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instruments

TF 2002B
MF/HF AM/FM
SIGNAL GENERATOR

Instruction Manual

NOTES AND CAUTIONS

ELECTRICAL SAFETY PRECAUTIONS

This equipment is protected in accordance with IEC Safety Class 1. 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.

Fuses

Note that there is a supply fuse in both the live and neutral wires of the supply lead. If only one of these fuses should rupture, certain parts of the equipment could remain at supply potential.

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.

Instruction Manual

No. EB 2002B

for

MF/HF AM/FM Signal Generator TF 2002B

MARCONI INSTRUMENTS LIMITED
ST. ALBANS HERTFORDSHIRE ENGLAND

G.L. 1.5c
5/79/I

EB 2002B
1f - 5/79

Contents

Chapter 1

General information

1.1 FEATURES

The TF 2002B gives high quality a. m. outputs from 10 kHz to 88 MHz and f. m. outputs between 100 kHz and 88 MHz. It has very high frequency discrimination which, coupled with the good stability reached soon after switching on, makes it particularly suitable for setting up and adjusting crystal controlled receivers where the channel spacing is small and the i. f. pass band must have an accurate absolute setting. Another feature is the low leakage which will be found of advantage for tests on receivers that have an internal ferrite rod aerial.

Permeability tuning of the oscillator and output filter modules enables the complete range to be covered in only eight bands. The hand calibrated near-logarithmic tuning scale is displayed in a continuous zig-zag pattern, with scales running alternately left and right. This cuts out much of the tedium usually associated with tuning about the band-change frequencies. Above 100 kHz (carrier frequency) direct reading incremental tuning gives high discrimination. Frequency control can also be achieved by externally applied d. c. or by the use of Digital Synchronizer TF 2170B.

Crystal check points are available at intervals of 1 MHz, 100 kHz or 10 kHz. Subsidiary check points can be switched in at 1 kHz relative to each of the main points. The dial of the incremental control can be adjusted to high accuracy against the crystal check points by means of two independent trimmer controls.

Up to 1 V p. d. can be obtained with 100% modulation over all the range and up to 2 V p. d. is available with c. w. or f. m. outputs. Output is controlled by cam operated 20 dB and 1 dB step attenuators with voltage and dB calibration in terms of p. d. across a 50 Ω load or of source e. m. f. ; interpolation between attenuator steps is provided by the carrier level control and meter. Automatic level control holds the output constant against frequency or range changing.

An auxiliary unmodulated output is available for driving a counter or the Digital Synchronizer TF 2170B.

Internal a. m. up to 100% is produced by a continuously tuned low distortion oscillator covering a frequency range 20 Hz to 20 kHz. This means that the generator can be used for r. f. , i. f. and a. f. response measurements on a receiver with no additional equipment other than a receiver output meter. The oscillator output is available for external use at terminals situated at the rear of the instrument. Envelope negative feedback ensures a good modulation quality up to at least 80%, and modulation depth is independent of both carrier tuning and carrier level.

The continuously variable a.f. oscillator also provides frequency modulation, and deviation is indicated directly on the modulation meter. Three ranges of deviation are provided for each carrier range above 200 kHz.

External frequency control terminals can be used to provide dynamic sweep measurements (with or without internal AM), FSK, phase modulation or digital f. m.

External amplitude control terminals can be used for level control programming or modulation at a very low frequency without phase shift.

Silicon devices are used throughout and emphasis has been placed on accessibility despite the compact structure and thorough screening. The instrument has three major horizontal sections; the centre one containing the oscillators and other circuits can be withdrawn and operated without electrical disconnection.

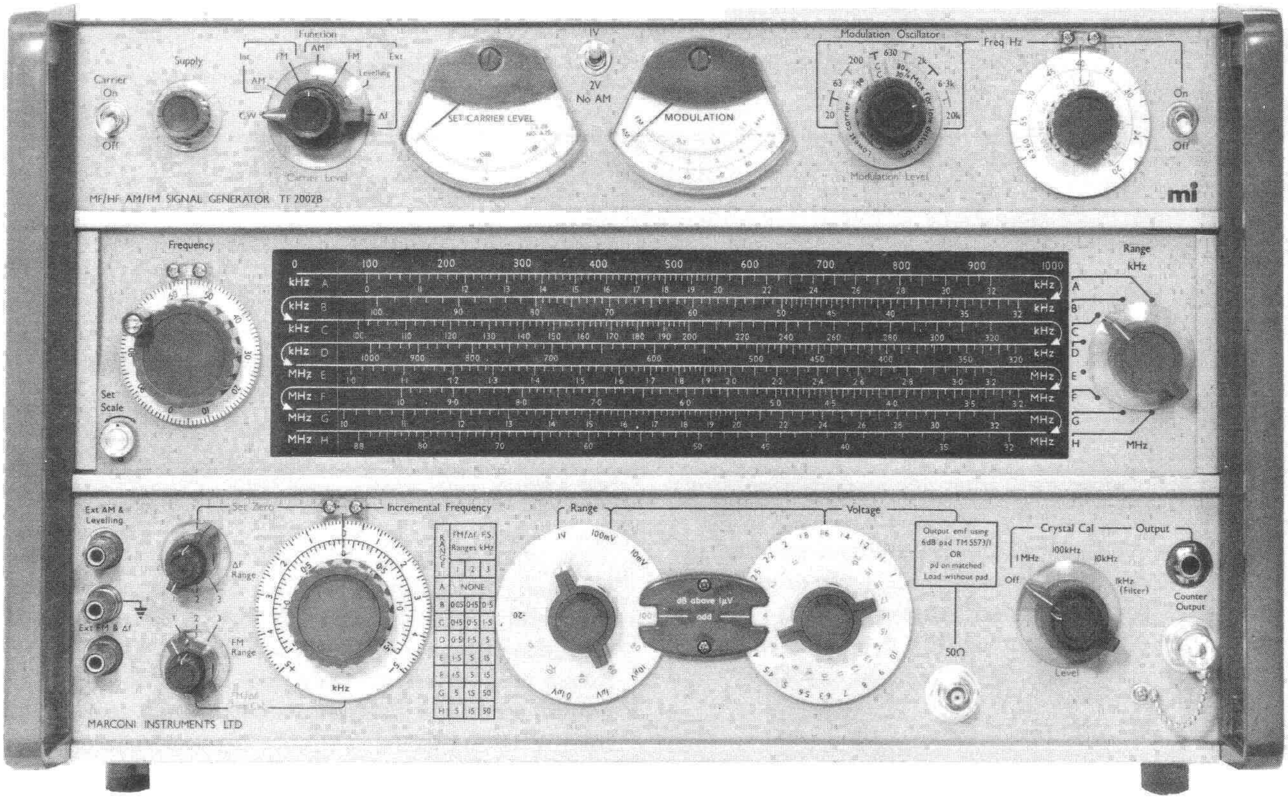


Fig. 1.1 TF 2002B M.F./H.F. A.M./F.M. Signal Generator

1.2 DATA SUMMARY

Characteristic — *Performance* — *Supplementary information*

Frequency

Ranges

10 kHz to 88 MHz in 8 bands.

