W	24573-073W

Note...

Carbon resistors have now been changed to metal film type - tolerance ±2%, rating 1/4W at 70°C also metal oxide type resistors are re-rated - tolerance ±2% 1/4W at 70°C.

Circuit ref.	Description	MI code
R106	Met ox 2.2MΩ 10% 1/4W	24322-974W
R108	Met ox 18kΩ 3% TE 1/2W	24512-416C
R109	Met film 150kΩ 1% 1/4W	24637-702T
R110	Met film 100kΩ 1% 1/4W	24637-701D
R111	Met film 1kΩ 2% 1/4W	24773-273A
R112	Met ox 1MΩ 2% 1/2W	24573-145T
R113	Met film 56kΩ 1% 1/4W	24637-602X
R114	Met ox 56kΩ 7% TE 1/2W	24552-129P
R115	Met ox 22kΩ 2% 1/2W	24573-105G
R116	Met ox 22kΩ 2% 1/2W	24573-105G
R117	Met ox 16kΩ 7% TE 1/2W	24552-115Y
R118	Met ox 120kΩ 7% TE 1/2W	24552-137B

Circuit ref.	Description	MI code
R119	Met ox 150Ω 7% TE 1/2W	24552-054V
R120	Met ox 1.6kΩ 1% 1/4W	24637-108G
R121	Carb film 30kΩ 1% 1/4W	24135-300S
R122	Met film 33kΩ 1% 1/4W	24637-556S
R123	Met ox 15kΩ 2% 1/2W	24573-101N
R124	Met ox 180Ω 3% TE 1/2W	24512-356E
R125	Met ox 22kΩ 3% TE 1/2W	24512-418B
R126	Met ox 18kΩ 3% TE 1/2W	24512-416C
R127	Met ox 7.5kΩ 3% TE 1/2W	24512-407W
R128	Met ox 150Ω 7% TE 1/2W	24552-054V
R129	Met ox 6.2kΩ 3% TE 1/2W	24512-404G
R130	Met film 1.6kΩ 1% 1/4W	24637-108G
R131	Carb film 30kΩ 1% 1/4W	24135-300S
R132	Met film 33kΩ 1% 1/4W	24637-556S
R133	Met ox 15kΩ 2% 1/2W	24573-101N
R134	Met ox 180Ω 3% TE 1/2W	24512-356E
R135	Met ox 22kΩ 3% TE 1/2W	24512-418B
R136	Met ox 47Ω 7% TE 1/2W	24552-037A
R137	Met ox 18kΩ 3% TE 1/2W	24512-416C
R138	Met ox 7.5kΩ 3% TE 1/2W	24512-407W
R139	Met ox 150Ω 7% TE 1/2W	24552-054V
R140	Met ox 6.2kΩ 3% TE 1/2W	24512-404G
R141	Met ox 4.7kΩ 7% TE 1/2W	24552-100P
R142	Met ox 27kΩ 2% 1/2W	24573-107S

Circuit ref.	Description	MI code
R143	Met ox 560Ω 3% TE 1/2W	24512-372W
R144	Met ox 4.7kΩ 3% TE 1/2W	24512-400N
R145	Met ox 8.2kΩ 7% TE 1/2W	24552-108Z
R146	Met film 1kΩ 2% 1/4W	24773-273A
R147	Met film 1kΩ 2% 1/4W	24773-273A
R148	Met film 1kΩ 2% 1/4W	24773-273A
R149	Met ox 47Ω 7% TE 1/2W	24552-037A
R150	Met ox 3.6kΩ 7% TE 1/2W	24552-095X
R151	Met ox 100Ω 7% TE 1/2W	24552-050L
R152	Met ox 2.2kΩ 7% TE 1/2W	24552-088W
R153	Met ox 39Ω 7% TE 1/2W	24552-035B
R154	Met ox 10kΩ 2% 1/2W	24573-097J
R155	Met ox 10kΩ 2% 1/2W	24573-097J
R156	Met ox 33kΩ 2% 1/2W	24573-109D
R157	Met ox 33kΩ 2% 1/2W	24573-109D
R158	Met ox 3.6kΩ 3% TE 1/2W	24512-395L
R159	Met ox 3.6kΩ 3% TE 1/2W	24512-395L
R160	Met ox 6.8kΩ 7% TE 1/2W	24552-106K
R161	Met ox 7.5kΩ 7% TE 1/2W	24552-107A
R162	Met ox 100Ω 7% TE 1/2W	24552-050L
R163	Met ox 1.8kΩ 2% 1/2W	24573-079C
R164	Met ox 75kΩ 7% TE 1/2W	24552-132P
R165	Met ox 1kΩ 7% TE 1/2W	24552-080Y
R166	Met ox 75kΩ 7% TE 1/2W	24552-132P
R167	Met ox 6.8kΩ 7% TE 1/2W	24552-106K

