No. EB 2331

for

Distortion Factor Meter

TF 2331/A

including TF 2331R

FOR SERVICE MANUALS
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C.P. 2.5c
1/75/N

EB 2331
1m - 1/75

CONTENTS

I GENERAL INFORMATION

1.1 FEATURES

The Distortion Factor Meter Type TF 2331 measures the total distortion and noise of audio signals in the fundamental range from 20 c/s to 20 kc/s. A distortion bandwidth of either 100 kc/s or 20 kc/s can be selected and a low-frequency stop filter enables power supply frequencies to be eliminated from the result. Noise can be measured in the same two bandwidths or via a weighting filter to show the noise level in terms of its interference value in a broadcast system.

The instrument consists of a selective amplifier tuned to reject the fundamental component and a wide band voltmeter to measure the noise and distortion content. Terminals are provided for connecting the voltmeter output to an external meter or oscilloscope.

By switching the voltmeter directly to the input terminals the instrument can be used for direct measurement of voltage in a bandwidth of at least 20 c/s to 100 kc/s.

By using the R.F. Detector, distortion and noise measurements can be made on the modulating envelope of r.f. signals from 500 kc/s to 500 Mc/s.

TF 2331R is a rack-mounting model which differs only in having a special case with flanges for fitting to a 19-inch rack.

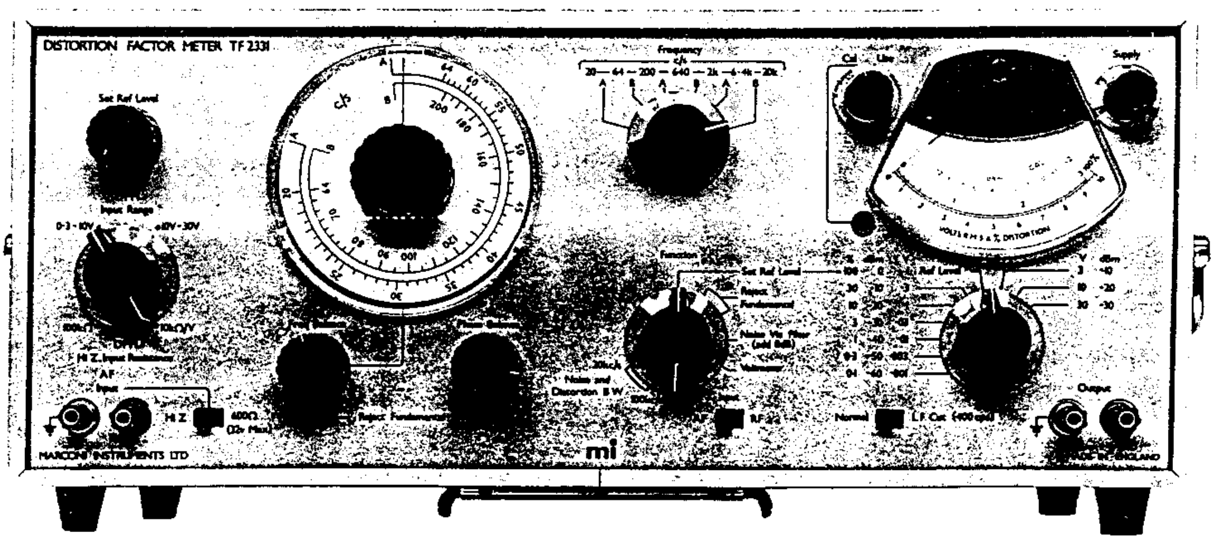


Fig. 1.1 Distortion Factor Meter TF 2331

1.2 DATA SUMMARY

FUNDAMENTAL FREQUENCY	
Range :	20 c/s to 20 kc/s in 6 ranges of 3.16:1 ratio.
Accuracy :	±3%.

DISTORTION MEASUREMENT

RANGE :	7 ranges in 1-3-10 sequence from 0.1% full-scale upwards.
INSTRUMENT DISTORTION :	Less than 0.025% from 200 c/s to 6 kc/s. Less than 0.04% elsewhere.
Fundamental Rejection :	At least 80 dB.
2nd Harmonic Attenuation :	Less than :- 0.5 dB up to 1 kc/s fundamental, 1 dB up to 6 kc/s fundamental, 2 dB up to 20 kc/s fundamental.
Bandwidth (3 dB points) :	Nominally 100 kc/s or 20 kc/s, switch selected.
Residual Measurement :	Within ±2% of full-scale ±1% of reading from 200 c/s to 12 kc/s. Within ±2% of full-scale ±2% of reading from 20 c/s to 100 kc/s.
L.F. Cut :	Can be introduced below 400 c/s to attenuate power supply frequencies.
INPUT RESISTANCE	
Terminated :	Nominally 600 Ω.
High Resistance :	Nominally 10 kΩ/V up to 10 V input. Nominally 100 kΩ from 10 V to 30 V input.
INPUT REQUIREMENTS (For 600 Ω and HiZ)	
Minimum :	300 mV (less than -8 dBm into 600 Ω).
Maximum :	Approximately 30 V (+32 dBm into 600 Ω).

NOISE MEASUREMENT

(Made with tone off)

INDICATION : Mean value of noise relative to signal is indicated in 7 ranges in 1-3-10 sequence from 0.1% full-scale upwards.

INSTRUMENT NOISE : 20 kc/s bandwidth, 100 kc/s bandwidth } less than 0.02% (200 μV).

BANDWIDTH : 100 kc/s or 20 kc/s or via broadcast-type weighting network approximating to C.C.I.F. specification.

VOLTAGE MEASUREMENT

INDICATION : Mean-level meter calibrated in volts r.m.s./sinusoidal has 10 ranges in 1-3-10 sequence from 1 mV to 30 V full-scale. Also decibel scale calibrated from -12 to +2 dB relative to 1 mW in 600 Ω.

VOLTAGE ACCURACY (Above 100 μV) : Within ±2% of full-scale ±1% of reading from 200 c/s to 12 kc/s.
Within ±2% of full-scale ±2% of reading from 20 c/s to 100 kc/s.

INPUT RESISTANCE : Nominally 1 MΩ or 600 Ω.

R.F. INPUT

Frequency Range: 500 kc/s to 500 Mc/s.

Input Impedance: 50 Ω type N connector.

Amplitude Range: 1 V to 4 V at maximum modulation depth.

GENERAL

POWER SUPPLY

Mains : 190 to 260 V or 95 to 130 V, 40 to 500 c/s, 3 W.

External Battery : 18 to 45 V d.c., 25 mA.

DIMENSIONS & WEIGHT :

Height	Width	Depth	Weight
8 in	17 1/4 in	11 in	18 lb
(20.5 cm)	(44 cm)	(28 cm)	(8.16 kg)

ACCESSORIES SUPPLIED

Mains Lead, for a.c. supply operation. M.I. code 43129-071

2 OPERATION

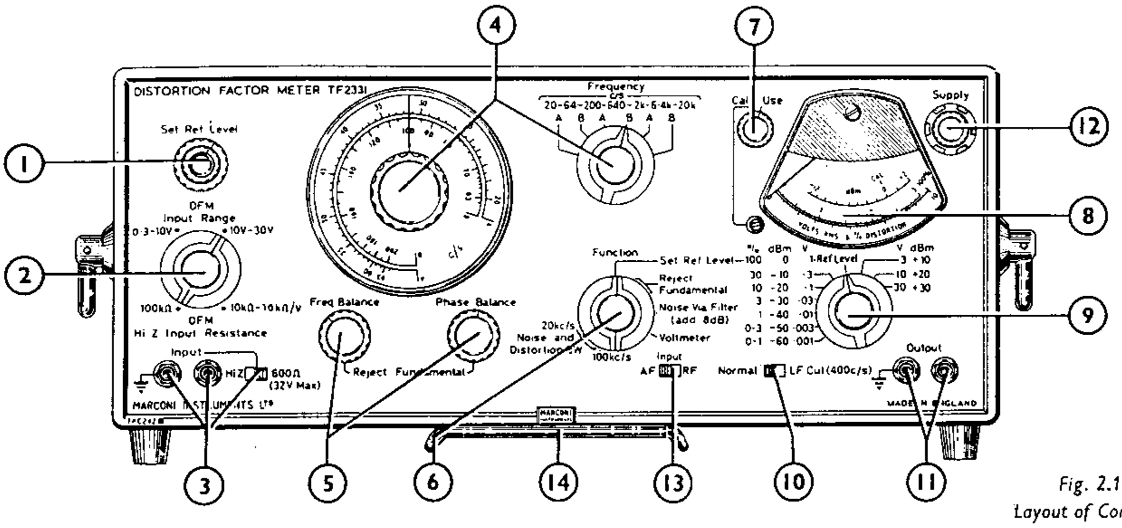


Fig. 2.1
Layout of Controls

(1) SET REF LEVEL controls : Adjust in conjunction with (8) and (9) to bring meter reading to 100% (or to 0 dB for decibel measurements).

(2) DFM INPUT RANGE selector : Set to suit level of total signal at INPUT terminals.

(3) INPUT terminals and switch : For DFM (Distortion Factor Meter) measurements the input resistance at Hi Z is shown by the INPUT RANGE setting. For Voltmeter measurements Hi Z equals about 1 MΩ.

(4) FREQUENCY controls : Set to reject fundamental frequency. Use A or B scale according to switch setting. Fig. 2.1 shows controls set to 1 kc/s.

(5) BALANCE controls : Adjust in turn for maximum rejection of fundamental. PHASE BALANCE is a high discrimination 10-turn potentiometer.

(6) FUNCTION selector : Switches in fundamental rejection filter in positions 2 and 3, weighting network in position 4.

(7) CAL-USE switch : To standardize meter for Voltmeter measurements, switch to CAL and adjust preset to bring meter to CAL mark.

(8) METER : For DFM measurements reads distortion and/or noise relative to total signal in percentage or decibels. For Voltmeter measurements reads input level in volts, or dBm in 600 Ω.

(9) METER RANGE selector : The three right-hand settings are for Voltmeter measurements only.

(10) LF CUT switch : Attenuates frequencies below 400 c/s to eliminate supply hum components.

(11) OUTPUT terminals : Provide a signal from the output of the voltmeter amplifier. At meter full-scale the output is 150 mV at a nominal 1 kΩ source impedance.

(12) SUPPLY switch : Controls a.c. mains or battery supply. Selection of supply is made by the MAINS-BATTERY switch at rear.

(13) AF - RF INPUT : Switches in the r.f. detector enabling measurement of noise and distortion on the modulation envelope of r.f. signals. The RF INPUT socket is located at the rear of the instrument.

(14) SUPPORT : Hinges down to raise front of instrument.

2.2 PRELIMINARIES

The instrument may be operated from a.c. mains of a nominal 115 V or 230 V, 40 to 500 c/s; or from a d.c. supply of 18 to 45 V. For a.c. operation the stabilizer allows mains voltages of up to ±20% of the two nominal settings to be used. The instrument is normally despatched with the 230 V setting unless specified to the contrary. In order to check or change the mains input setting see section 4.3.

For measurements in the field the instrument may also be d.c. powered from an external battery of from 18 to 45 V, the approximate current drain being 25 mA.

FUSES

Two fuses are fitted, one in the a.c. mains input circuit, the other in the h.t. supply to the stabilizer. The a.c. input fuse should be 100 mA rating for 230 V operation or 250 mA for 115 V. The other fuse is in circuit for both a.c. and d.c. operation and should be 250 mA rating. Both fuses are 20 x 5 mm, the a.c. input fuse a delay type, the h.t. fuse a quick-blow type.

SWITCHING ON

Before switching on :

(1) Check that the mains transformer primary connections are correct for the local supply voltage. If they have to be changed remember that the a.c. input fuse must also be changed.

(2) Set the MAINS/BATTERY slider switch on the rear panel to the position appropriate to the type of supply to be used.

(3) Connect to the power supply.

For a.c. mains use the lead supplied, fitting the small 3-pin socket to the MAINS plug at the rear of the instrument. Initially it will also be necessary to fit a suitable mains supply plug to the lead: note that the earth (or chassis) conductor has a yellow designation sleeve with a green circuit earth symbol, the neutral conductor has a black sleeve with a white 'N' and the line (or phase) conductor has no sleeve.

For d.c. connect the battery to the terminals at the rear of the instrument observing the required polarity. It is also advisable to disconnect the a.c. mains lead.

(4) Check and, if necessary, adjust the mechanical zero of the meter.

Switch on by turning the SUPPLY switch clockwise.

2.3 PRINCIPLES OF MEASUREMENT

Distortion factor is defined as :

$$\sqrt{\frac{V_2^2 + V_3^2 + \ldots. V_n^2 + N^2}{V_1^2}} \times 100\% \ldots. (1)$$

where V_1 = amplitude of fundamental

$V_2, V_3 \ldots. V_n$ = amplitudes of 2nd, 3rd .... nth harmonics

N = amplitudes of noise and hum components

If the distortion factor is small, say less than 15%, the error involved in measuring it as :

$$\sqrt{\frac{V_2^2 + V_3^2 + \ldots. V_n^2 + N^2}{V_1^2 + V_2^2 + V_3^2 + \ldots. V_n^2 + N^2}} \times 100\% \ldots (2)$$

is also small. It is this latter quantity that is measured by the Distortion Factor Meter.