A	10	-	32 kHz
B	32	-	100 kHz
C	100	-	320 kHz
D	320	-	1000 kHz
E	1	-	3.2 MHz
F	3.2	-	10 MHz
G	10	-	32 MHz
H	32	-	88 MHz

Mechanical tuning

The frequency scales are near logarithmic and a 1000 division linear logging scale is provided.

Calibration accuracy

± 1%, with the scale in the index position. Provision is made for adjusting the scale position against the internal calibrator.

Characteristic	Performance	Supplementary information
Stability	At constant ambient temperature within the range +10° to 35 °C and in the 15 minute period commencing 3 hours after switch on, the frequency variation is typically : 30 p.p.m. +3 Hz and will not exceed 90 p.p.m. +3 Hz. During the period 10 minutes to 3 hours after switch on the maximum frequency variation per 15 minutes will not exceed three times the amounts stated above. Following a 10 °C change in the ambient temperature within the range +10 °C to 35 °C occurring after the above period of operation, the maximum frequency variation over the next 3 hours is typically 200 p.p.m. per 15 minutes.	For a supply voltage change of +10% or -10% about 230 V or 115 V the frequency change is less than 1 p.p.m. +1 Hz measured after a 2 hour warm-up period. Improvement in stability can be achieved using the Digital Synchronizer TF 2170B.
Attenuator reaction		With the output loaded with 50 Ω and the coarse attenuator at maximum output, the maximum frequency shift between the extremes of the fine attenuator control is not greater than 88 Hz at 88 MHz.
Electrical fine tune	Operative above 32 kHz only. Each carrier frequency band is provided with three ranges of electrical fine tuning as shown below :	

Table 1.1

Frequency	Band	Δf range or f.m. deviation (kHz) 1	2	3
32 - 100 kHz	B	±0.05	±0.15	±0.5
100 - 320 kHz	C	±0.15	±0.5	±1.5
320 -1000 kHz	D	±0.5	±1.5	±5.0
1 - 3.2 MHz	E	±1.5	±5.0	±15
3.2 - 10 MHz	F	±1.5	±5.0	±15
10 - 32 MHz	G	±5.0	±15	±50
32 - 88 MHz	H	±5.0	±15	±50

Characteristic	Performance	Supplementary information
	Sweep widths in excess of the table may be obtained; between 100 kHz and 320 kHz (Range C) up to 5.0 kHz is obtainable and between 320 kHz and 1000 kHz (Range D) up to 30 kHz.	Electrical fine tuning up to the maximum in table 1.1 may be used as an external frequency shift facility for manual or automatic frequency control, frequency modulation, phase modulation, or sweeping (see under frequency modulation).
Discrimination	Better than 0.005% of carrier frequency.	

Characteristic	Performance	Supplementary information
Discrimination with Digital Synchronizer TF 2170B		10 Hz at any carrier frequency 32 kHz to 88 MHz.
Incremental frequency accuracy	±15% of full scale when the FM/ Δ f Fine Cal control is centralized. ±5% of full scale when standardized on the + Δ f, or - Δ f range against the internal crystal calibrator.	
Crystal calibrator	Check points at 1 MHz, 100 kHz and 10 kHz intervals. Additional check points at ±1 kHz about these points. Accuracy. Crystal 0.01%. 1 kHz null ±10 Hz.	
R.F. output	10 kHz - 88 MHz	
Max level (with 50 Ω load)	1 V p.d. with up to nominal 100% a.m. or 2 V p.d. without a.m. Variable down to 0.1 μV at all frequencies.	
Attenuators		Seven position coarse attenuator with 20 dB steps. Twenty-one position fine attenuator with 1 dB steps. External 6 dB pad TM 5573/1 provides 6 dB.
Total level accuracy (50 Ω load)	±1 dB up to 88 MHz. An additional error of ±0.5 dB above 32 MHz may occur at 10 °C and 35 °C.	
Levelling accuracy	A.L.C. maintains carrier level meter setting constant within 0.5 dB at all carrier frequencies.	
Impedance	Effectively 50 Ω at all level settings. V.S.W.R. 1.1:1 with attenuator set at +106 dB μV or lower; with or without 6 dB pad TM 5573/1.	
Counter output	Greater than 100 mV into 50 Ω.	
Amplitude modulation		
Depth	Continuously variable up to a nominal 100%.	
Meter		Indicates equivalent peak modulation.
Accuracy	Up to 80% depth: ±5% modulation from 20 Hz to 20 kHz subject to the limitations of table 1.2.	Above 32 MHz the accuracy is ±7% with modulation frequencies from 15 kHz to 20 kHz.

Characteristic	*Performance*	*Supplementary information*

Frequency modulation

Deviation	Above 100 kHz carrier frequency, continuously variable with three ranges to maximum peak deviations as shown in table 1.1.	The fine tuning and f.m. facilities can be used simultaneously provided the total excursion does not exceed the range maximum shown for fine tuning, but the deviation accuracy will be impaired. When using $\frac{1}{2}$ f.s.d. on maximum fine tuning and f.m. ranges the f.m. accuracy is then ±20%.
Meter		Indicates peak deviation.
Accuracy	With mod frequencies between 20 Hz and 4 kHz: ±15% of full scale when the FM/ Δf fine cal control is centralized or ±6% of full scale when the Δf system has been standardized.	
Modulation frequency characteristic	With carrier frequencies above 1 MHz the modulation frequency range is extended to 20 kHz with a flatness of ±2 dB with respect to 1 kHz.	
Distortion	Less than 3% at maximum deviation with mod frequencies between 20 Hz and 4 kHz.	
Internal oscillator	As for amplitude modulation.	
External f.m. (a.c.)	20 Hz to 20 kHz, accuracy of deviation and frequency limitations as for internal modulation. Input approximately 1.2 V r.m.s. (impedance varies between 2 to 2.5 kΩ) for maximum deviation as shown in table 1.1. (Deviation adjustable at panel).	
External Δf (d.c.)	An input between -5.75 V and -7.75 V gives control of the carrier frequency by at least the maximum deviations shown in table under electrical fine tuning. Polarity; negative going voltage increases frequency. The input impedance is 100 kΩ (in series with -6.75 V).	
Synchronizer input	BNC socket on rear panel for TF 2170B. Standing voltage -6.75 V. Polarity; negative going voltage increases frequency. Sensitivity per volt applied varies between 5% on carrier frequency on lower ranges and 0.5% on higher ranges.	