Circuit ref.	Description	MI code
R168	Met ox 22Ω 7% TE 1/2W	24552-028X
R169	Met ox 10kΩ 2% 1/2W	24573-097J
R170	Met ox 27kΩ 2% 1/2W	24573-107S
R171	Met ox 1.6kΩ 3% TE 1/2W	24512-385A
R172	Met ox 10kΩ 2% 1/2W	24573-097J
R174	Met ox 4.7kΩ 3% TE 1/2W	24512-400N
R175	Met ox 2.2kΩ 7% TE 1/2W	24552-088W
R176	Met ox 100Ω 7% TE 1/2W	24552-050L
R177	Met ox 1.8kΩ 2% 1/2W	24573-079C
R178	Met ox 3.9kΩ 7% TE 1/2W	24552-096M
R179	Met ox 18kΩ 2% 1/2W	24573-103J
R180	Met ox 300Ω 3% TE 1/2W	24512-362N
R181	Met ox 1.3kΩ 3% TE 1/2W	24512-383B
R182	Met ox 470Ω 3% TE 1/2W	24512-369W
R183	Met ox 6.2kΩ 7% TE 1/2W	24552-104R
R184	Met ox 1.8kΩ 2% 1/2W	24573-079C
R185	Met ox 22MΩ 10% 1/2W	24323-989S
R201	Met ox 10kΩ 7% TE 1/2W	24552-110A
R202	Met ox 4.7kΩ 7% TE 1/2W	24552-100P
R203	Met ox 33kΩ 2% 1/2W	24573-109D
R204	Met film 3.9kΩ 2% 1/2W	24773-287V
R205	Met ox 5.1kΩ 2% 1/2W	24573-090Z
R206	Met ox 1.8kΩ 7% TE 1/2W	24552-086V
R301	Met ox 1.5kΩ 7% TE 1/2W	24552-084F
R302	Met ox 10kΩ 7% TE 1/2W	24552-110A

Circuit ref.	Description	MI code
R303	Met ox 910Ω 2% TE 1/2W	24573-072S
R304	Met ox 82Ω 7% TE 1/2W	24552-046M
R305	Met ox 9.1kΩ 7% TE 1/2W	24552-109H
R306	Met ox 1kΩ 7% TE 1/2W	24552-080Y
R307	Met ox 4.7kΩ 7% TE 1/2W	24552-100P
R308	Met ox 10kΩ 7% TE 1/2W	24552-110A
R309	Met ox 4.7kΩ 7% TE 1/2W	24552-100P
R310	Met ox 8.2kΩ 7% TE 1/2W	24552-108Z
R311	Met ox 22kΩ 7% TE 1/2W	24552-118J
R312	Met ox 15Ω 7% TE 1/2W	24552-024W
R313	Met ox 1.6kΩ 7% TE 1/2W	24552-085G
R314	Met ox 390Ω 7% TE 1/2W	24552-065C
R315	Met ox 2kΩ 7% TE 1/2W	24552-087S
R316	Met ox 470Ω 7% TE 1/2W	24552-069A
R317	Met ox 22kΩ 7% TE 1/2W	24552-118J
R318	Met ox 7.5kΩ 7% TE 1/2W	24552-107A
R319	Met ox 4.7kΩ 7% TE 1/2W	24552-100P
R320	Met ox 820Ω 7% TE 1/2W	24552-078M
R321	Met ox 1.3kΩ 7% TE 1/2W	24552-083J
R401	Met film 33kΩ 2% 1/4W	24773-309Z
R402	Met film 33kΩ 2% 1/4W	24773-309Z
R403	Met film 47kΩ 2% 1/4W	24773-313H
R404	Met film 100kΩ 2% 1/4W	24773-321L
R405	Met film 3.3kΩ 2% 1/4W	24773-285F
R406†	Met film 1kΩ 2% 1/4W	24773-273A
R407†	Met film 470Ω 2% 1/4W	24773-265M