Measurement is made by first adjusting the gain of the instrument so that a voltage representing the total signal reads 100% or 0 dB on the meter. The fundamental component is then removed by switching in a tunable rejection filter with the result that the meter indicates the sum of all residual components relative to the level of the total signal.

This residue is made up of harmonics of the fundamental plus supply hum and noise. Assuming that harmonics are the dominant components the instrument indicates the distortion factor, in terms of equation (2), in percentage or in decibels relative to total signal. Hum components at the usual supply frequencies or their harmonics can be eliminated by an l.f. cut filter. The noise level alone can be measured by switching off the wanted signal at source; noise can also be measured in terms of its interference value by introducing a weighting network.

For correct evaluation of distortion a true r.m.s. meter is required but, for reasons of economy, the TF 2331 uses a meter that responds to average value but is calibrated in terms of the r.m.s. value of a sinewave.

NOTE : When adjusting the SET REF LEVEL control, the meter does NOT indicate the volts across the input terminal.

At low values of distortion the discrepancy is negligible; this is dealt with in more detail in Section 2.7 - Sources of Error.

2.4 MEASUREMENTS ON MODULATION

The built-in r.f. detector stage can accommodate carrier frequencies within the range of 500 kc/s to 500 Mc/s, modulation depths up to 80% and levels between 1 V and 4 V. The input impedance at the r.f. detector socket is 50 Ω. The r.f. detector has the addition of a low-pass filter which eliminates false readings due to carrier breakthrough into the TF 2331.

2.5 NOISE AND DISTORTION MEASUREMENT

(1) Set the FUNCTION selector to SET REF LEVEL and the Meter Range selector to REF LEVEL.

(2) Set DFM INPUT RANGE selector according to the range in which the total signal amplitude lies. If the signal amplitude is unknown it can be checked as described in Section 2.6.

(3) Set the INPUT switch to either AF or RF. Connect the signal leads to the INPUT terminals or, in the case of r.f., to the RF INPUT socket at the rear of the instrument. Set the Input Impedance switch to 600 Ω or Hi Z; if set to Hi Z the input impedance, as indicated by the setting of the FUNCTION selector, is 10 kΩ/V up to 10 V input and 100 kΩ above 10 V.

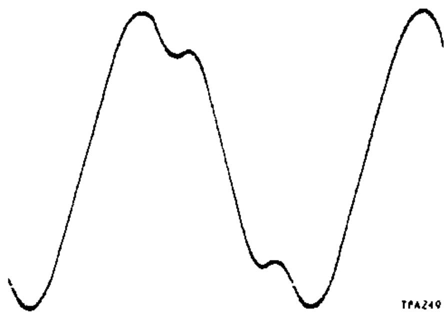


Fig. 2.2 1 kc/s Waveform with Noise and Distortion (The equivalent spectrum is shown below)

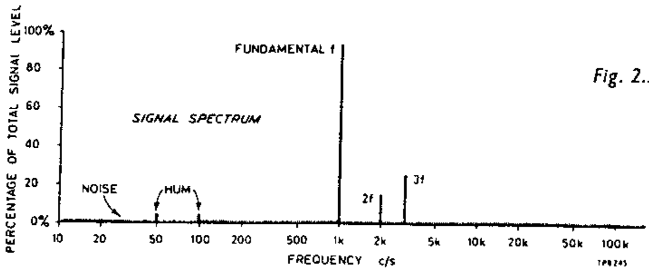
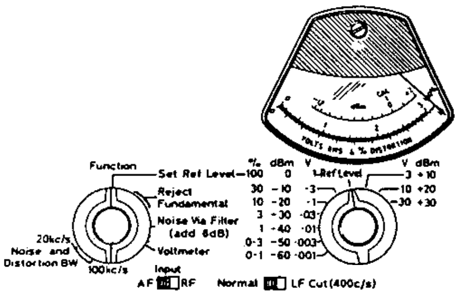


Fig. 2.3 Set Reference



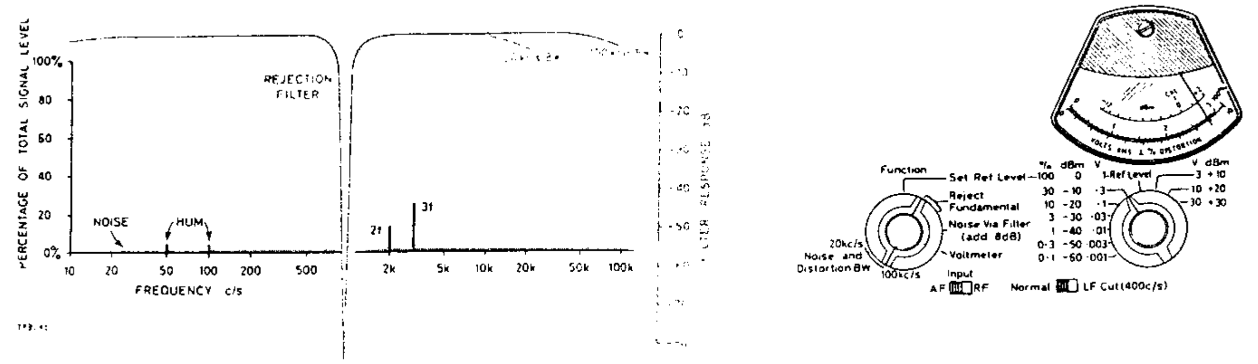


Fig. 2.4 Fundamental Rejection

For percentage measurements adjust the SET REF LEVEL control for a meter reading of 100%. This condition is illustrated in Fig. 2.3.

For decibel measurements adjust the SET REF LEVEL control for a meter reading of 0 dB. (In distortion and noise measurements the dBm scale indicates relative levels in decibels, not absolute levels in dBm. The latter calibration is only valid in voltmeter measurements across 600 Ω.)

(4) Move the FUNCTION selector to one of the two REJECT FUNDAMENTAL positions depending on the bandwidth required. In the case of r.f. measurements, the r.f. detector filter bandwidth is 50 kc/s. Set the LF CUT switch to NORMAL.

(5) Set the FREQUENCY range selector and dial to the frequency of the fundamental. With the FREQ BALANCE and PHASE BALANCE controls midway adjust the dial for a dip on the meter. Adjust the FREQ BALANCE and PHASE BALANCE controls in turn for maximum dip, switching to successively lower meter ranges - these controls have no significant effect above 10% distortion, but become very critical below 0.1%.

The meter now shows the level of the total residual components in the selected bandwidth - see Fig. 2.4. Components below 400 c/s can be attenuated by switching to LF CUT - see Fig. 2.5 (a typical LF CUT characteristic is shown in Fig. 4.3). This will show whether power supply hum, for example, is significant; if the reading drops appreciably it is advisable to check that the FREQ BALANCE and PHASE BALANCE controls are still correctly adjusted.

To eliminate harmonics from the residual content, switch off the fundamental tone at the signal source. The meter now indicates noise (including any hum) in the selected bandwidth - see Fig. 2.6. Note

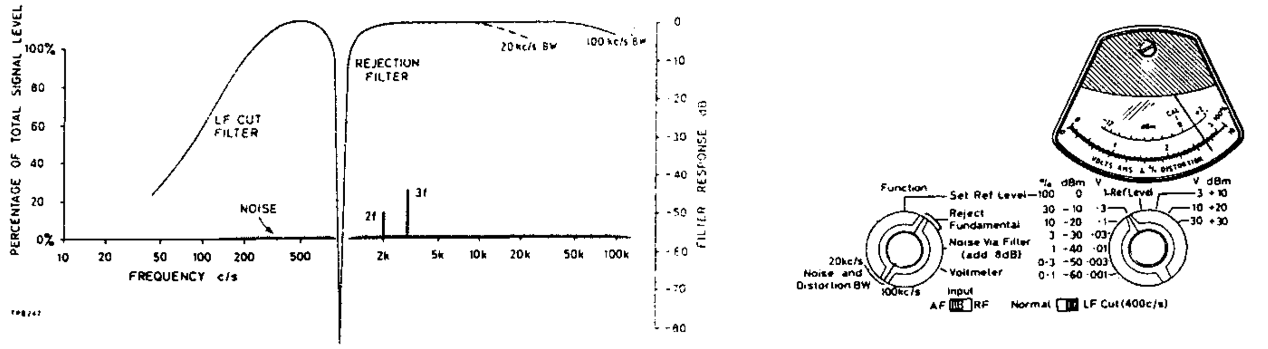


Fig. 2.5 Fundamental Rejection with LF Cut

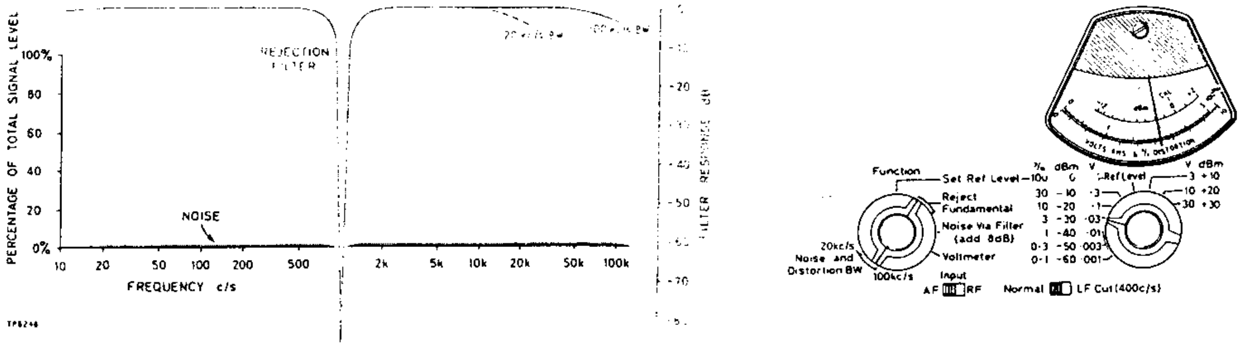


Fig. 2.6 Tone Off

that if very low noise levels are to be measured, lower residual noise in the instrument can be obtained by turning the FUNCTION switch back to SET REF LEVEL. In this case the bandwidth will be 100 kc/s and LF CUT can still be used if required.

(7) To measure the weighted noise set the FUNCTION selector to NOISE VIA FILTER. This introduces a filter - see Fig. 2.7 - with characteristics as defined by the CCIF weighting network for broadcast systems. However, the filter used has an extra loss of 8 dB compared to the CCIF curve and it is necessary therefore to add 8 dB to the meter reading to obtain the true weighted noise level.

High Signal Levels

Signals of greater than 30 V can be measured by connecting a variable resistor in series with the right hand INPUT terminal. Its value should be 500 kΩ for voltages of 30 V to 100 V, or 1 MΩ for voltages of 100 V to 200 V, or 1.5 MΩ for voltages of 200 V to 300 V.

Low Signal Levels

If the signal level, whether a.f. or modulated r.f., is too low it may still be possible to make measurements in decibels by setting the 0 dB reference level with the Meter Range Selector on a different range. For example:-

It is required to measure a distortion factor of about -30 dB in a signal of about 0.3 V amplitude.

Turn the Meter Range Selector to the .3 V range and set the meter pointer to the 0 dB calibration with the SET REF LEVEL control.

Reject the fundamental as described above and turn the Meter Range Selector to the .01 V range. Since three ranges (10 dB steps) have been turned through, the distortion factor is -30 dB plus the meter reading.

Note that setting the reference level on a lower range reduces the total measuring range.

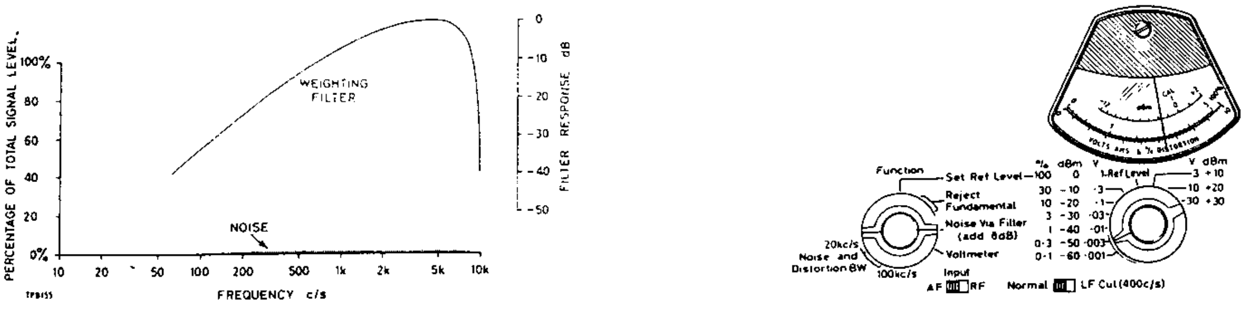


Fig. 2.7 Tone Off with Weighting Filter

2.6 VOLTMETER MEASUREMENTS

The internal voltmeter can be used to indicate the level of a signal up to 100 kc/s at the INPUT terminals either in volts or in decibels relative to 1 mW in 600 Ω. Before using the instrument in this way the meter should be standardized against the internal calibrating signal. For Voltmeter measurements the DFM INPUT RANGE switch, SET REF LEVEL control, FREQUENCY and BALANCE controls are not in circuit and can be left at any setting.

CALIBRATING THE VOLTMETER

Turn the CAL-USE switch to CAL and adjust the calibrating preset control to make the meter read at the CAL mark. This may be done at any setting of the meter range selector.