Characteristic	*Performance*	*Supplementary information*
Spurious signals		
Carrier harmonics	-40 dB 32 kHz to 10 MHz at all levels. -35 dB 10 MHz to 88 MHz at 1 V meter setting. -30 dB 10 kHz to 88 MHz at 2 V meter setting.	
Leakage	Negligible. Allows measurement to be made close to the signal generator.	
Spurious AM on CW	-75 dB relative to the carrier in a 3 dB bandwidth of 650 Hz at carrier frequencies below 450 kHz and in a 20 kHz bandwidth above 450 kHz.	
Spurious FM on AM	For 30% a.m., up to 88 MHz at 1 kHz mod. frequency, deviation is less than 250 Hz and at 10 kHz mod. frequency, deviation is less than 3 kHz	
Spurious FM on CW	Less than 6 Hz in the CCITT (1960) psophometric telephone weighted bandwidth. Less than 25 Hz in a 50 Hz to 20 kHz bandwidth.	
Spurious AM on FM	Less than 1% from 320 kHz to 3.2 MHz, less than 0.3% above 3.2 MHz at 1 kHz modulation frequency and maximum deviation for the band in use.	
Microphony	Less than 1.5 kHz deviation is caused by ½ g acceleration in the range 10 Hz - 100 Hz.	
Power requirements		
AC SUPPLY		
Voltage		Any voltage within the limits 190 to 264 V or 95 to 130 V at any frequency between 45 and 500 Hz.
Consumption		15 VA approximately.
DC SUPPLY		
Voltage		Any voltage within the limits 19 to 32 V d.c. (with positive earth).
Current		0.40 A approximately.
Dimensions and weight		Height: 284 mm (11.2 in) Width: 473 mm (18.6 in) Depth: 392 mm (15.4 in) Weight: 26.4 kg (58 lb)

1.3 ACCESSORIES

Accessories supplied

1. Trimming tool. M. I. code 22951-221.
   (Stowed inside the instrument).

2. Hexagon wrench for removing r. f. box cover. M. I. code 22951-012
   (Stowed inside the instrument).

3. 6 dB Pad type TM 5573/1; BNC plug to BNC socket.
   (stowed in clip at the rear of the instrument).

4. Output lead, type TM 4969/3; BNC plug to BNC plug.

5. Telephone Jack Plug. M. I. code 23421-607. For crystal calibrator output socket.

6. Mains lead, M.I. code 43129-071.

7.* 2:1 Voltage Ratio Matching Pad type TM 5573/3; 50 to 75 Ω BNC plug to BNC socket.

* TM 5573/3 is a 3 resistor pad which introduces a 2:1 voltage ratio but provides a 2 way match.

Accessories available

1.** Matching Pad, type TM 5569; 50 to 75 Ω BNC socket to Belling-Lee L734/P plug.

** TM 5569 is a 25 Ω series resistor and provides unity voltage ratio.

2. Matching Pad, type TM 6599; 50 to 75 Ω BNC plug to Burndept PR 4E plug.

3. Dummy Aerial DC Isolating Unit, type TM 6123; input, BNC plug on 3 ft lead; output, spring loaded terminals. For general receiver testing or for use on circuits with d. c. potentials up to 350 V.

4. Matching transformer, type TM 5955/5; 50 Ω unbalanced to 300 Ω balanced, BNC socket to 4 mm terminals. Voltage ratio 1 :0. 5 +0. 5.

5. 20 dB Attenuator Pad, TM 5573.

6. Shielded Adapter, M.I. code 43168-008. Converts 3/4 in spaced terminals to BNC socket.

7. RF Fuse Unit, BNC plug to BNC socket with spare fuses. TM 9884.

8. Protective Lid, M.I. code 41690-018. Provides storage space for all accessories.

9. Rack Mounting Kit, M.I. code 54127-021.

10. Impedance adaptor 50-75 Ω, M.I. code 54411-051.

Chapter 2 Operation

2.1 INTRODUCTION

Signal Generator TF 2002B is an instrument of very wide application and a few typical examples of its capabilities are given at the end of this chapter. Preliminary requirements before switching on are detailed in Sects. 2.2 to 2.4. The function of all the controls is listed in Sects. 2.6 to 2.8 and locations are shown in Figs. 2.1 and 2.2.

2.2 PRELIMINARY REQUIREMENTS

Prior to connecting the instrument to the a.c. supply check that :

1. Voltage selector switch is set to accept the local supply (voltage regulation eliminates transformer tap changing except between 95/130 V and 190/264 V ranges).

   To change the range, remove locking plate, set the switch correctly, reverse the plate and refit.

2. Fuses are of the required rating, not open circuit and secure in the holders.

3. Meter pointers are at zero. If necessary, adjust the screws on the meters to set the pointers at mechanical zero.

2.3 A.C. SUPPLY CABLE

The a.c. supply cable is fitted at one end with a female plug which connects with the instrument. When fitting the supply plug ensure that the conductors are connected as follows :-

Earth	-	Green/yellow
Neutral	-	Blue
Live	-	Brown

2.4 BATTERY OPERATION

For battery operation it is only required to connect the battery to the appropriate terminals located at the rear of the instrument.

A mains/battery switch is not provided since this input functions automatically and the circuits are protected against reverse polarity, etc. This feature could be used for emergency standby battery operation which would cut in automatically in the event of a mains supply failure.

2.5 FUSES

Two 160 mA fuses are fitted for 190-264 V operation but for 95-130 V supplies 250 mA fuses are required.

DC fuse

A fuse rated at 500 mA is included in the unregulated d.c. line.

All supply fuses are standard 20 mm x 5 mm and all are slow blow (time lag) types.

RF fuse

An r.f. fuse is available as an optional accessory for the purpose of instrument protection when using the generator for checking the receiver section of transceivers.