Circuit ref.	Description	MI code
RV1	WW 5kΩ 10% 1W	25815-129T
RV2	WW 1kΩ 10% 1W	25815-110K
RV3	WW 2.5kΩ 10% 1W	25815-116Y
RV4	WW 1kΩ 10% 1W	25815-110K
RV5	WW 1kΩ 10% 1W	25815-110K
RV6	WW 1kΩ 10% 1W	25815-110K
RV7	WW 1kΩ 10% 1W	25815-110K
RV8	WW 500Ω 10% 1W	25815-147U
RV9	WW 500Ω 10% 1W	25815-147U
RV10	WW 250Ω 10% 1W	25815-102X
RV11	WW 250Ω 10% 1W	25815-102X
RV12	WW 250Ω 10% 1W	25815-102X
RV13	WW 500Ω 10% 1W	25815-147U
RV14	WW 2.5kΩ 10% 1W	25815-116Y
RV201	Carb 1kΩ 20% 1/4W	25611-072D
RV301	WW 470Ω 10% 1W	25811-017D
RV302	WW 100Ω 10% 1W	25811-013G
RV401	Cerm 2kΩ 10% 1/2W	25711-639V
SA	RANGE 1 pole, 8 pos. 9 sect.	44325-607A
SB	MAINS/BATT DPDT	23467-161W
SC	SUPPLY switch 2 pole, 2 pos.	44321-406F
SD	Mains voltage range DPDT	23467-161W
SKT1	Mains lead and socket	43129-071D
T1	Mains transformer	43457-004M

Circuit ref.	Description	MI code
TH1	Thermistor K23	25683-405G
THT1†	Thermostat T40SS	23488-554W
TP1	Test point, r.f. socket	23441-044V
TP2	Battery input terminal	23235-176V
TP3	Battery input terminal	23235-176V
TP101	Test point	23421-085T
TP102	Test point	23421-085T
TP103	Test point	23421-085T
VT1	MJ491	28435-876Z
VT101	BC550	28455-427A
VT102	BCY72	28433-487R
VT103	BCY72	28433-487R
VT104	BCY72	28433-487R
VT105	BCY72	28433-487R
VT106	BCY72	28433-487R
VT107	BCY72	28433-487R
VT108	BCY72	28433-487R
VT109	BCY72	28433-487R
VT110	BCY72	28433-487R
VT111	BCY72	28433-487R
VT112	BCY72	28433-487R
VT113	BCY72	28433-487R
VT114	BCY72	28433-487R

Circuit ref.	Description	MI code
VT115	2N404†	44522-004P
VT201	BC251A	28435-227H
VT202	BC252B	28433-455R
VT301	2N404	44522-004P
VT302	2N404	44522-004P
VT303	2N404	44522-004P
VT304	2N404	44522-004P
VT305	BC109	28452-777K
VT401	BCY72	28433-487R
VT402	BC239C	28452-771P
<u>Knob assemblies</u>		
	RANGE	41145-206Z
	BALANCE	41142-210M
	SUPPLY	41142-209R
<u>Complete printed board assemblies</u>		
	Oscillator TM 7667	44621-001G
	Amplifier TM 7668	44643-006D
	Power Unit TM 7669	44686-402W
	Driver board 44828-621U	49200-821U
Probe assembly		44990-151T