USING THE VOLTMETER

Turn the CAL-USE switch back to USE.

Turn the FUNCTION selector to VOLTMETER and set the Meter Range selector to the required full-scale V or dBm value.

Move the INPUT impedance switch to the setting required - the Hi Z position gives an input impedance of about 1 MΩ. The dBm scale on the meter is only valid for measurements across 600 Ω; if the circuit under test is already terminated switch to Hi Z, if not switch to 600 Ω.

Read the voltage from the black scale that corresponds to the full-scale V setting of the meter range selector; or read the signal level in dBm by adding the indication on the red scale to the dBm setting of the Meter Range selector.

2.7 SOURCES OF ERROR

(1) <u>Average-reading Meter</u>

Tends to read low when measuring complex signals, particularly those consisting of two or more nearly equal components; the amount of error depends not only on the degree of distortion but on the order and phase of the harmonics.

If, for example, you are measuring a signal with one predominant large harmonic, an error will be introduced, as shown in Fig. 2.8, when setting reference level but not when measuring the distortion. The indicated distortion will therefore be high by the amount that the set reference level deflection is low. The error, which lies between the limits shown in the shaded part of Fig. 2.8, is negligible except at high distortion levels and is even lower with combinations of different harmonics.

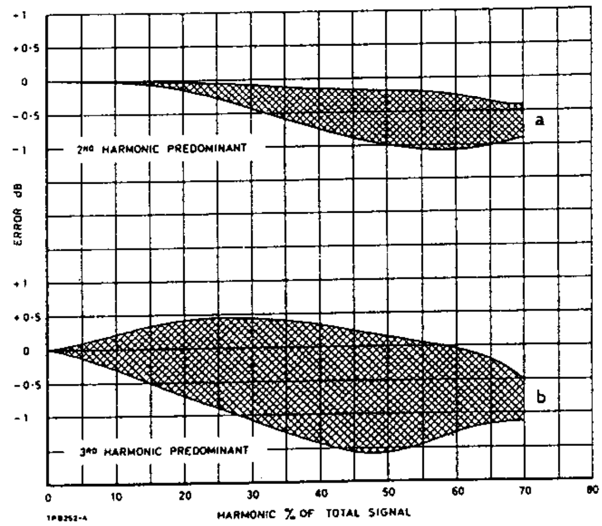


Fig. 2.8
Average/R.M.S. Error Limits

If, on the other hand, the distortion is low but consists of two or more harmonics of comparable level then the set reference level reading will be correct but the distortion reading will be low. For distortion caused by two harmonics the error will have a maximum value of -0.75 dB when the harmonics are equal, regardless of the level of distortion, and will be less at other ratios as shown in Table 2.1.

TABLE 2.1

Ratio of harmonic levels	Meter error
1 : 1	-0.75 dB
2 : 1	-0.35 dB
5 : 1	-0.2 dB

All errors arising from this cause can be eliminated by using a true r.m.s. voltmeter connected to the output terminals. Ideally the voltmeter should have full-scale deflections of 100 mV, 30 mV, 10 mV, 3 mV, etc.; if so, the set reference level deflection can be made at 100 mV and the other scales will correspond to the % settings of the Meter Range Selector.

(2) Harmonic attenuation

Makes the reading low - see Fig. 2.9. The upper-frequency skirt of the fundamental rejection filter causes a slight attenuation of the lower order harmonics. Harmonics are also attenuated as their frequency approaches the 100 kc/s or 20 kc/s bandwidth limit; this is naturally more likely to affect the higher order harmonics.

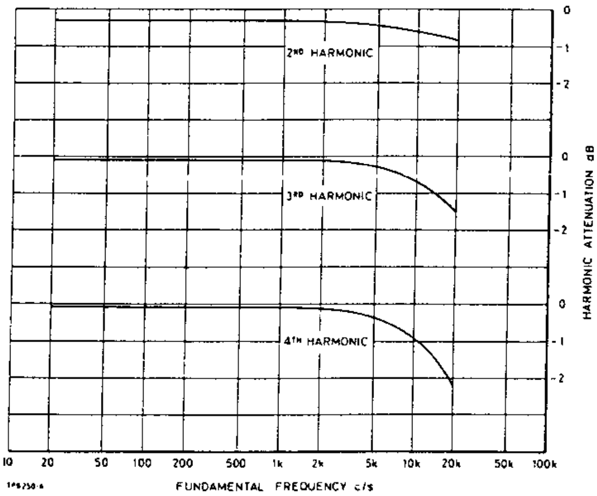


Fig. 2.9 Attenuation of Harmonics (100 kc/s Bandwidth)

(3) Residual content of instrument

Tends to make the reading high at very low distortion - say less than 0.1%. Residual noise and distortion introduced by the instrument itself gives an error which will be within ±0.025% from 200 c/s to 6 kc/s and ±0.04% elsewhere.

(4) Distortion on modulated r.f.

Fig. 2.10 shows the working area of the r.f. detector and providing the r.f. input signal falls inside the area shown, the distortion should not be greater than 1%.

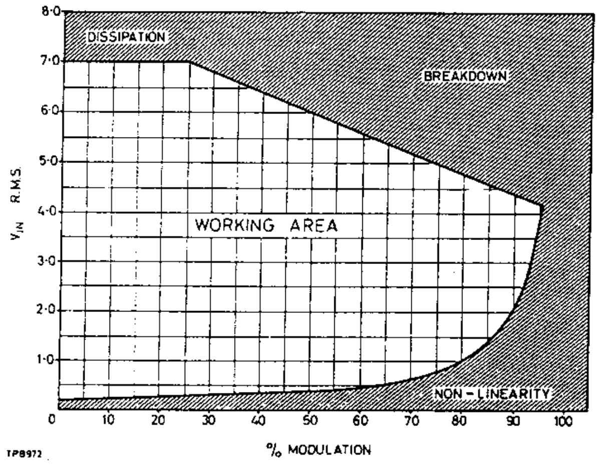


Fig. 2.10 Curve showing the working area of the r.f. detector

(5) Metering errors

The accuracy with which the meter indicates the residual content is within the limits given in Sect. 1.2.

(6) Formula conversion

As mentioned in Section 2.2 the Distortion Factor Meter measures distortion relative to total signal rather than relative to fundamental. Below 10% distortion the discrepancy is negligible but it becomes large at high distortion. Conversion from indicated to true distortion factor can be made by means of Fig. 2.11.

Example :

Measurements on a 1 kc/s signal with predominantly 2nd harmonic distortion gives a reading of 28% (= -11 dB) distortion.

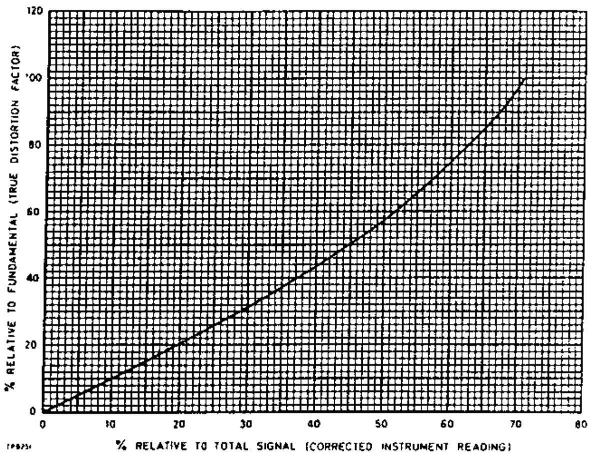


Fig. 2.11
Distortion Formula Conversion

(1) Fig. 2.8b shows the set reference level reading is low, and therefore the distortion reading high, by between 0.1 dB and 0.3 dB. Therefore, partially corrected reading is -11.3 to -11.1 dB (= 27.2 to 27.9%).

(2) Fig. 2.9 shows reading is low by a further 0.3 dB. Therefore, partially corrected reading = -11 to -10.8 dB (= 28 to 28.8%).

(3) Error due to instrument residual content, i.e., an additional uncertainty of ±0.025% distortion, is negligible.

(4) Metering error = ±2% of 30% (full-scale) ±1% of 28% = ±0.88%, say ±0.9% distortion. Therefore, final corrected reading = 27.1 to 29.7%.

(5) Formula conversion. The final corrected reading in terms of true distortion factor (relative to fundamental) is given by Fig. 2.11 as 28.5 to 31%.

Note : If the signal contains two significant harmonics their approximate ratio should be determined and a further correction obtained from Table 2.1 and carried out after step (1) above.

2.8 USE AS AN AMPLIFIER OR WAVEMETER

The instrument can be used to amplify signals in a range of at least 20 c/s to 100 kc/s or to measure frequency between 20 c/s and 20 kc/s.

AMPLIFIER

Set up as for Voltmeter measurements. The voltmeter amplifier provides a gain of up to x 150 between the INPUT and OUTPUT terminals. Maximum output, which is limited by full-scale deflection, is 150 mV. Output impedance is about 1 kΩ, and input impedance can be switched to either 600 Ω or 1 MΩ. The Meter Range selector must be set so that the range full-scale value is greater than the input voltage. Therefore, the full amplifier gain of x 150 is only obtained with inputs below 1 mV.

WAVEMETER

Set up as for DFM measurements. The frequency of the input signal is shown by the FREQUENCY controls when adjusted for maximum rejection. If the FREQ. BALANCE control is set mid-way the accuracy of indication is ±3% - the range of this control is about ±0.25% at the h.f. end of the scale to ±0.85% at the l.f. end.

3 TECHNICAL DESCRIPTION

3.1 GENERAL SUMMARY

There are three main sections in the instrument - DFM, Voltmeter, and Power Supply. The DFM section provides for selection of measurement function, adjustment of reference level, and rejection of fundamental. The Voltmeter section measures the output level of the DFM section and has an l.f. cut facility to remove power supply frequency components; it can also be used to measure the voltage applied to the input of the DFM section.

3.2 DISTORTION FACTOR METER SECTION

(Circuit Diagram Fig. 4.5)

On a.f., a choice of input impedances is available: 600 Ω or high impedance. 600 Ω is selected by switching in the input terminating resistor, R1. The actual Hi value depends on the amplitude of the input signal. Because of negative feedback the impedance at the base of VT1 is very low (the signal current corresponding to full scale being approximately 100 μA). RV1 and R5, in series in the signal path, therefore determine the input impedance on the 1-10 V range. At maximum sensitivity, corresponding to an input of about 0.6 V, the impedance is at its minimum value of 6.2 kΩ. This rises, as the sensitivity is reduced, to a maximum of about 100 kΩ at an input of 10 V. The input impedance is 50 Ω at the r.f. input socket for signals from 1 V to 4 V.

When the DFM INPUT RANGE selector is switched to the 10-30 V range an attenuator, R2-R3, is introduced. This is sufficient to prevent large variations in input sensitivity affecting the impedance appreciably and so it remains at a nominal 100 kΩ from 10 to 30 V.

Transistor VT1 is a phase-splitter and provides outputs of opposite phase and appropriate amplitude relationship (2:1) to drive a 'Wien Bridge' type of network. This network is the fundamental rejection filter and the overall negative feedback taken to the base of VT1 (via R17 and C18) serves to flatten the skirts of its response and so presents a sharper curve to the amplifier.

VT1 is a critical stage for noise and distortion and its operating conditions provide a good compromise between the two. It has a fixed emitter load of 750 Ω and a collector load which is adjustable around a nominal 1500 Ω by the PHASE BALANCE control, RV6 - the latter is a 10-turn potentiometer to give the necessary precis-

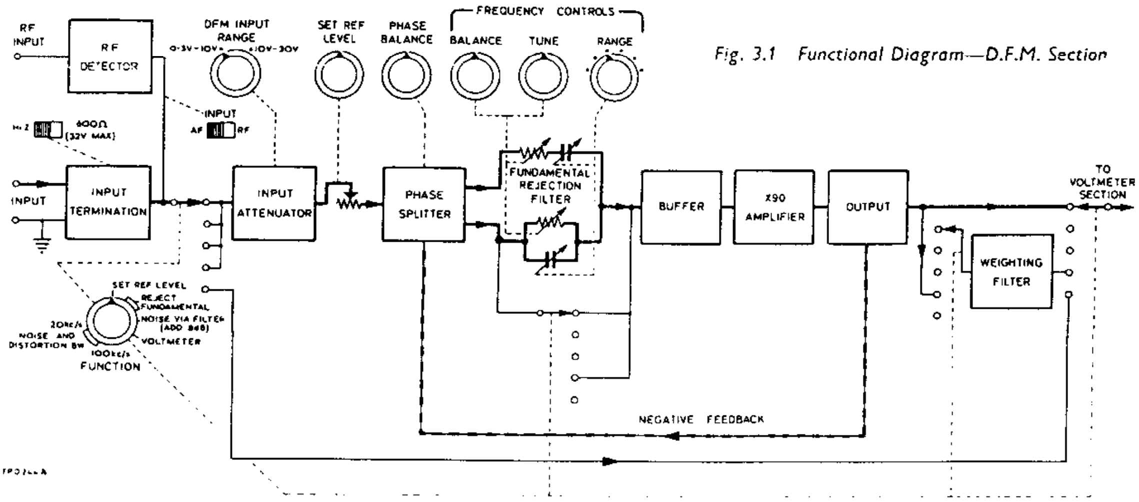


Fig. 3.1 *Functional Diagram—D.F.M. Section*

ion of adjustment. The collector load feeds the series CR branch of the fundamental rejection filter and the emitter load the parallel CR branch.