2.6 CONTROLS—supply and tuning

1. SUPPLY switch. Turn clockwise to switch on.
2. Main tuning scale. The scale is engraved in a continuous zig-zag from 10 kHz to 88 MHz.
3. RANGE switch. 8 positions, lettered to correspond to the frequency bands.
4. Main FREQUENCY control. The knob skirt carries a logging scale that enables the main tuning scale to be divided into 1000 divisions.
5. SET SCALE control. Mechanical adjustment of main tuning scale for frequency standardization. A positive index locates the nominal centre position.
6. INCREMENTAL FREQUENCY control and scale. Provides calibrated frequency shifts up to the limits indicated alongside the control.
7. SET ZERO control. Sets the frequency of the zero calibration mark of the INCREMENTAL FREQUENCY control (6).

8. Δ f RANGE. Range of incremental tuning selected by this switch, according to table on front panel.

9. FM RANGE. Range of frequency modulation selected by this switch, according to table on front panel.

10. FM/ Δ f FINE CAL. Control for increasing the accuracy of the INCREMENTAL FREQUENCY and deviation scale setting. To maintain unstandardized accuracy, control should be central.

11. CRYSTAL CALIBRATOR selector. Selects the intervals at which marker pips are provided (1 MHz, 100 kHz, 10 kHz). An additional switch position gives a sharp null separated by 1 kHz from each 10 kHz marker.

12. CRYSTAL CALIBRATOR LEVEL control. Adjust the a. f. level of the markers.

14. FUNCTION switch. Three internal switch positions: CW, AM, FM: four external switch positions: AM, FM, LEVELLING, Δ f (internal AM is also available in the EXTERNAL Δ f mode).

2.7 CONTROLS—modulation and output

1. Coarse attenuator. Six 20 dB steps.

2. Fine attenuator. Twenty 1 dB steps.

3. RF output socket. 50 Ω BNC socket.

4. COUNTER OUTPUT. 50 Ω BNC socket. Output is an unmodulated c. w. signal greater than 100 mV independent of attenuator setting useful as an auxiliary output or for driving digital synchronizer.

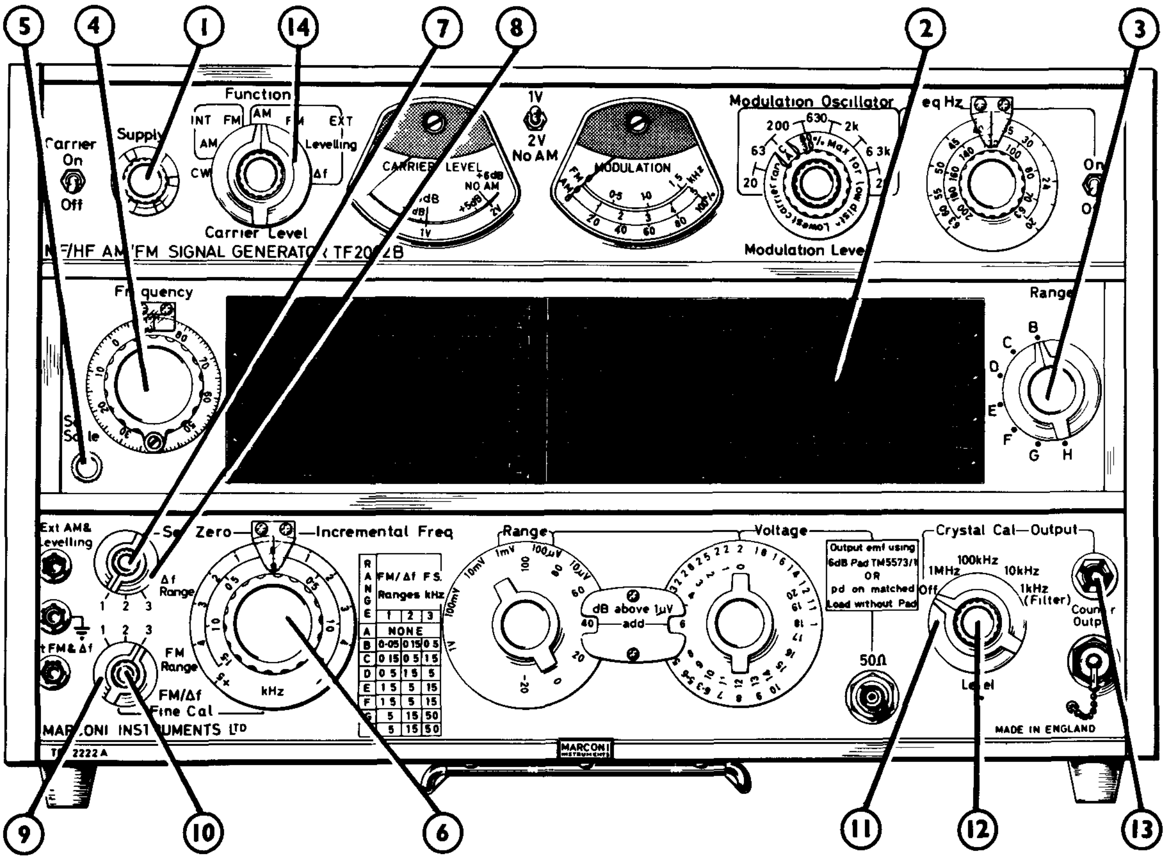


Fig. 2.1 Controls—supply and tuning

13. CRYSTAL CALIBRATOR OUTPUT socket. Phones jack; (1/4 in two pole) the internal loudspeaker is disconnected when a plug is inserted.

5. CARRIER LEVEL control. Used in conjunction with 7. sets the carrier to calibrated level indicated by 6. Permits fine adjustment of carrier level for interpolation between attenuator steps.

6. CARRIER LEVEL meter. With the meter pointer at 1 V (0 dB) mark, the attenuator dials are direct reading in dB above 1 μV or voltage across a 50 Ω load. With the pointer at 2 V double the attenuator voltage reading or add 6 dB.

7. 1 V/2 V switch. In the 2 V position the output level is doubled. In this position amplitude modulation is not possible.

8. MODULATION meter. Scaled in percentage AM depth and in kHz for f. m. deviation. Ranges 0-1.5 kHz: 0-5 kHz: 0-100% a. m. depth.

9. MODULATION LEVEL control. Adjusts modulation level of either internal or external f. m. or a. m. modulation signals.

10. MODULATION OSCILLATOR range switch. Selects internal modulation frequency range.

11. MODULATION FREQUENCY control and scale. Continuously variable internal modulation frequency control.

12. EXTERNAL AM and LEVFLLING terminal. Inlet for external amplitude modulating signals. AC coupled for EXT AM and DC coupled for EXT levelling functions. With FUNCTION switch at 'EXT LEVELLING' position, a potential appears at the terminal and carrier level may be varied by d. c. from a remote source.