Chapter 7

CIRCUIT DIAGRAM

CONTENTS

CIRCUIT NOTES

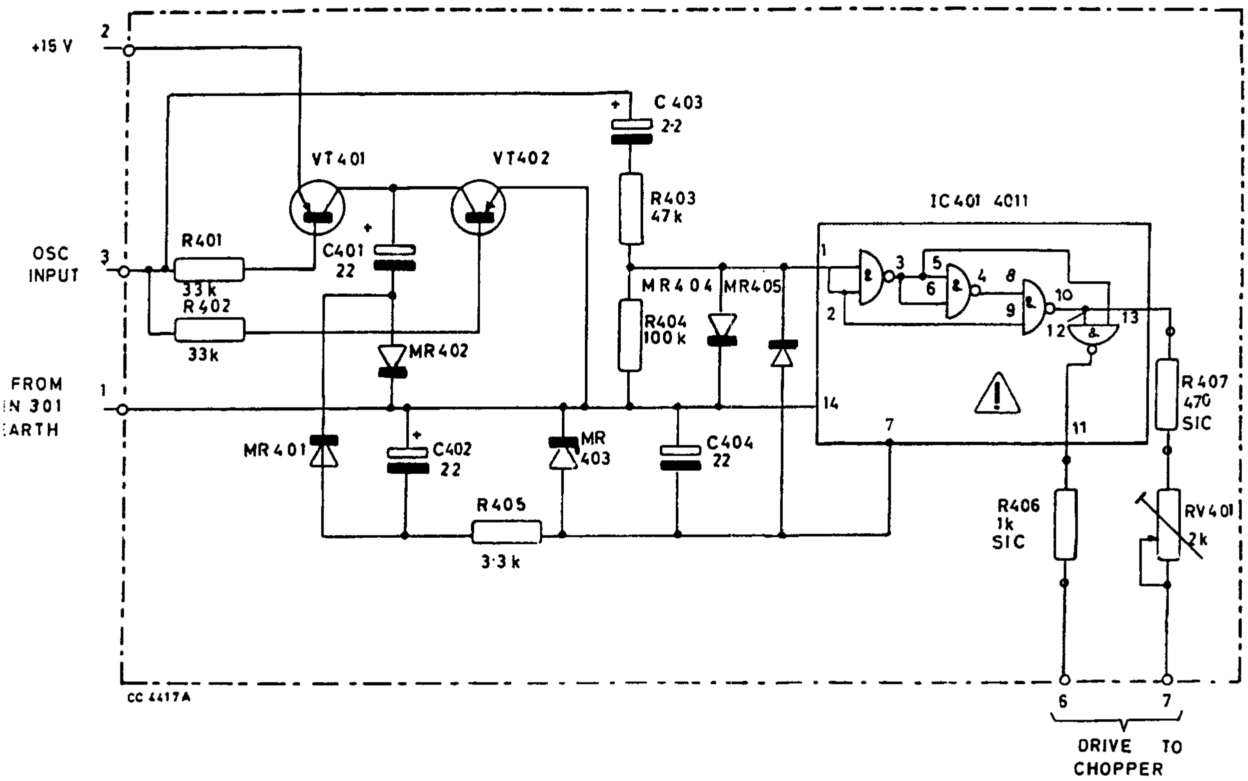
Component values

1. Resistors : No suffix = ohms, k = kilohms, M = megohms.
   Capacitors : No suffix = microfarads, p = picofarads.
   SIC : value selected during test, nominal value shown.

Switches

2. Rotary switches are drawn schematically. The sections are identified :

   1st section, front : 1F
   1st section, back : 1R
   2nd section, front : 2F
   2nd section, back : 2R
   etc.