The fundamental rejection filter network provides at least 80 dB rejection using only resistors and capacitors. Variable resistors RV2 and RV5 are ganged together to form the MAIN TUNE control and RV3 and RV4 are ganged together to form the FREQ. BALANCE control. The latter is necessary at distortion values below 10% when the MAIN TUNE control becomes too critical. RV2 and RV3 are in the series CR branch of the filter and RV4 and RV5 are in the parallel CR branch.

VT2 is a buffer emitter follower. It is a silicon type to keep the working point of VT3 independent of temperature. VT3 provides the gain in the system (about x90). Its emitter load is by-passed at high frequencies by C20 to maintain the response. VT4 is the output stage and is connected as an emitter follower.

The 100 kc/s bandwidth is determined by C30 and the 20 kc/s bandwidth by C23 and C30 in parallel. Alternatively the output can be passed through a weighting filter which simulates the response of the ear to a typical broadcast system. This response was originally defined by the CCIF and the filter design is an agreed one issued by the British Standards Institution. (It has subsidiary peaks at 13 kc/s and 22 kc/s which are not shown on the curve in Fig. 3.2 as they are outside the range defined by the CCIF.)

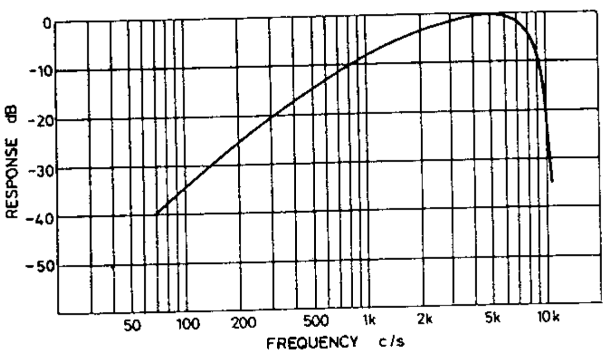


Fig. 3.2 Weighting Filter Response

3.3 VOLTMETER SECTION

(Circuit Diagram Fig. 4.6)

Input transistors VT5, VT6, and VT7 combine to form the equivalent of a very good cathode follower with an overall gain of approximately unity. VT5 operates at a collector current of approximately 10 µA at which it produces current gain to drown the noise of VT6, but produces very little noise itself. It is selected for a fairly high gain at this low collector current, which gives it its low noise characteristic plus a high input impedance.

VT7 is an emitter follower with a 2 kΩ load in its collector circuit to feed the attenuator, controlled by the voltmeter range selector. Since the attenuator itself presents 2 kΩ the resultant a.c. collector load is 1 kΩ.

The fine attenuator, R52 to R61, is a simple potentiometer device with four 10 dB steps giving 10 dB, 20 dB, 30 dB and 40 dB for the 10 V, 3 V, 1 V, and .3 V ranges respectively. When the voltmeter range is set to .1 V the input is attenuated 50 dB by R40, R41 and RV10 (which are capacitance compensated by C40 and C41), and the fine attenuator switched out. As the voltmeter range is lowered further the four 10 dB steps are switched in again.

VT13 is the first transistor in the main voltmeter amplifier. It has a gain of about 3 and always operates at around the 1 mV level. It is, therefore, selected for low noise.

VT14 is a buffer emitter follower and its bias is provided by d.c. feedback from the output stage. R78 provides preliminary bias and so protects VT15 from complete saturation when switching on.

VT15 is an n-p-n transistor connected as an amplifier. Its gain is variable by the a.c. coupled CAL preset potentiometer on the front panel. The collector circuit comprises a 3 kΩ resistor, R84, and a 1 kΩ resistor, R85, in series, the latter being decoupled with a 10 µF capacitor, C61, giving an l.f. boost to level the frequency response.

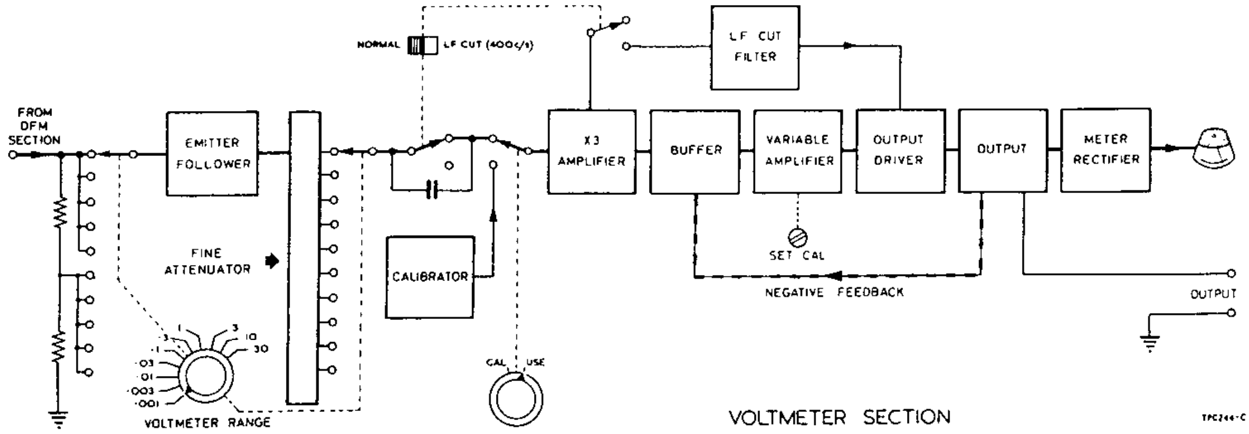


Fig. 3.3 Functional Diagram—Voltmeter Section

VT16 is the driver transistor for the output stage. Its d.c. conditions are set by RV14 so that the output stage transistors have a centralized d.c. output to prevent crushing, limiting or low gain.

VT17 and VT18 are the output pair and are connected in push-pull. Their bases are clamped 6 V apart by MR11 and a collector swing of about ±2 V is possible before any limiting starts. This is quite adequate to drive the meter diodes. Each emitter circuit has a 220 Ω resistor in series with an 820 Ω resistor bypassed by a 500 μF capacitor to stabilize the a.c. gain and d.c. working conditions. An output is taken from the emitter of VT18 to the OUTPUT terminals on the front panel. It gives about 150 mV r.m.s. and has a nominal impedance of 1 kΩ. C71 is selected for best accuracy at 100 kc/s on all ranges from 1 mV to 100 mV.

A constant standard signal is available at the base of VT13 to set up the gain of the main voltmeter amplifier. It is provided by VT9 and VT12. These transistors form a multivibrator controlled in amplitude of output by MR10. RV11 is set to optimize the full scale accuracy at medium frequencies on all ranges from 1 mV to 100 mV.

The LF CUT filter removes hum at supply frequencies from the distortion measurement. When it is switched in, low frequencies in the signal path are attenuated by C49 and extra l.f. degeneration is achieved by switching C64 and C65 in series with C59, and C66 in series with C63. Also, a.c. negative feedback at low frequencies is introduced by coupling the emitter circuits of VT16 and VT13 through RV15.

3.4 POWER SUPPLY SECTION

(Circuit Diagram Fig. 4.4)

The design of the power supply caters for the use of a.c. supply voltages of 190 to 260 V or 95 to 130 V at 40 to 500 c/s, and d.c. supply voltages of 18 to 45 V. It provides an h.t. of -15 V via a 3-transistor stabilizer network.

If an a.c. supply is used it is rectified by a conventional full-wave rectifier using silicon diodes MR7 and MR8 and smoothed by capacitor C48. Resistor R56 and capacitor C50 ensure that the collector supply to VT8 is free of ripple.

From the filter, or from a battery, the supply is fed to the stabilizer circuit. This consists of a series stabilizer, VT11, an amplifier, VT8, and an emitter follower, VT10. Part of the output voltage is compared by the amplifier with a reference voltage provided by the Zener diode MR9. The resultant error signal is fed back to the series stabilizer via the emitter follower.

Diode MR6 provides protection against a d.c. supply being connected with reversed polarity.

4 MAINTENANCE NOTES

4.1 GENERAL

This part of the handbook is for guidance where it is most needed in servicing the instrument. In case of difficulties that cannot be resolved with the aid of this book, or for advice on maintaining the instrument, please write or phone our Service Division, or nearest Area Office, or Agent. Always mention the type number and serial number of your instrument (for addresses see rear cover).

This instrument uses semiconductor devices which, although having inherent long-term reliability and mechanical ruggedness, are susceptible to damge 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, the use of insulation testers, or accidentally applied short circuits.

4.2 ACCESS TO COMPONENTS

REMOVING CASE

The case can be removed by unplugging the mains lead from the back panel, unscrewing the six coin-slotted screws holding the rear cover and then removing the rear cover and the case.

OPENING THE CHASSIS

To allow easy access to components the chassis is hinged in several places and can be opened out, as shown in Fig. 4.1, by removing the right-angled cross-member from the five pillars and then slackening or removing the appropriate 4BA and 6BA cheese-headed screws, and unsolder wires to tags 26, 27 and 30.

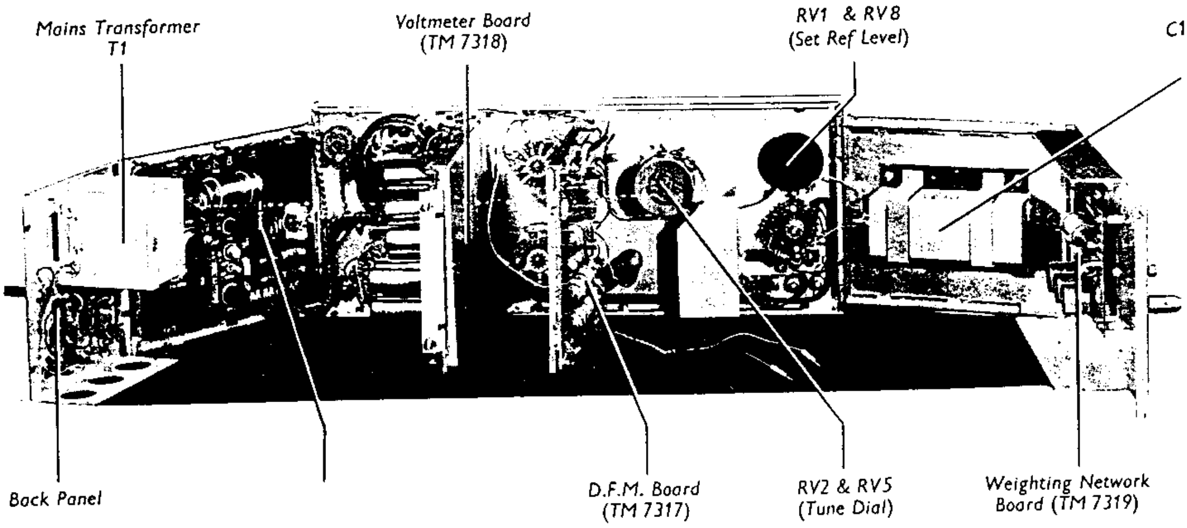


Fig. 4.1 The Instrument Opened Out

PRINTED CIRCUIT BOARD IDENTIFICATION

Starting from the right-hand end of the instrument viewed from front : the first printed circuit board, marked TM 7070, carries the main power supply components; the second, marked TM 7318, carries the main voltmeter components; the third, marked TM 7317, carries the main DFM components; and the small board on the left-hand back-plate, marked TM 7319, carries the weighting network components.

4.3 A.C. MAINS INPUT RANGES

The mains transformer is mounted in a screening can on the right-hand back-plate of the instrument. The two primary windings should be connected in series for the 190 to 260 V range and in parallel for the 95 to 130 V range, as shown in Fig. 4.2.

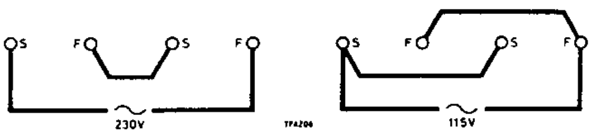


Fig. 4.2 Mains Input Connections

4.4 REPLACEMENT OF SEMICONDUCTORS

GENERAL

Replacement transistors should be the exact types quoted in Table 4.3 if the published specification for this instrument is to be maintained.

BASE CONNECTIONS

Diagrams of the electrode connections for each type of semiconductor are shown in Table 4.3. Some of the transistors are plugged into holders; when replacing these align the pip on the transistor body with the groove on the side of the holder.

When replacing soldered-in transistors always use a heat shunt and apply the soldering iron for the minimum time necessary to achieve a sound joint.

If VT3 is replaced ensure that its gain is adequate or attenuation of second harmonics will be greater than that shown in Fig. 2.9.

LOW NOISE REQUIREMENTS

Transistors VT1, VT2, VT3 and VT4 are critical for internal noise. To check for noise when replacing them :-

Short-circuit the INPUT terminals; set the FUNCTION selector to SET REF LEVEL and the METER RANGE selector to the .001 V range; select a transistor to give a meter reading under 10% of full-scale (< 100 μV).

As a further guide :-

With VT1 removed the meter should read about 600 μV; with VT3 removed it should read about 200 μV.

4.5 CIRCUIT VOLTAGES

Some typical circuit voltages are given below and on the circuit diagram. Those on the circuit diagram are d.c. voltages and those in Tables 4.1 and 4.2 are a.c. signal voltages.