13. EXTERNAL FM and Δ f terminal. AC coupled for EXT FM and DC coupled in EXT Δf functions. A standing potential is present on the terminal when function switch is at EXT Δ f.

14. CARRIER switch. Switches carrier signal on or off. For interuptions of the carrier. Operates in any position of the FUNCTION switch.

15. MODULATION switch. Switches internal modulation oscillator on or off.

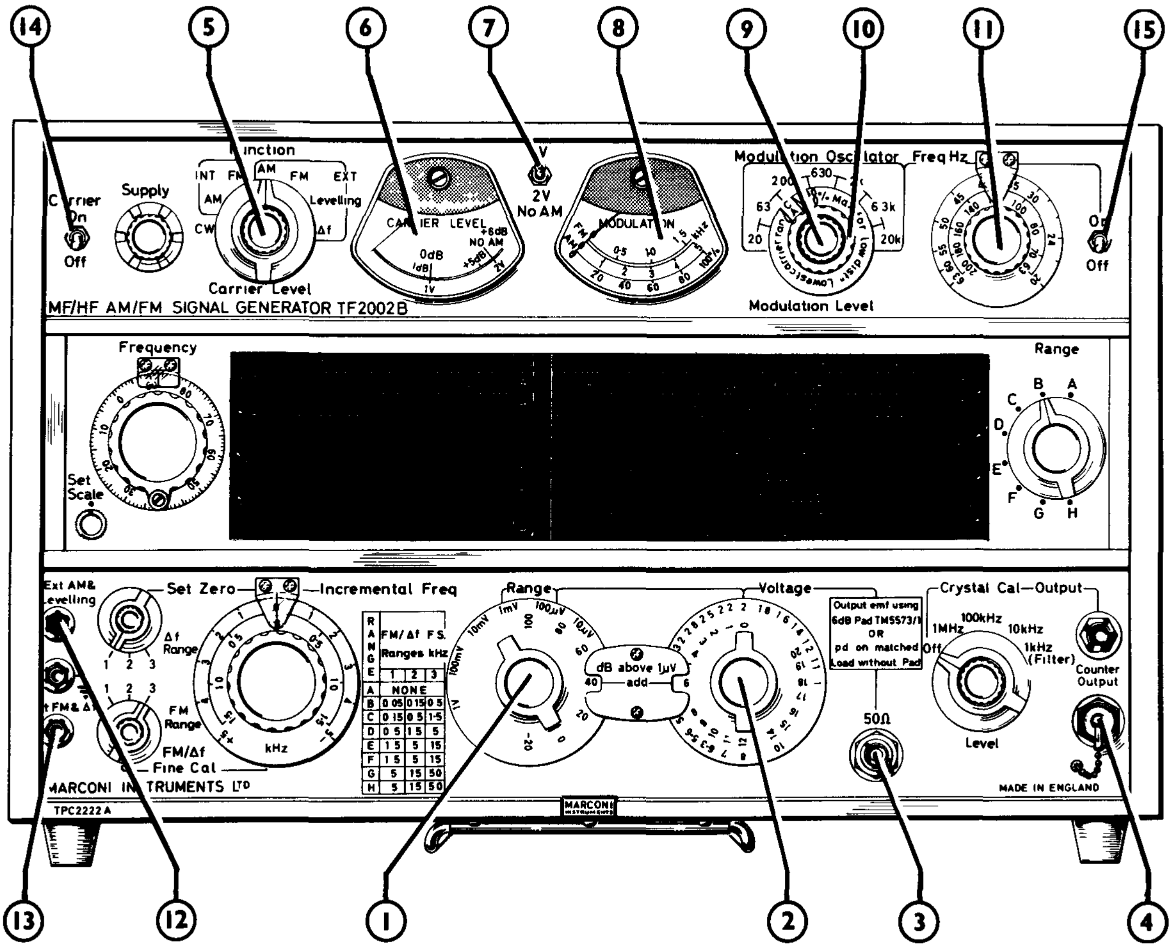


Fig. 2.2 Controls—modulation and output

2.8 REAR PANEL CONNECTORS

1. Δ f/LEVELLING NEUTRAL terminal. A very low impedance -6.75 V potential is available at this terminal. The two terminals EXT AM/LEVELLING and EXT FM/ Δ f on the front panel also carry a -6.75 V potential when the FUNCTION switch is in the appropriate position. Therefore, if it is required to use either of these functions such that the -6.75 V potential does not appear across the drive source and does not shift the mean carrier level or frequency, the external source can be connected between the appropriate front panel terminal and this terminal.

2. MODULATION OSCILLATOR OUTPUT. For triggering an oscilloscope when viewing modulated waveforms or for a.f. testing. 600 Ω source impedance.

3. INPUT FROM TF 2170 or TF 2170B. BNC connector which accepts the output from Digital Synchronizer TF 2170 series.

4. MAINS VOLTAGE SELECTOR. Enables instrument to be set to suit local supply.

5. MAINS INPUT connector. 3 pin - third pin connected directly to chassis.

6. BATTERY terminals. For d.c. operation during mobile use.

7. AC fuses. 160 mA time-lag.

8. DC fuse. 500 mA time-lag.

9. Clips for 6 dB pad.

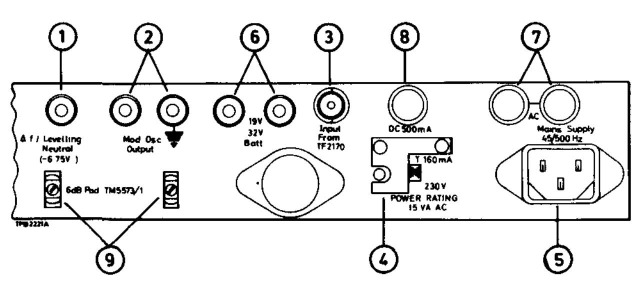


Fig. 2.3 Controls at the rear of the instrument

2.9 SETTING THE CARRIER FREQUENCY using the crystal calibrator

Position the SUPPLY and CARRIER switches at ON and the FUNCTION switch at CW then allow a period of not less than 10 minutes for the instrument to stabilize.

Using the range switch, select the range that includes the required carrier frequency. The ranges are as given in table 2.1.