Driver board (44828-621U)

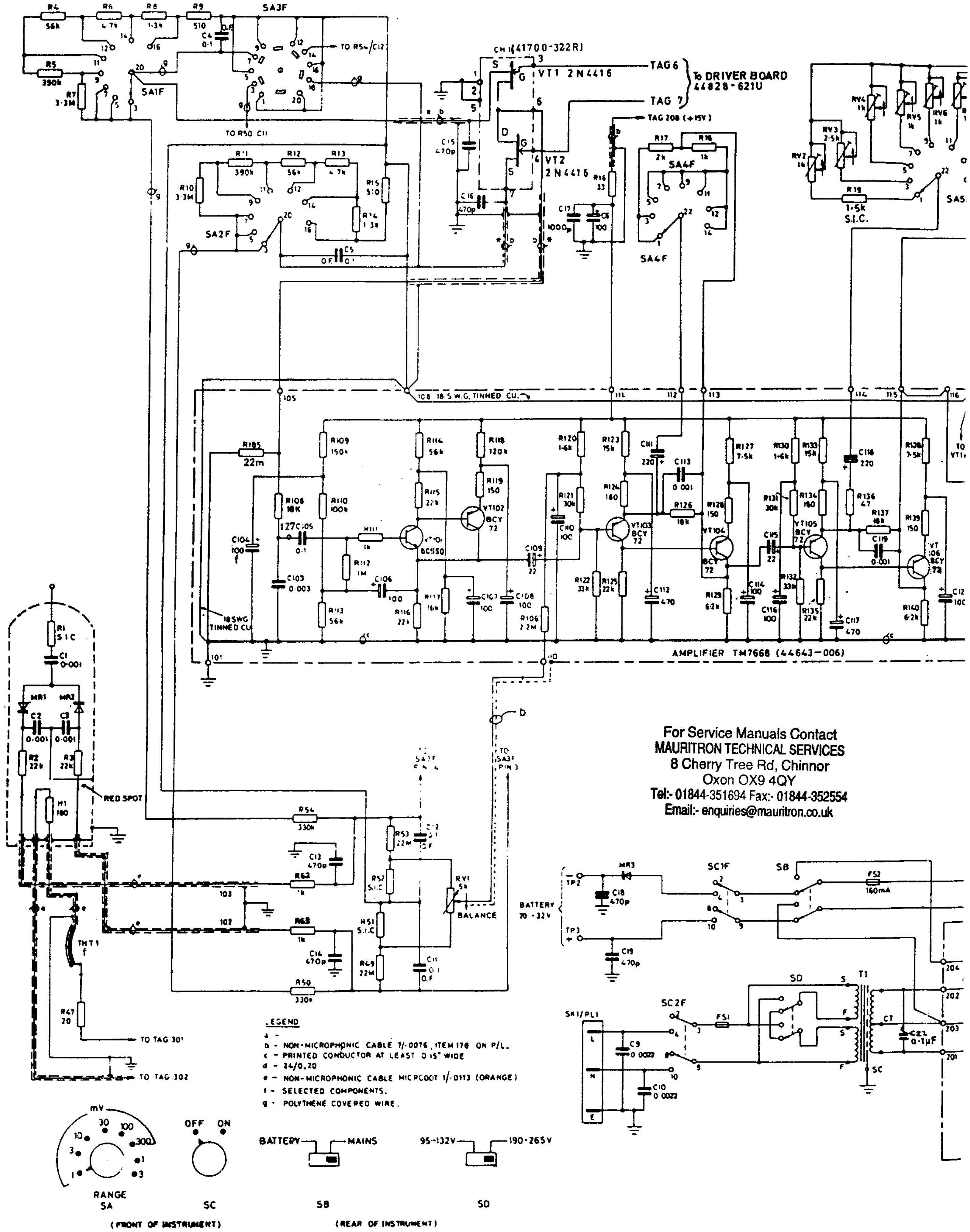