The voltages shown in Tables 4.1 and 4.2 were measured on a 400 c/s signal with the FUNCTION selector set to SET REF LEVEL, the Meter Range selector set to the 100% range and the meter set to 100%. To measure them use a valve voltmeter such as Marconi Instruments type TF 2600, or type TF 1100 (series).

TABLE 4.1

Transistor Terminals

Transistor	*Base*	*Emitter*	*Collector*
VT1	10 mV	10 mV	20 mV
VT2	10 mV	10 mV	–
VT3	10 mV	–	1 V
VT4	1 V	1 V	–
VT13	1 mV	–	2 mV
VT14	2 mV	2 mV	–
VT15	2 mV	–	10 mV
VT16	4 mV	–	170 mV
VT17	170 mV	–	900 mV
VT18	170 mV	–	900 mV

TABLE 4.2

Circuit Points

Point	Voltage
tag 1	0.55 V
tag 35	3.1 mV
tag 40	3.1 mV
tag 45	1 mV

Note that when measuring circuit voltages the test leads should be kept well clear of circuitry.

4.6 PRESET CONTROLS

Apparatus required:

(a) Universal test meter; 20 kΩ/V e.g., Avometer model 8.

(b) Standardized valve millivoltmeter; 1 mV-30 V; e.g., Marconi Instruments type TF 1100 (series) or type TF 2600 (series).

(c) Oscillator; 400 c/s, 1 mV-30 V; e.g., Marconi Instruments type TF 1101 (series).

SET H.T.

The h.t. voltage should be checked if VT8, VT10 or VT11 is replaced. Connect to the supply and switch on. Connect the test meter between tag 70 and earth, positive terminal to earth, on the power unit board and adjust RV12 until it indicates 15 V.

D.C. AT METER INPUT

The d.c. voltage at the collectors of VT17 and VT18 should be checked if any transistors or large value electrolytic capacitors are replaced - if an electrolytic capacitor is replaced the voltage should be rechecked after the instrument has been in use for about one day.

Connect the test meter between the collector of VT17 or VT18 and earth, positive terminal to earth. Switch the Meter Range selector to the 30 V range and keep the meter test leads well clear of any circuitry to reduce the possibility of overall oscillation. Adjust RV14 until the meter indicates 7.25 V.

VOLTMETER ACCURACY

The accuracy of the voltmeter and its calibrating voltage should be checked if any of the transistors VT5 to VT18 are replaced. Connect the oscillator to the INPUT terminals and set it to 400 c/s. Monitor the signal with the standardized valve millivoltmeter. Set the signal amplitude to 1 mV, 3 mV, 30 mV and 100 mV in turn and optimize the full scale error between respective voltmeter ranges with the SET CAL control (RV13).
Set the CAL/USE switch to CAL and adjust preset potentiometer RV11 to bring the meter pointer to the CAL calibration. Reset the CAL/USE switch to USE, set the input signal amplitude to 300 mV, 1 V, 3 V, 10 V and 30 V in turn and optimize the full scale error between the respective voltmeter ranges with preset potentiometer RV10.

L.F. CUT

The L.F. Cut response should be checked if capacitors C59, C63, C64, C65 or C66 are changed. It should conform to the following :-

within ±0.25 dB above 1 kc/s within +0.5 dB, -1.0 dB 400 to 600 c/s at least -30 dB at 60 c/s } relative to the response when switched to NORMAL

If it does not, adjust with variable resistor RV15.

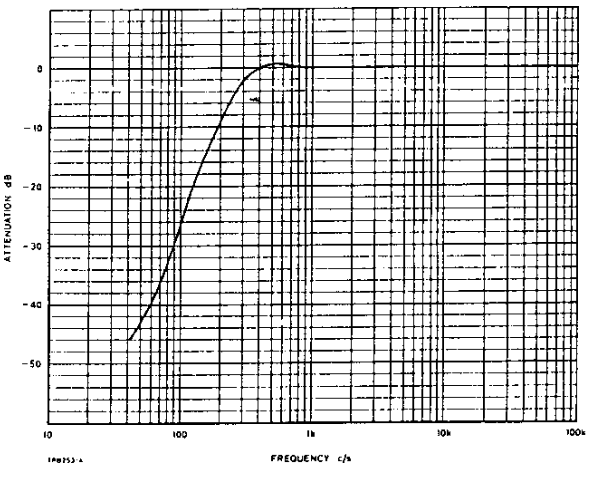


Fig. 4.3 Typical LF Cut Response

A typical curve is shown in Fig. 4. 3. To avoid overloading the input of TF 2331 when checking this response start at 1 kc/s with the Meter Range selector set to the .1 V range and, leaving the input constant, adjust the Meter Range selector to increase the meter sensitivity as required at other frequencies.

LOW RANGES FREQUENCY RESPONSE

Set the instrument controls for use as a voltmeter. Connect the oscillator to the INPUT terminals and set the input signal amplitude to 1 mV, 3 mV, 10 mV, and 100 mV in turn at various frequencies between 20 c/s and 100 kc/s. Check that the full-scale accuracy of the respective voltmeter ranges is within specification. If it is out at the higher frequencies reselect capacitor C71 (ensure that lifting of the response at 100 kc/s is not exaggerated or excessive r.f. gain will result). If it is out at the very low frequencies reselect capacitor C61.

HIGH RANGES FREQUENCY RESPONSE

Set the instrument controls for use as a voltmeter. Connect the oscillator to the INPUT terminals and set the input signal amplitude to 0.3 V, 1 V, 3 V, 10 V and 30 V in turn at various frequencies from 12 kc/s to 100 kc/s and check that the full-scale error of the respective voltmeter ranges is within specification. If it is not adjust variable capacitor C40.

4.7 R.F. DETECTOR CHECK

The following tests may be carried out to check the operation of the r.f. detector. Set the front panel controls as follows:-

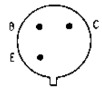
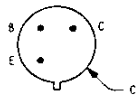
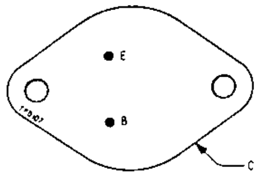
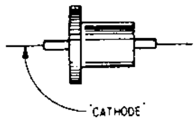
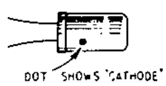
AF/RF INPUT to RF
SET REF LEVEL fully clockwise
INPUT RANGE to 0.3 V - 10 V
FUNCTION switch to SET REF LEVEL

(1) Using a suitable signal generator such as a Marconi Instruments TF 144H, apply an R.F. input of 500 kc/s, 2 V r.m.s. and modulated by 1 kc/s at 80%. With the voltmeter range switch at REF LEVEL, the meter reading should be not less than -6 dB.

(2) Apply the same signal as in (1) but without modulation and the meter reading should be at least 55 dB down on the reading obtained in (1).

NOTE: A voltmeter, such as a Marconi Instruments TF 2600 should be used to monitor the r.f. input.

TABLE 4.3

Circuit reference	Type	Manufacturer	Connection Diagram
VT1, VT2, VT3, VT4, VT13, VT19	BCY71		
VT8	2N404	various	
VT6, VT7, VT14, VT16, VT18	BCY72		
VT15	BSY26	Standard Telephones & Cables	
VT5	BC108		
VT17	BSX20		
VT9, VT12	ACY20	Mullard	
VT10	ACY17	Mullard	
VT11	OC25	Mullard	
MR1, MR2, MR4, MR5	MS2H	Associated Electrical Industries	
MR6, MR7, MR8	1N540	various	
MR9	ZB10V	Brush Crystal	
MR10, MR11	ZB6.2V	Brush Crystal	
MR12, MR13	HD5004	Hughes International	

REPLACEABLE PARTS

Introduction

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

C	:	capacitor
Carb	:	carbon
Cer	:	ceramic
CO	:	change-over
Elec	:	electrolytic
FS	:	fuse
JK	:	jack
L	:	inductor
Log	:	logarithmic law
M	:	meter
Met film	:	metal film
Met ox	:	metal oxide
Min	:	minimum value
MR	:	semiconductor diode
PL	:	plug
Plas	:	plastic
PW	:	printed wiring
R	:	resistor
RV	:	variable resistor
S	:	switch
SKT	:	socket
SPDT	:	single-pole double-throw
T	:	transformer
TE	:	total excursion
TP	:	terminal
Var	:	variable or preset
VT	:	transistor
WW	:	wirewound
*	:	value selected during test; nominal value shown

Ordering

Send your order for replacement parts to our Service Division at the address given on the back cover. Specify the following information for each part required :

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

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

Circuit reference	*Description*	*M.I. code*
C1	Paper 8 μF ±20% 350 V	26144-350
C2	Elec 100 μF +100-20% 25 V	26417-158
C3	Elec 25 μF +100-20% 25 V	26417-143
C4	Plas 0.432 μF ±1% 50 V	26518-358
C5	Plas 0.432 μF ±1% 50 V	26518-358
C6	Plas 0.1264 μF ±1% 50 V	26518-297
C7	Plas 0.04 μF ±1% 50 V	26518-244
C8	Plas 0.01264 μF ±1% 50 V	26518-222
C9	Mica .003950 μF ±½% 350 V	26257-359
C10	Plas 0.4 μF ±1% 50 V	26518-355
C11	Plas 0.432 μF ±1% 50 V	26518-358
C12	Plas 0.432 μF ±1% 50 V	26518-358
C13	Plas 0.1264 μF ±1% 50 V	26518-297
C14	Plas 0.04 μF ±1% 50 V	26518-244
C15	Plas 0.01264 μF ±1% 50 V	26518-222
C16	Mica .003950 μF ±½% 350 V	26257-359
C17	Plas 0.4 μF ±1% 50 V	26518-355
C18	Elec 100 μF +100-20% 6 V	26417-154
C19	Elec 100 μF +100-20% 6 V	26417-154
C20	Paper 0.01 μF ±20% 400 V	26174-147
C21	Elec 25 μF +100-20% 25 V	26417-143
C22	Elec 500 μF +50-20% 25 V	26417-175
C23	Plas 0.007 μF ±2% 125 V	26516-687
C24	Plas 706 pF ±2% 125 V	26516-449
C25	Plas 0.0068 μF ±1% 125 V	26516-684
C26	Plas 0.014 μF ±1% 125 V	26516-741
C27	Plas 0.00478 μF ±1% 125 V	26516-651
C28	Plas 0.00926 μF ±1% 125 V	26516-698
C29	Plas 0.113 μF ±1% 125 V	26516-848
C30	Plas 0.0018 μF ±5% 125 V	26516-544
C34	Plas 100 pF ±2% 350 V	26272-315
C35	Plas 250 pF ±2% 125 V	26516-341
C36	Plas 250 pF ±2% 125 V	26516-341
C40	Var plas 4 pF	26872-104

For abbreviations, see introduction to this section

Circuit reference	Description	M.I. code
C41	Plas 0.001 µF ±1% 125 V	26516-481
C42	Paper 0.1 µF ±25% 350 V	26174-174
C43	Paper .001 µF ±20% 500 V	26174-126
C44	Elec 100 µF +100-20% 6 V	26417-154
C45	Plas 0.1 µF ±10% 200 V	26582-208
C46	Elec 500 µF +100-20% 25 V	26427-319
C47	Elec 68 µF ±10% 15 V	26486-597
C48	Elec 500 µF +50-20% 50 V	26417-178
C49	Plas 0.033 µF ±10% 125 V	26511-331
C50	Elec 25 µF +100-20% 70 V	26417-145
C51	Plas 0.1 µF ±10% 100 V	26582-211
C52	Paper .005 µF ±20% 250 V	26174-141
C53	Paper .005 µF ±20% 250 V	26174-141
C54	Elec 100 µF +100-20% 25 V	26417-158
C55	Elec 33 µF 5% 20V	26486-589
C56	Elec 100 µF +100-20% 25 V	26417-158
C57	Elec 500 µF +100-20% 25 V	26427-319
C58	Elec 50 µF +100-20% 25 V	26417-152
C59	Elec 500 µF +100-20% 25 V	26427-319
C60	Elec 500 µF +100-20% 25 V	26427-319
C61	Elec 47 µF +100-20% 40 V	26415-810
C62	Elec 1000 µF +100-20% 16 V	26417-184
C63	Elec 500 µF +100-20% 25 V	26427-319
C64	Plas 1 µF ±10% 125 V	26511-383
C65	Plas 1 µF ±10% 125 V	26511-383
C66	Elec 6.8 µF ±10% 6 V	26486-560
C67	Elec 22 µF +100-20% 63 V	26415-806
C68	Elec 500 µF +100-20% 25 V	26427-319
C69	Elec 500 µF +100-20% 25 V	26427-319
C70	Elec 100 µF ±20% 10 V	26486-606
C71	*Plas 2000 pF ±1% 125 V	80-TM 7321
C72	Elec 100 µF +100-20% 6 V	26417-154
C73	Elec 47 µF +100-20% 40 V	26415-810

Circuit reference	Description	M.I. code
C74	Elec 33 µF 5% 20 V	26486-589
C75	Cer 33 pF ±5% 750 V	26324-822
C76	Cer 0.1 µF +50-25% 30 V	26383-031
C77	Elec 2 µF +100-20% 25 V	26414-109
C78	Elec 220 µF +100-20% 25 V	26415-818
C79	Elec 220 µF +100-20% 25 V	26415-818
FS1	100 mA or 250 mA	23411-052 23411-055
FS2	250 mA	23411-055
L1	Filter coil	44267-602
L2	Filter coil	44271-408
L3	Filter coil	44271-601
L4	Filter coil	44271-417
M1	500 µA	44572-003
MR1	AEI MS2H	28337-121
MR2	AEI MS2H	28337-121
MR4	AEI MS2H	28337-121
MR5	AEI MS2H	28337-121
MR6	Int Rect 1N540	28357-044
MR7	Int Rect 1N540	28357-044
MR8	Int Rect 1N540	28357-044
MR9	Brush Z10 5%	28371-846
MR10	Brush Z6.2 5%	28371-486
MR11	Brush Z6.2 5%	28371-486
MR12	Hughes HD 5004	28335-235
MR13	Hughes HD 5004	28335-235
MR14	Rect CG91H	28321-311
PL1	3 way mains	23423-151

See introduction to this section for notes on abbreviations and symbols

(Unless otherwise stated, tolerance refers to initial selection and rating refers to 55°C.)