Table 2.1

A	10 - 32 kHz	E	1 - 3.2 MHz
B	32 - 100 kHz	F	3.2 - 10 MHz
C	100 - 320 kHz	G	10 - 32 MHz
D	320 - 1000 kHz	H	32 - 88 MHz

Using the crystal calibrator

Marker points at 1 MHz, 100 kHz or 10 kHz intervals can be chosen by the CRYSTAL CALIBRATOR selector switch. The last position of the switch gives markers at 10 kHz and connects into circuit a 1 kHz rejection filter that gives a null 1 kHz either side of each 10 kHz point.

A loudspeaker is fitted to detect the crystal calibrator markers, but if greater sensitivity is desired, plug a pair of headphones into the CRYSTAL CALIBRATOR OUTPUT socket. Headphones with an impedance in the range 50 Ω to 50 kΩ are suitable. Switch the calibrator on by setting the CRYSTAL CALIBRATOR selector switch to a position that gives markers at convenient intervals. To avoid ambiguity due to the limitation of the main frequency scale use the initial settings shown in Table 2.2.

Table 2.2

Frequency range	Crystal calibrator selector setting
A	10 kHz
B	10 kHz
C	10 kHz
D	100 kHz
E	100 kHz
F	1 MHz
G	1 MHz
H	1 MHz

Tune the signal generator approximately to the marker frequency nearest to the desired carrier frequency and adjust the main FREQUENCY control for zero beat. Bring the beat note amplitude to a convenient level with the CRYSTAL CALIBRATOR LEVEL control (red knob).

If it is desired to standardize the scale, turn the SET SCALE control to position the scale point corresponding to the crystal marker, coincident with the cursor.

By switching the CRYSTAL CALIBRATOR selector switch in turn to the 100 kHz and 10 kHz marker intervals, advancing the main FREQUENCY control and counting the marker pips as they are heard, it is possible to set the frequency of the signal generator to any 10 kHz point.

Example 1: To tune the signal generator to a frequency of 4. 23 MHz.

Set the incremental tuning control at 0. Switch to RANGE F (3. 2 - 10 MHz) then using the main FREQUENCY control, set the cursor at 4 MHz on the main tuning scale. Plug in headphones and set the CRYSTAL CALIBRATOR selector at 1 MHz. Slightly adjust the main FREQUENCY control until a marker is heard. Set the CRYSTAL CALIBRATOR selector to 100 kHz and advance the main FREQUENCY control past the 4. 0 MHz marker, then past the 4. 1 MHz marker and stop at the 4. 2 MHz marker. Reset the CRYSTAL CALIBRATOR selector to 10 kHz and advance the main FREQUENCY control past the first two 10 kHz markers (4. 21 and 4. 22 MHz) and stop at the zero beat point of the third.

Incremental tuning

Electrical fine tuning is obtained by adjusting the INCREMENTAL FREQUENCY control. This has a centre zero scale and the facility is provided to enable carrier frequency shifts of less than ±1% to be made for accurate bandwidth and other measurements.

Three ranges of Δ f are available for each carrier range B to H and the full-scale frequency shifts available for the various ranges are given in the table on the front panel of the instrument.

The sensitivity, i. e. the frequency shift (± from centre zero) produced by the incremental tuning is substantially the same for any carrier frequency in any one range and with the FM/ Δ f FINE CAL control centrally positioned, the incremental scale calibrations will be accurate to within ±15% but, accuracies of ±5% are obtainable at any particular carrier frequency by following the standardizing procedure given below.

1. Set the INCREMENTAL scale at zero and the Δ f RANGE switch as required.

2. Using the internal crystal calibrator adjust the carrier frequency to produce a convenient beat note close to the required carrier frequency, e. g. 10. 700 MHz, using both the main carrier FREQUENCY control and the SET ZERO control.

3. Adjust the INCREMENTAL scale to a frequency close to the frequency shift required at which the next crystal marker is available, e. g. 10. 710 MHz.

4. Adjust the FM/ Δ f FINE CAL control to obtain a crystal beat which corresponds with the INCREMENTAL scale setting. The incremental tuning is now adjusted very accurately between the calibration points and to 5% accuracy or better elsewhere on that Δ f range.

Subsequent small changes in carrier frequency do not significantly affect the accuracy.

Always use a calibration point close to required frequency shift, e. g. 20 kHz on the 50 kHz Δ f range.

For low deviation ranges such as the ±0. 5 kHz range it is necessary to calibrate the range higher, i. e. 1. 5 kHz and then switch down. Alternatively it is possible to calibrate the interval between +0. 5 kHz and -0. 5 kHz against the 1 kHz calibrator points by careful adjustment of the FM/ Δ f FINE CAL control. The ±5 kHz range can also be calibrated in a similar way against the 10 kHz markers.

Calibrating the incremental scale simultaneously improves the accuracy of the f. m. deviation.

External frequency shift

The EXTERNAL FM/ Δ f terminal enables frequency shifts to be remotely controlled or alternatively it can be used as the input for phase locking signals. There is a potential of -6. 75 V between the terminal and earth, and the source impedance is 100 kΩ (nominal) and the sense of operation is such that an increase of this potential in the negative direction increases the carrier frequency.

The limits of frequency shift that can be employed depend on the amount of non-linearity that is acceptable. In general, at the low frequency ends of the carrier ranges the maximum usable excursions are defined by the Table 2.3 (front panel table). At the high frequency end of the ranges, the maximum usable excursions are approximately three times greater.

Ranges C and D can accept increased drive enabling greater frequency excursions than shown in Table 2.3. Range C allows a 5 kHz total swing and Range D a 30 kHz total swing at the low end of the band, whilst at the high frequency end of the bands, three times these figures can be expected.

Table 2.3

Range	FM and Δ f scale ranges (kHz)		
	1	2	3
A	-	-	-
B	0.05	0.15	0.5
C	0.15	0.5	1.5
D	0.5	1.5	5
E	1.5	5.0	15
F	1.5	5.0	15
G	5.0	15	50
H	5.0	15	50

The voltage at the EXTERNAL FM/ Δ f terminal should not fall outside the limits of -2 V and -11.5 V if severe non-linearity is to be avoided.

The EXT Δ f setting of the FUNCTION switch also provides simultaneous internal a.m. The modulation depth can be monitored and adjusted by temporarily setting the FUNCTION switch to the INT AM position.

If a c.w. external Δ f function is required, the MODULATION LEVEL control must be fully counter-clockwise.

Frequency shift using Digital Synchronizer TF 2170B

Very small (increments of 10 Hz) accurate and stable frequency shifts can be obtained when TF 2002B is used with TF 2170B.