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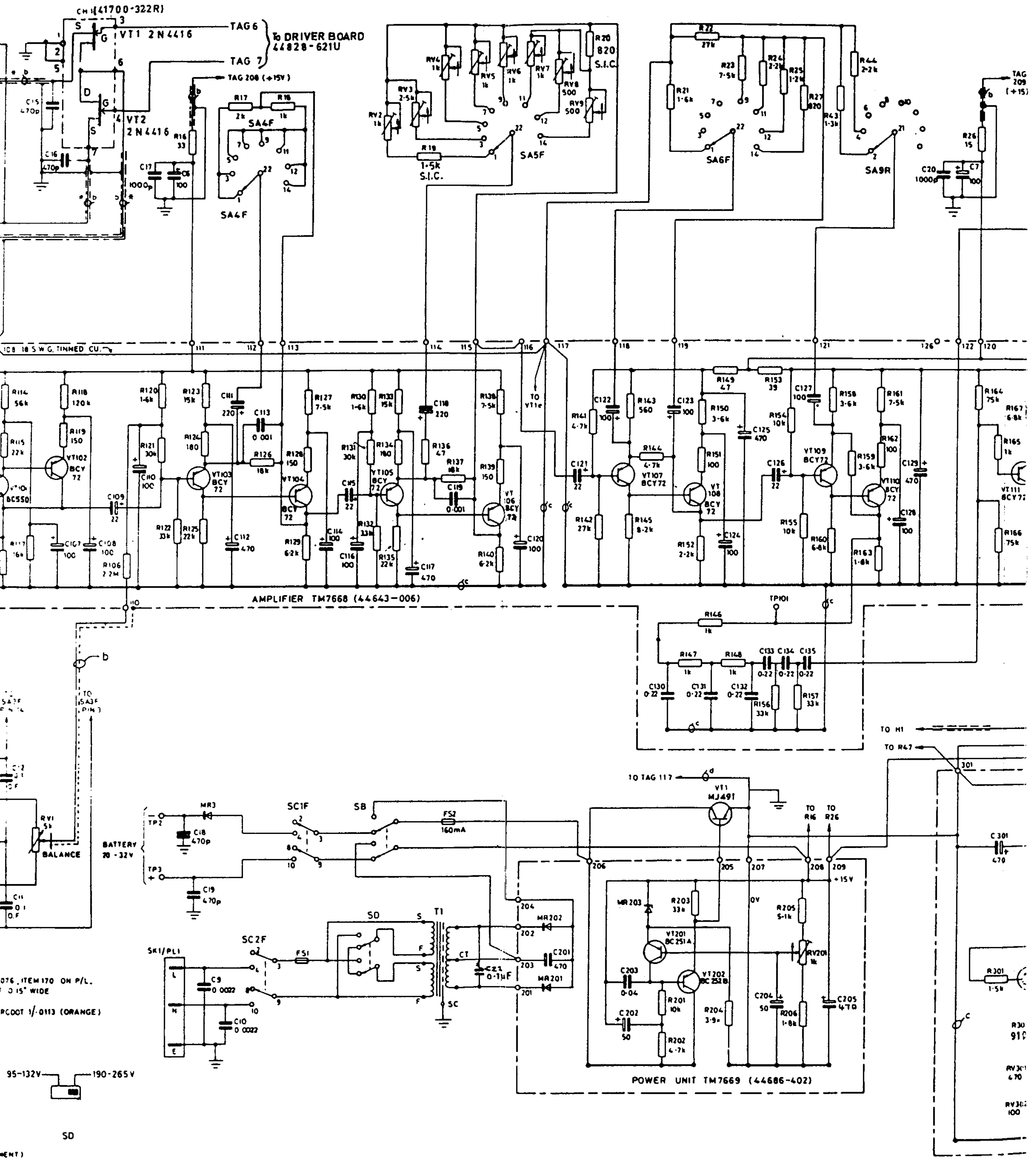