Circuit reference	Description	M.I. code
R1	Carb film 620 Ω ±1% 2W/70°C	24223-620
R2	Met ox 82 kΩ ±5% 1 W	24587-272
R3	Met ox 68 kΩ ±5% 1 W	24587-270
R4	Carb 470 kΩ ±10% ½W	24342-152
R5	Met film 2.7 kΩ ±2% ¼ W	24773-382
R6	Carb film 3.9 kΩ ±1% ¼W/70°C	24254-390
R7	Carb film 1.5 kΩ ±1% ¼W/70°C	24254-150
R8	Met ox 5.6 kΩ ±7% TE 3/8 W	24552-103
R9	Carb film 750 Ω ±1% ¼W/70°C	24253-750
R10	Carb film 1.8 kΩ ±1% ¼W/70°C	24254-180
R11	Carb 150 kΩ ±10% ½ W	24342-139
R12	Carb 150 kΩ ±10% ½ W	24342-139
R13	Carb film 1.8 kΩ ±1% ¼W/70°C	24254-180
R14	Carb film 1.8 kΩ ±1% ¼W/70°C	24254-180
R15	Carb film 370 kΩ ±1% ¼W/70°C	24256-370
R16	Carb film 220 kΩ ±1% ¼W/70°C	24256-220
R17	Carb film 13 kΩ ±1% ¼W/70°C	24255-130
R18	Carb 4.7 kΩ ±10% ½ W	24342-100
R19	Met ox 75 kΩ ±7% TE 3/8 W	24552-132
R20	Carb 270 Ω ±10% ½ W	24342-061
R21	Met ox 47 kΩ ±7% TE 3/8 W	24552-126
R22	Carb 10 kΩ ±10% ½ W	24342-110
R23	Carb 100 kΩ ±10% ½ W	24342-135
R24	Carb 100 Ω ±10% ½ W	24342-050
R25	Met ox 820 Ω ±7% TE 3/8 W	24552-078
R26	Carb 180 Ω ±10% ½ W	24342-056
R27	Carb 33 Ω ±10% ½ W	24342-033
R28	Met ox 5.1 kΩ ±7% TE 3/8 W	24552-101
R32	Carb 100 Ω ±10% ½ W	24342-050
R33	Carb 47 kΩ ±5% ¼ W	24342-126
R34	Carb 2.2 MΩ ±5% ¼ W	24332-174
R35	Carb 10 kΩ ±10% ½ W	24342-110
R40	Met film 1 MΩ ±½% ½ W	24655-901
R41	Met film 3.1 kΩ ±½% ¼ W	24655-203
R42	Carb 100 Ω ±10% ½ W	24342-050
R43	Carb 1 MΩ ±10% ½ W	24342-166
R44	Carb 100 kΩ ±10% ½ W	24342-135
R45	Met ox 470 kΩ ±2% ½ W	24573-137
R46	Carb 470 kΩ ±10% ½ W	24342-152
R47	Carb 470 kΩ ±10% ½ W	24342-152
R48	Met film 6.2 kΩ ±2% ¼ W	24773-292
R49	Carb film 2 kΩ ±1% ¼W/70°C	24254-200
R50	Carb film 1 kΩ ±1% ¼W/70°C	24254-100
R51	Carb 680 Ω ±10% ½ W	24342-076
R52	Carb film 467 Ω ±1% ¼W/70°C	24253-467
R53	Carb film 810 Ω ±1% ¼W/70°C	24253-810
R54	Carb film 937 Ω ±1% ¼W/70°C	24253-937
R55	Carb film 980 Ω ±1% ¼W/70°C	24253-980
R56	Carb 4.7 kΩ ±10% ½ W	24342-100
R57	Met film 1367 Ω ±½% 1/8 W	24625-101
R58	Met film 432.4 Ω ±½% 1/8 W	24624-701
R59	Met film 136.7 Ω ±½% 1/8 W	24624-601
R60	Met film 43.24 Ω ±½% 1/8 W	24624-226
R61	Met film 20 Ω ±½% 1/8 W	24624-101
R62	Met film 39 kΩ ±1% 1/8 W	24627-551
R63	Carb 10 Ω ±5% M.I.P. 52301	25123-020
R64	Carb 10 kΩ ±10% ½W	24342-110
R65	Met ox 4.7 kΩ ±7% TE 3/8 W	24552-100
R66	Met ox 68 kΩ ±7% TE 3/8 W	24552-131
R67	Carb 1 kΩ ±10% ½ W	24342-080
R68	Met ox 150 kΩ ±7% TE 3/8 W	24552-139
R69	Carb 10 kΩ ±10% ½ W	24342-110
R70	Met ox 4.7 kΩ ±7% TE 3/8 W	24552-100
R71	Carb 3.9 kΩ ±10% ½ W	24342-096

See introduction to this section for notes on abbreviations and symbols

Circuit reference	Description	M.I. code
R72	Carb 33 kΩ ±10% $\frac{1}{2}$ W	24342-122
R73	Carb 33 kΩ ±10% $\frac{1}{2}$ W	24342-122
R74	Carb 1 kΩ ±10% $\frac{1}{2}$ W	24342-080
R75	Met ox 3.3 kΩ ±7% TE 3/8 W	24552-094
R76	Met ox 1 kΩ ±7% TE 3/8 W	24552-080
R77	Carb 5.6 kΩ ±10% $\frac{1}{2}$ W	24342-103
R78	Carb 100 kΩ ±10% $\frac{1}{2}$ W	24342-135
R79	Carb 10 kΩ ±10% $\frac{1}{2}$ W	24342-110
R80	Met ox 1.8 kΩ ±7% TE 3/8 W	24552-086
R81	Met ox 3.9 kΩ ±7% TE 3/8 W	24552-096
R82	Carb 8.2 kΩ ±10% $\frac{1}{2}$ W	24342-108
R83	Met ox 6.2 kΩ ±7% TE 3/8 W	24552-104
R84	Met ox 3 kΩ ±7% TE 3/8 W	24552-093
R85	Carb 1 kΩ ±10% $\frac{1}{2}$ W	24342-080
R86	Carb 33 Ω ±10% $\frac{1}{2}$ W	24342-033
R87	Carb 680 Ω ±10% $\frac{1}{2}$ W	24342-076
R88	Carb 15 kΩ ±10% $\frac{1}{2}$ W	24342-114
R89	Met ox 20 kΩ ±7% TE 3/8 W	24552-117
R90	Carb 2.2 kΩ ±10% $\frac{1}{2}$ W	24342-088
R91	Met ox 2.7 kΩ ±7% TE 3/8 W	24552-092
R92	Met ox 3.9 kΩ ±7% TE 3/8 W	24552-096
R93	Met ox 820 Ω ±7% TE 3/8 W	24552-078
R94	Met ox 220 Ω ±7% TE 3/8 W	24552-058
R95	Met ox 220 Ω ±7% TE 3/8 W	24552-058
R96	Met ox 820 Ω ±7% TE 3/8 W	24552-078
R97	Carb 1 kΩ ±10% $\frac{1}{2}$ W	24342-080
R98	Met ox 270 Ω ±7% TE 3/8 W	24552-061
R99	Met ox 270 Ω ±7% TE 3/8 W	24552-061
R 100	Met film 100 kΩ ±2% $\frac{1}{2}$W	24573-121
R 101	Met film 100 kΩ ±2% $\frac{1}{2}$W	24573-121

Circuit reference	Description	M.I. code
R102	Carb 470 kΩ ±10% $\frac{1}{4}$ W	24342-152
R103	Carb 1.5 kΩ ±10% $\frac{1}{4}$ W	24342-084
RV1	Carb 100kΩ ±10% 2W } Concentric	
RV8	Carb 10kΩ ±10% 2W } Concentric	25674-206
RV2	WW 5.1 kΩ ±2% 4 W	25874-576
RV3	WW 100 kΩ ±10% 4 W	25874-587
RV4	WW 100 kΩ ±10% 4 W	25874-587
RV5	WW 5.1 kΩ ±2% 4 W	25874-576
RV6	WW 1 kΩ ±5% 2 W	25885-069
RV7	WW 500 Ω ±10% 1 W	25811-535
RV10	WW 150 Ω ±10% $\frac{1}{2}$ W	25886-537
RV11	Carb 22 kΩ ±20% $\frac{1}{4}$ W	25611-080
RV12	Carb 1 kΩ ±20% $\frac{1}{4}$ W	25611-204
RV13	Carb 250 Ω ±20% $\frac{1}{4}$ W/70 $^{\circ}$C	25615-753
RV14	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611-213
RV15	Carb 10 kΩ ±20% $\frac{1}{4}$ W	25611-213
SA	Rotary DFM	44321-408
SB	Rotary FUNCTION	44324-410
SC	Rotary FREQUENCY	44324-710
SD	Rotary RANGE	44326-016
SE	Rotary SUPPLY	44321-406
SF	Slider BATT/MAINS	23467-115
SG	Slider NOR/LFC	23467-115
SH	Rotary USE/CAL	44321-406
SJ	Slider 600/HIZ	23467-160
SK	Slider INPUT AF/RF	23407-160
SKT6	Type N 50 Ω	23443-733

See introduction to this section for notes on abbreviations and symbols

Circuit reference	Description	M.I. code
T1	Mains	43456-003
TP1	Insulated	23235-176
TP2	Earthing	23235-177
TP3	Earthing	23235-177
TP4	Insulated	23235-176
TP5	Insulated	23235-176
TP6	Earthing	23235-177
VT1	BCY 71	28435-237
VT2	BCY 71	28435-237
VT3	BCY 71	28435-237
VT4	BCY 71	28435-237
VT5	BC108	28452-787
VT6	BCY72	28433-487
VT7	BCY72	28433-487
VT8	2N404	28423-508
VT9	Mullard ACY20	28424-747
VT10	Mullard ACY17	28426-497
VT11	Mullard OC25	28424-807
VT12	Mullard ACY20	28424-747
VT13	BCY 71	28435-237
VT14	BCY 72	28433-487
VT15	STC BSY26	28452-173
VT16	BCY 72	28433-487
VT17	BSX 20	28452-197
VT18	BCY 72	28433-487
VT19	BCY 71	28435-235

KNOBS

Description	M.I. code
Round knob for FREQ BALANCE control, etc.	41142-704
Bar knob with skirt for FUNCTION and INPUT RANGE switch	41145-206
Pointer knob with skirt for FREQUENCY and METER RANGE switch	41145-219
Knob for coarse SET REF LEVEL control	41141-304
Knob for fine SET REF LEVEL control	41141-602
CAL/USE switch	41142-210
SUPPLY switch	41142-209

See introduction to this section for notes on abbreviations and symbols

CIRCUIT NOTES

1. COMPONENT VALUES
Resistors : No suffix = ohms. k = kilohms. M = megohms.
Capacitors : No suffix = microfarads. p = picofarads.
✱ value selected during test; nominal value shown.

2. VOLTAGES
These are d.c. and relative to chassis unless otherwise indicated. Measured with 20 kΩ/V meter (or valve voltmeter where indicated by ϕ). Power Unit voltages relate to 240 V a.c. input.

3. SYMBOLS

⊘	preset component
↑	arrow indicates clockwise rotation of knob
BATTERY	panel marking
70	printed board tag number

4. SWITCHES
Rotary switches are drawn schematically. Numbers or letters indicate control knob setting as shown in key diagrams.
1F = 1st section (front panel), front
1B = 1st section, back
2F = 2nd section, front
etc.