This instrument which has been designed for use with other signal generators in the TF 2002 series, is constructed to fit on top of the generator such that the combination appears as a single instrument.

Only two interconnections are required and the signal generator can, if desired, be used independently by operating a switch located on the panel of TF 2170B.

Logging scale

For incremental shifts on range A or to obtain wider frequency shifts than are provided by the electrical fine tuning circuits on the other ranges, the logging scale can be used.

The 0 - 100 scale around the main FREQUENCY control relates to the top scale on the main tuning dial and this allows each frequency range to be divided into nearly 1000 divisions.

Calibrate the logging scale over a convenient number of divisions corresponding to a frequency change of 10% or less, using the crystal calibrator. Although the frequency scale has a logarithmic type law, linear interpolation of the logging scale can be used for a first approximation.

2.10 AMPLITUDE MODULATION

Internal a.m.

For amplitude modulation using the internal a.f. oscillator proceed as follows :

1. Set the FUNCTION switch to INT AM.

2. Set the 1 V/2 V switch to 1 V.

3. Set the MODULATION OSCILLATOR switch to ON.

4. Set the MODULATION OSCILLATOR switch to the frequency range that includes the required modulating frequency.

5. Set the MODULATION FREQUENCY control to provide the required frequency.

6. Advance the MODULATION LEVEL control (red knob) until the MODULATION METER shows the desired percentage depth. The maximum depth for low distortion modulation is limited when the modulation frequency exceeds certain percentage of the carrier frequencies. Table 1.2 gives the maximum modulating frequencies for 5% distortion at 80% modulation depth.

When the function switch is in the INT AM, INT FM or EXT Δ f positions the modulation frequencies 20 Hz to 20 kHz are available at the MODULATION OSCILLATOR OUTPUT terminals. This output which is independent of the setting of the MOD OSC ON/OFF switch, can be used to check the response of a.f. amplifiers or to trigger an oscilloscope at the modulation frequency.

The output level is 0.7 V r.m.s. (nominal) into 600 Ω and the source impedance is approximately 600 Ω.

External a.m. (a.c. coupled)

1. Set the FUNCTION switch at EXT AM.

2. Set 1 V/2 V switch to 1 V.

3. Apply the external modulating signal between the EXT AM/LEVELLING terminal and earth.

4. Set the MODULATION LEVEL control in conjunction with modulation meter to provide the required modulation depth.

NOTE. Since the modulation meter is a peak detector, non-sinusoidal modulating signals may be used without introducing over-modulation. The input required is approximately 1.2 V r.m.s. into 1 kΩ minimum for a nominal modulation depth of 100%.

For high modulating frequencies the modulation depth limitations given above for internal modulation, must be observed.

External levelling (direct coupled)

For low audio-frequency modulation with very low phase shift, or sub-audio modulation, direct coupling to the modulating circuit can be made through the EXT AM/LEVELLING terminal in the EXT LEVELLING function.

With the FUNCTION selector at EXT LEVELLING, a standing potential of -6.75 V is present between this terminal and earth. To avoid developing this voltage across any drive source, connection can be made between EXT AM LEVELLING and the -6.75 V neutral terminal, (Δf/LEVELLING NEUTRAL), located at the rear of the instrument. However, it should be mentioned that using these connections necessitates the use of a balanced and floating input.

The carrier amplitude can be controlled by using any one of the three methods given below :

1) An adjustable shunt resistor connected as shown in Fig. 2.4 can be used to raise the carrier level.

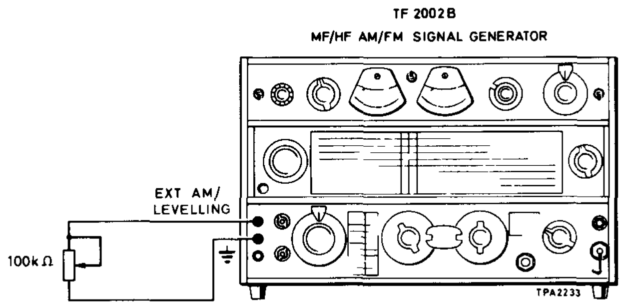


Fig. 2.4 External passive amplitude control circuit

2) By applying a direct or alternating potential from a high impedance source. The sensitivity is such that approximately -12 V will reduce the carrier to zero and 0 V will produce maximum available output. Fig. 2.5 shows the connections using an external d.c. supply.

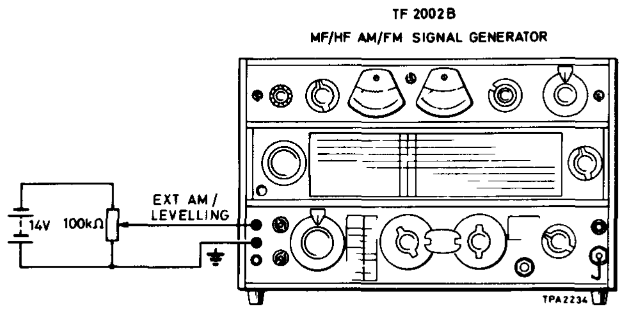


Fig. 2.5 External amplitude control circuit

3) By applying a two-terminal floating, direct or alternating potential between EXT AM LEVELLING terminal and the Δf/LEVELLING NEUTRAL terminal at the rear of the instrument. Fig. 2.6 shows a balanced d.c. source but an a.c. input can be used as an alternative to the circuit enclosed in the dotted area.

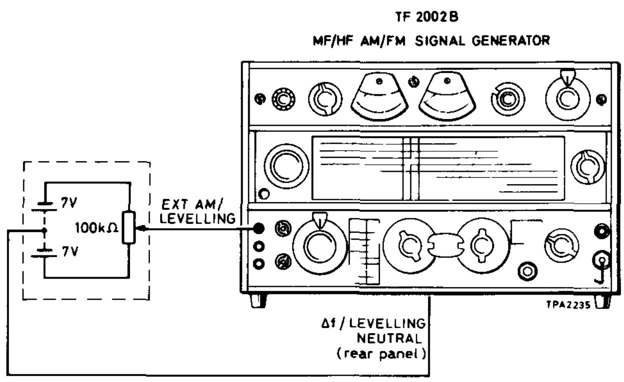


Fig. 2.6 External balanced drive source

The MODULATION LEVEL control is not operative when the FUNCTION switch is at EXT LEVELLING but the CARRIER LEVEL meter remains functional.