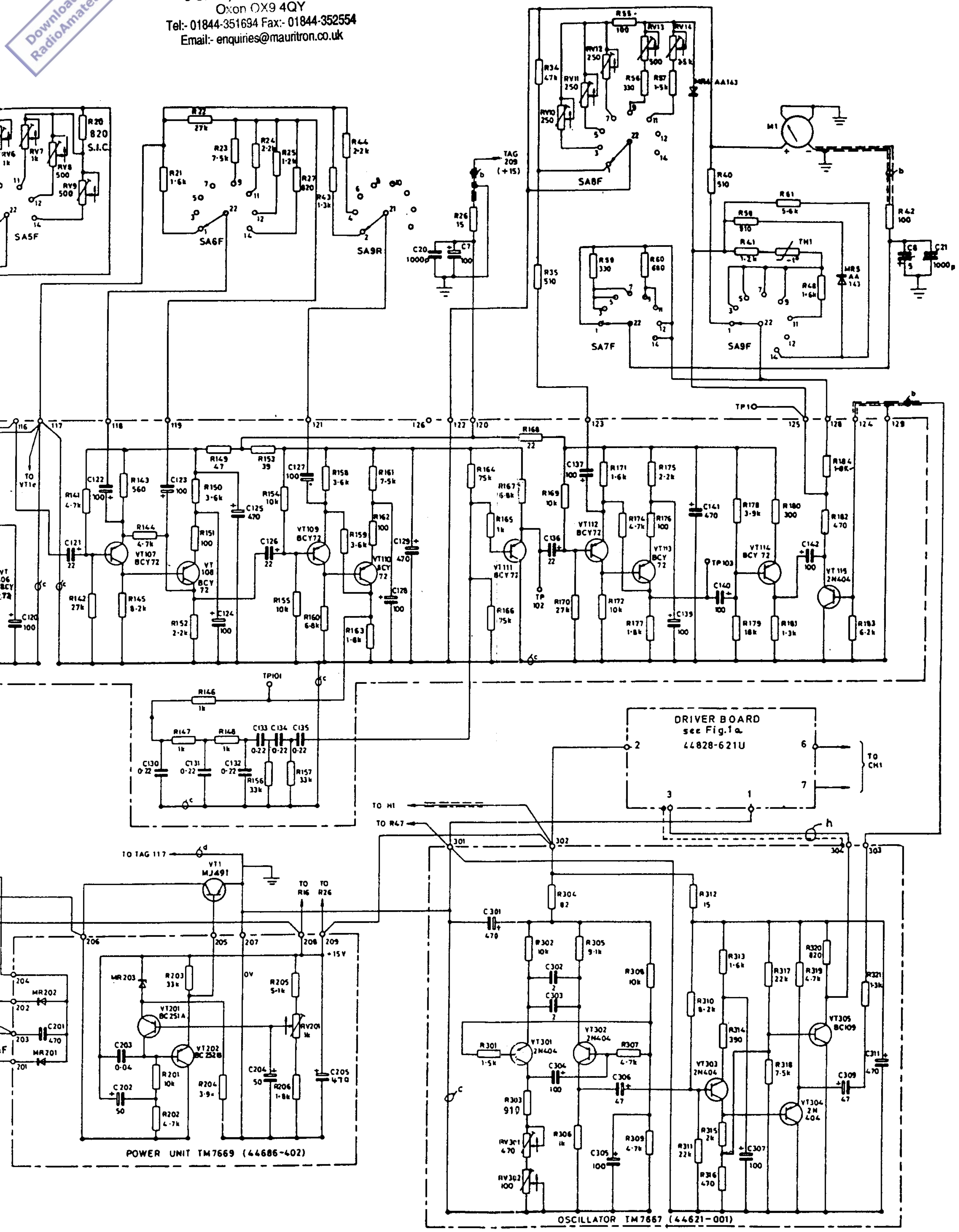
Fig. 1

TF 2603 : Ci



TF 2603 : Circuit diagram



Circuit diagram