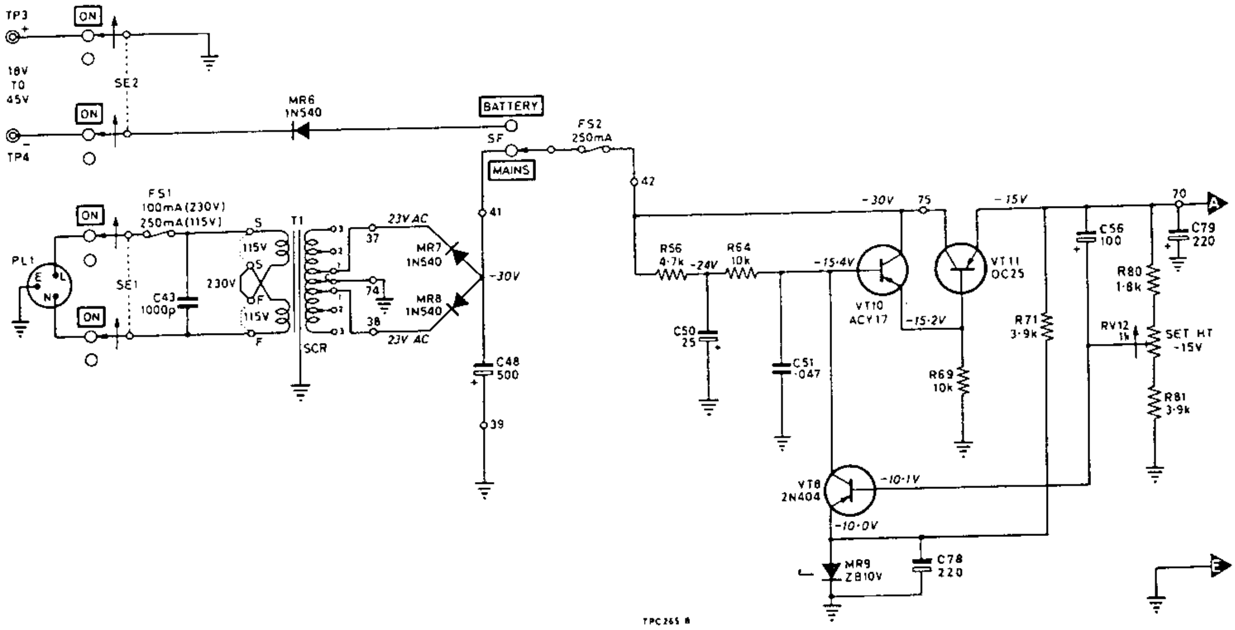
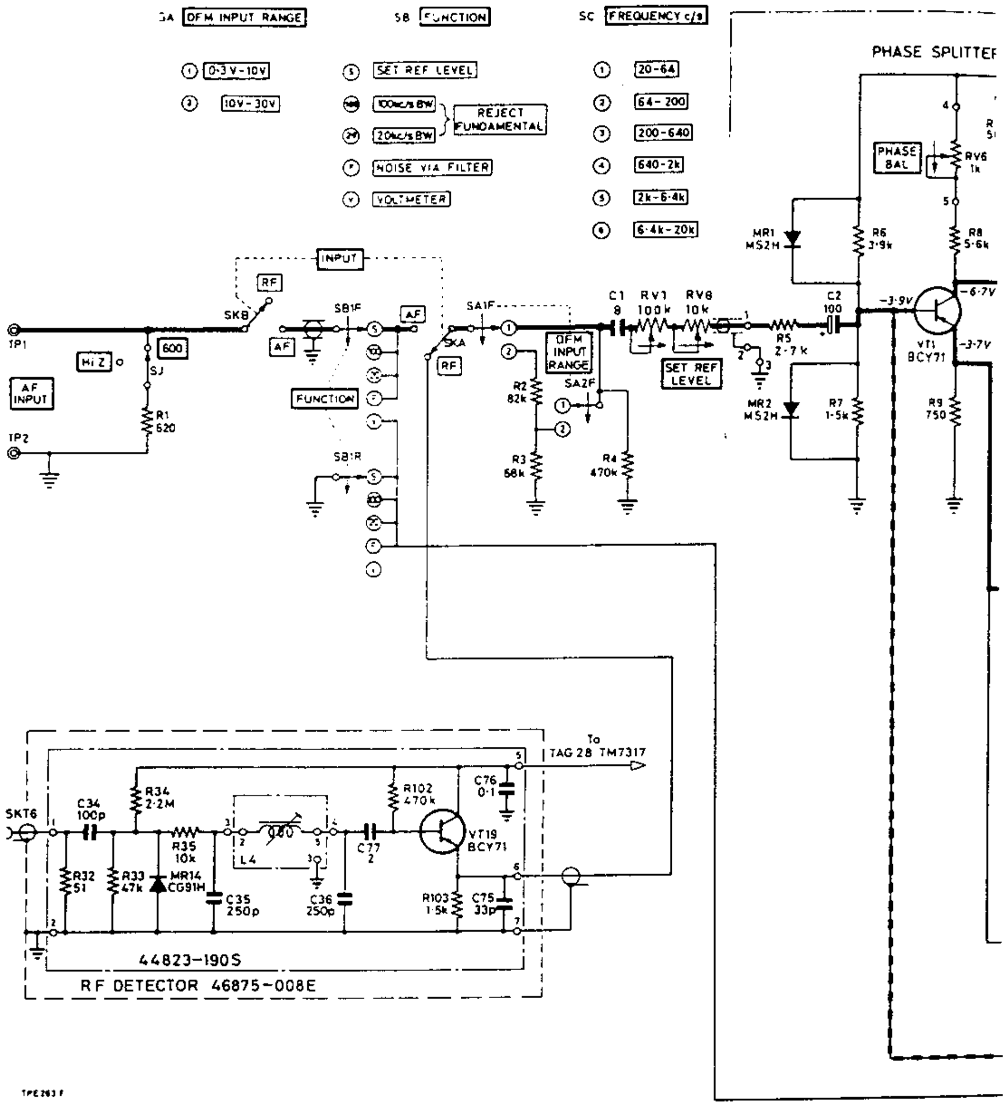


Fig. 4·4 POWER UNIT



OFM INPUT RANGE
SB FUNCTION
SC FREQUENCY c/s
0·3V-10V
10V-30V
SET REF LEVEL
100c/s BW
20kc/s BW
REJECT FUNDAMENTAL
NOISE VIA FILTER
VOLTMETER
20-64
64-200
200-640
640-2k
2k-6·4k
6·4k-20k
PHASE SPLITTER
PHASE BAL
RV6 1k
MR1 MS2H
R6 3·9k
R8 5·6k
INPUT
RF
AF
SKB
SB1F
SA1F
SKA
C1 8
RV1 100k
RV8 10k
C2 100
R5 2·7k
-3·9V
-6·7V
-3·7V
VT1 BCY71
TP1
TP2
HI Z
600
SJ
AF INPUT
R1 620
FUNCTION
SB1R
OFM INPUT RANGE
R2 82k
R3 56k
SA2F
R4 470k
SET REF LEVEL
MR2 MS2H
R7 1·5k
R9 750
To TAG 28 TM7317
SKT6
C34 100p
R34 2·2M
R35 10k
R32 51
R33 47k
MR14 CG91H
C35 250p
L4
C36 250p
C77 2
R102 470k
C76 0·1
VT19 BCY71
R103 1·5k
C75 33p
44823-190S
RF DETECTOR 46875-008E

Fig. 4·5

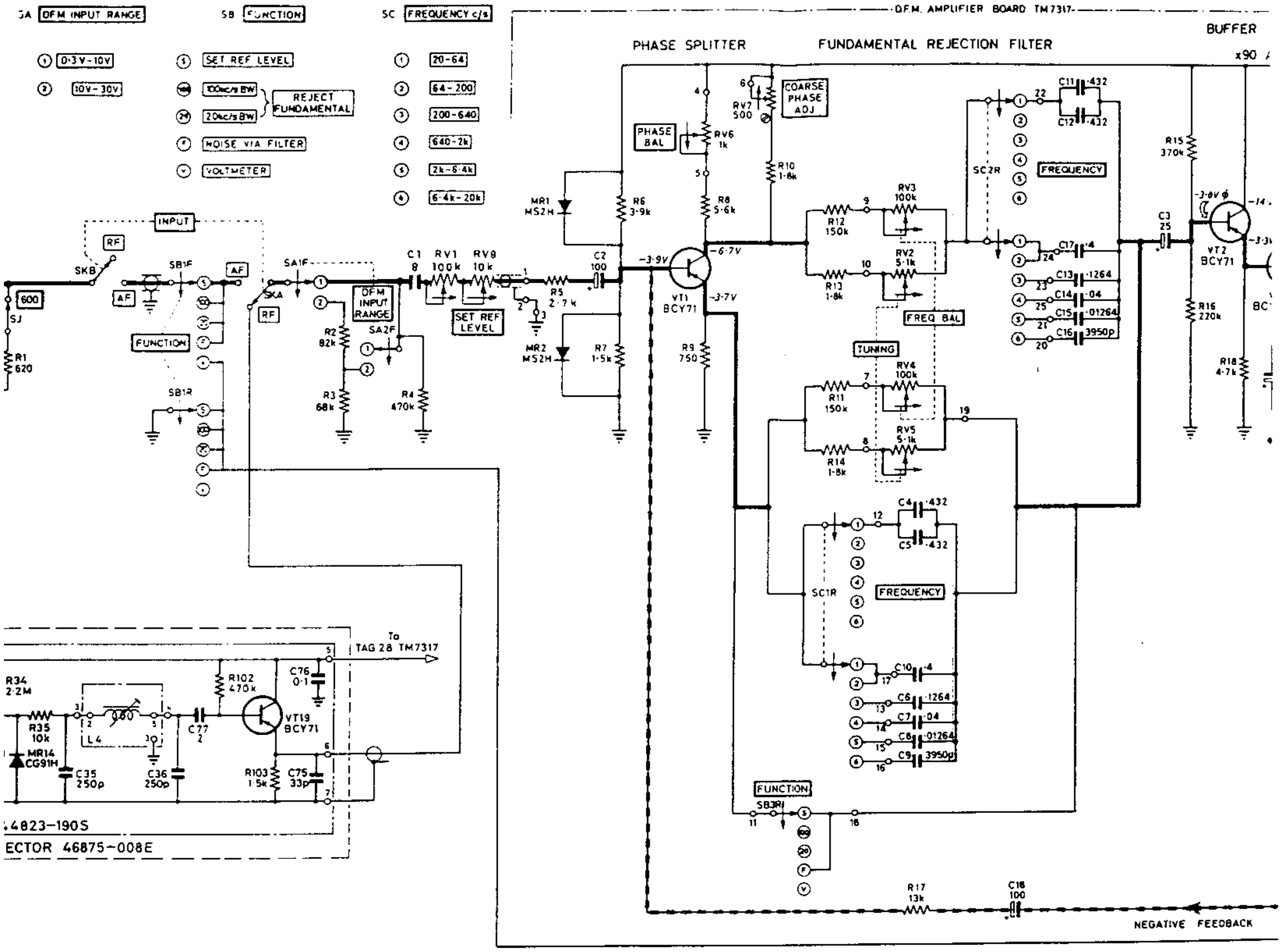
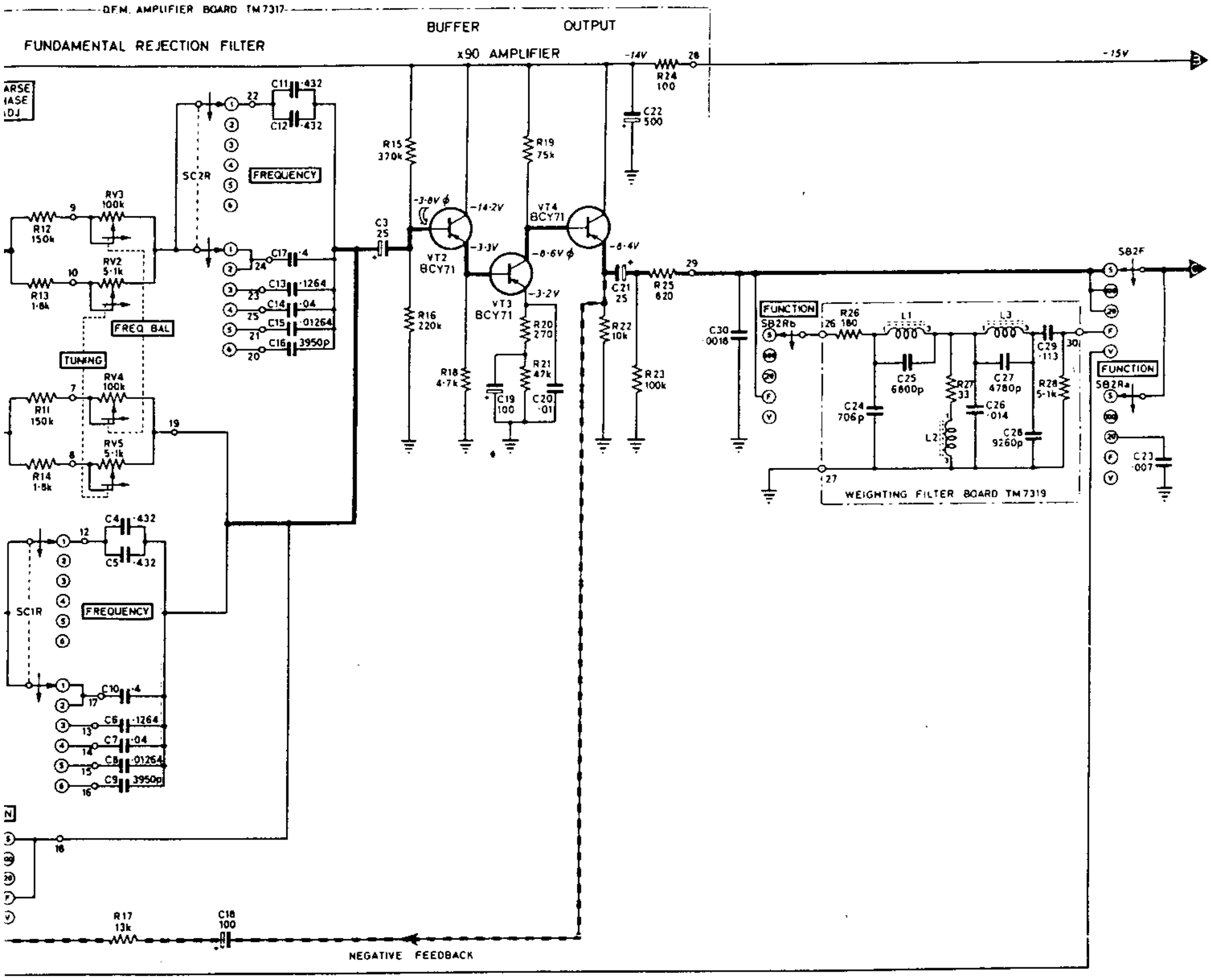


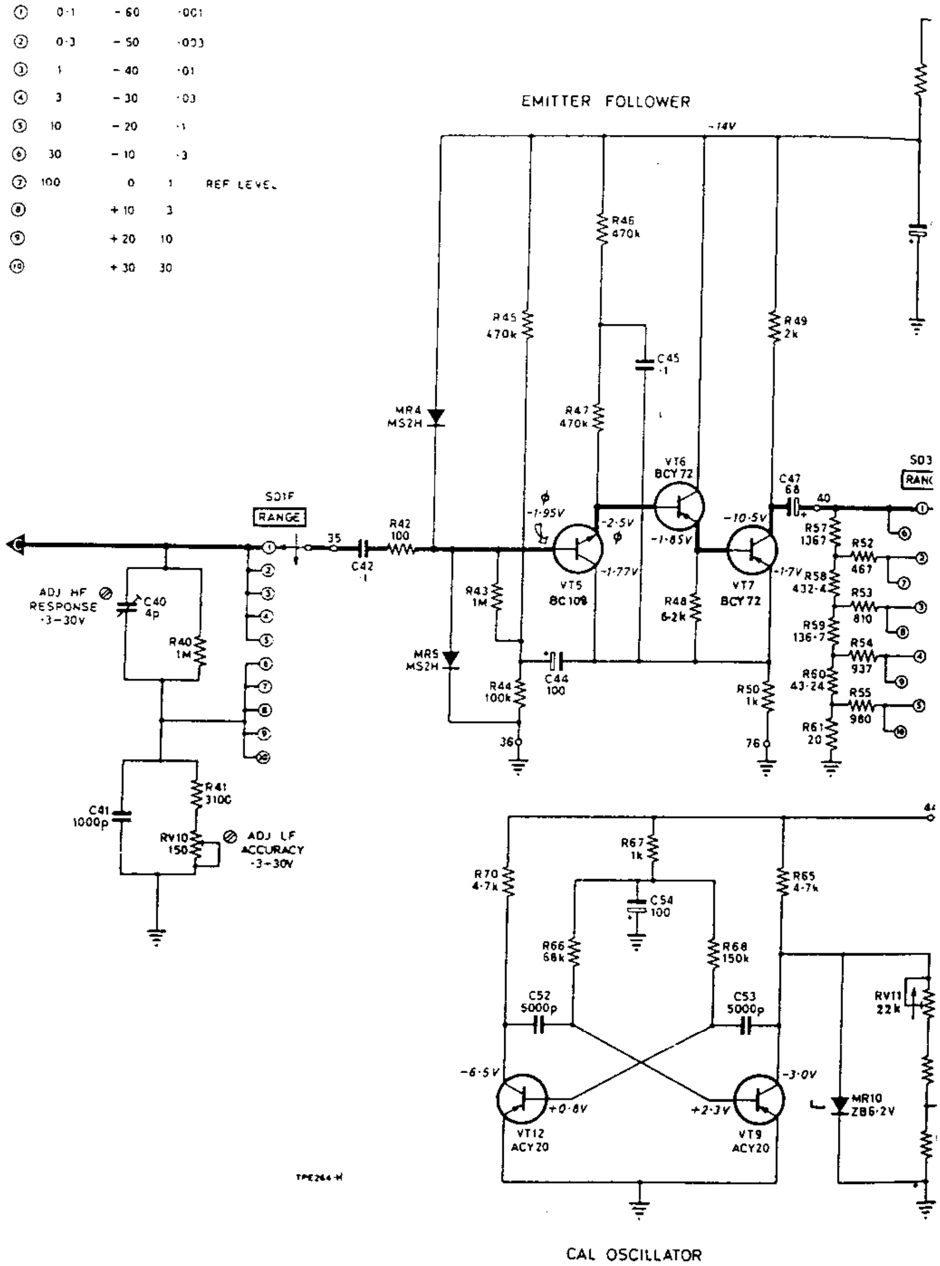
Fig. 4·5 DISTORTION FACTOR METER SECTIO



;TORTION FACTOR METER SECTION

SD RANGE

	%	dB	V	
①	0·1	− 60	·001	
②	0·3	− 50	·003	
③	1	− 40	·01	
④	3	− 30	·03	
⑤	10	− 20	·1	
⑥	30	− 10	·3	
⑦	100	0	1	REF LEVEL
⑧		+ 10	3	
⑨		+ 20	10	
⑩		+ 30	30	



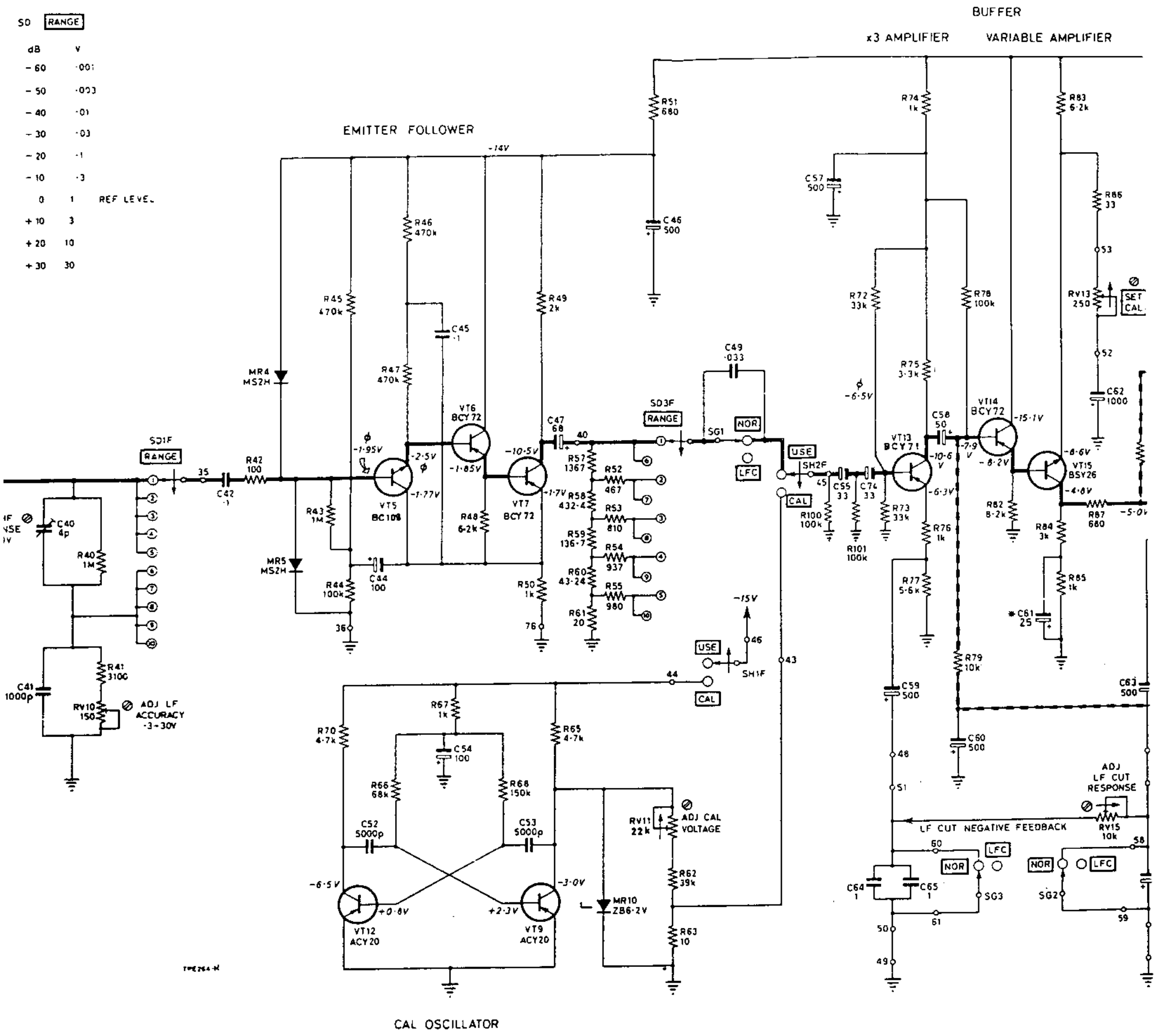
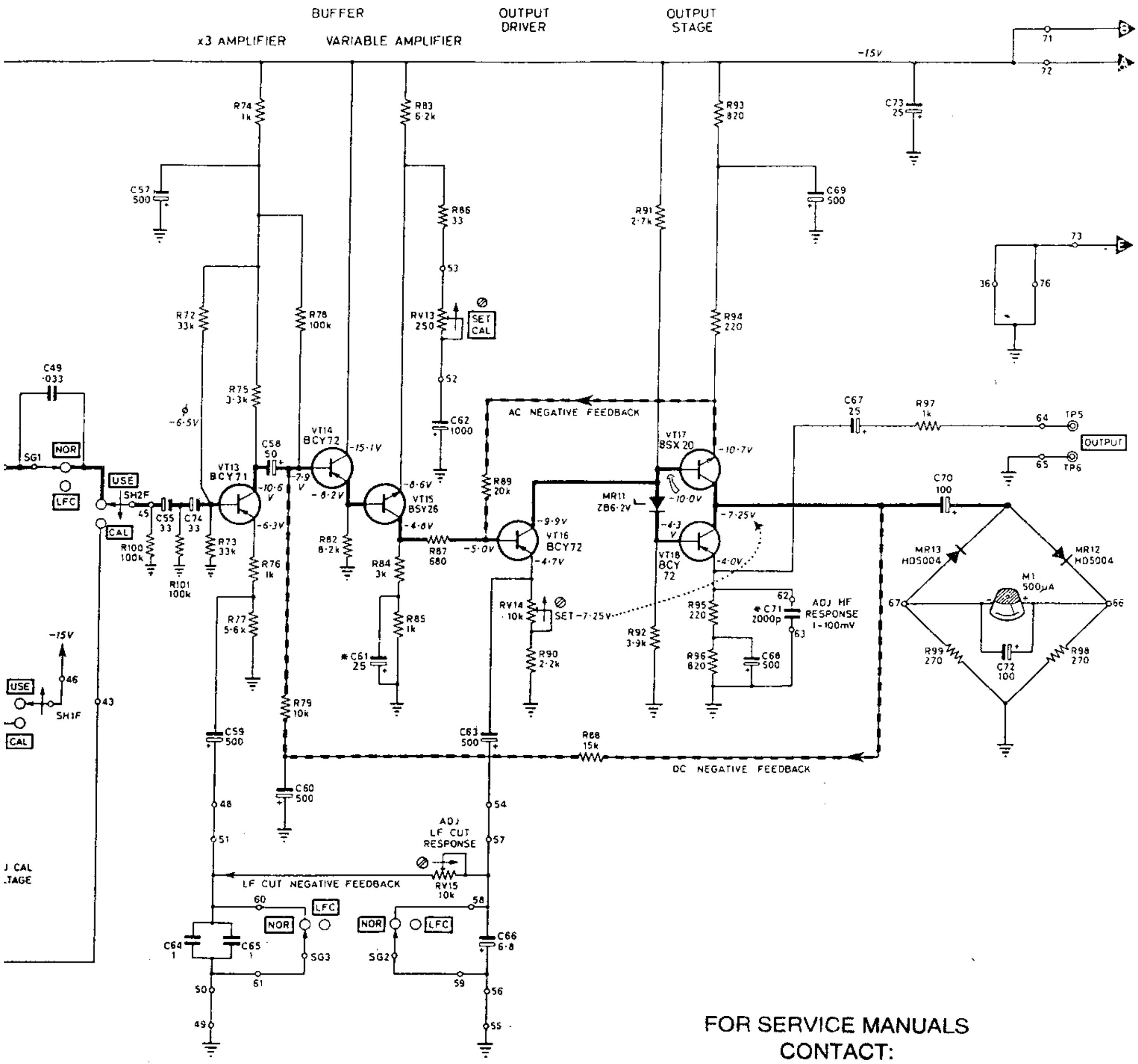


Fig 4·6 VOLTMETER SECTION

(1g)



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FAX: 01844 - 352554

ig 4·6 VOLTMETER SECTION

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

2331 (1a)

EB 2331
C10 - 9/75

MANUAL CHANGE

for

DISTORTION FACTOR METER TF 2331

Use of SET REF LEVEL controls

In Section 2.5 para. (3) insert :- NOTE. For ease of adjusting the SET REF LEVEL controls with inputs in range 0.3 V to about 1 V, it is advisable to turn the coarse control fully clockwise and adjust to the required reference level by means of the fine control only.