2.11 FREQUENCY MODULATION

Frequency modulation is possible only on carrier frequencies above 100 kHz. Modulation frequencies up to 20 kHz can be applied to carrier frequencies above 1 MHz: for carrier frequencies between 100 kHz and 1 MHz, 4 kHz is the maximum to maintain the specified accuracy. Frequency shifts may be applied together with frequency modulation but care is necessary to avoid over modulation. At the low frequency end of each carrier range the sum of the shift frequency and the peak f. m. deviation must not exceed the limits given in the table on the front panel - see Section 1.2, f.m. modulation (deviation).

To obtain frequency modulation using the internal oscillator :

1. Set the MODULATION OSCILLATOR to ON.

2. Set the FUNCTION switch to INT FM.

3. Set the MODULATION OSCILLATOR switch to the position corresponding to the frequency range that includes the required modulating frequency.

4. Set the MODULATION FREQUENCY control to provide the required frequency.

5. Select suitable FM RANGE switch setting from table on front panel.

6. Advance the MODULATION LEVEL control (red knob) until the MODULATION meter shows the required deviation.

The unstandardized accuracy of the f. m. is 15% (with the FM/ Δ f FINE CAL control central) and 6% when the INCREMENTAL fine tuning dial has been calibrated against the internal crystal calibrator.

When Δ f standardizing procedure has been performed for any one carrier frequency, the f. m. accuracy is simultaneously standardized.

The f. m. meter scale can be expanded in positions 2 and 1, of the FM RANGE switch where the improved accuracy is maintained.

External frequency modulation (a.c. coupled)

1. Set FUNCTION switch to EXT FM.

2. Apply a. c. modulating signal between EXT FM/ Δ f terminal and EARTH terminal.

3. Set MODULATION LEVEL control and FM RANGE switch to give required deviation (indicated on the MODULATION meter). The input required is approximately 1. 2 V r. m. s. into 2. 0 kΩ minimum for full-scale deflection on meter.

Since the MODULATION meter is a peak detector, non-sinusoidal modulating signals may be used without introducing a reading error.

The maximum deviation available is detailed in Table 2. 3. Provided the incremental fine tuning system has been standardized at a particular carrier frequency, the f. m. monitor circuit will be within 6% for external signals.

A factory modification is available which increases the maximum f. m. modulating frequency limit from 20 kHz to approximately 200 kHz. This permits pulse f. m. up to 20 kbit rates without serious distortion.

The leakage performance of the generator is, however, slightly degraded.

External Δf (d.c. coupled)

This input is used for low modulating frequencies, f. m., external frequency shift, manual or automatic frequency control, phase modulation or frequency sweeping, by direct coupling to the modulation circuit.

When the FUNCTION switch is set at EXT Δ f a standing -6. 75 V potential appears on the EXT FM/ Δ f terminal. To avoid applying this direct voltage to any drive source, and possible change in mean carrier frequency, connection may be made between the EXT FM/ Δ f terminal and the -6. 75 V neutral terminal, (marked Δ f/LEVELLING NEUTRAL), located at the rear of the instrument.

The tracking network normally used to correctly maintain the Δ f and f. m. deviation sensitivities over each carrier range, is bypassed when FUNCTION switch is at EXT Δ f. With this condition, the maximum possible frequency shift is obtained but the deviations are then neither monitored nor constant.

Sensitivity at the high frequency end of each range is generally three times greater than at the low frequency end.

The following three diagrams show methods for controlling the carrier frequency.

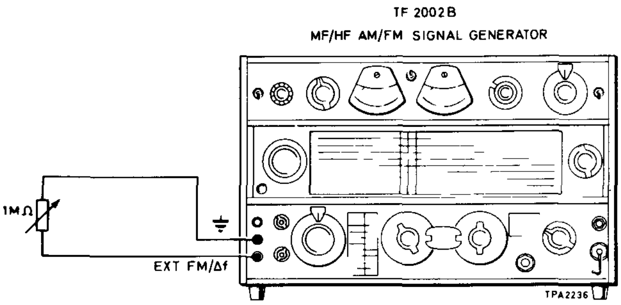


Fig. 2.7 Passive external frequency control

This circuit can be used only for downward changes in frequency.

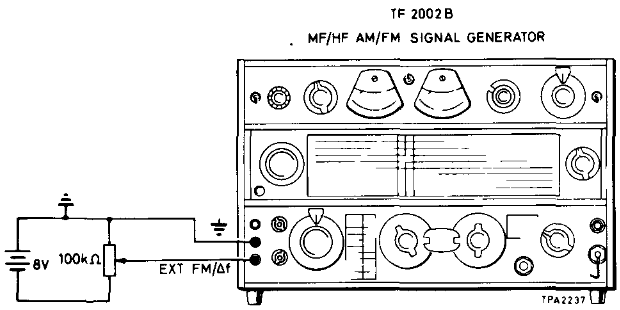


Fig. 2.8 External unbalanced drive source

This circuit can be used for positive or negative increments of the carrier frequency.

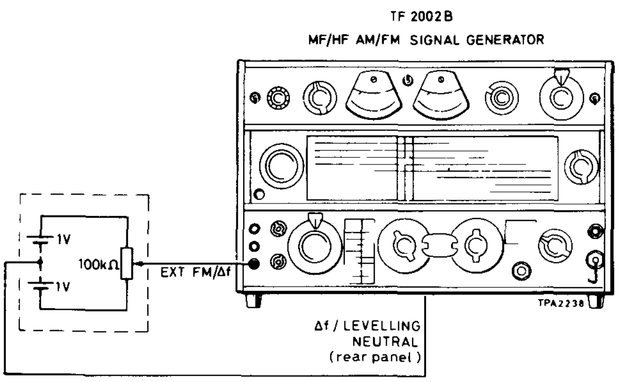


Fig. 2.9 External balanced drive source

This circuit can also be used for increases or decreases of incremental frequency; frequency shift is proportional to the voltage input, e.g. with 0 V input no frequency shift occurs.

An alternating voltage source can be used instead of the d.c. circuit enclosed in the dotted area.

Synchronizer input

The TF 2170 series Digital Synchronizer input on the rear panel may be used for frequency control or other applications if required. The input parameters are listed in Section 1.2.

Note that the standing voltage on this socket is -6.75 V and may be used with external circuits in conjunction with the Δ f/LEVELLING NEUTRAL (-6.75 V) if required.

2.12 SETTING OUTPUT

(1) Set the 1 V/2 V switch at 1 V, set the CARRIER switch at ON and adjust the CARRIER LEVEL control to position the pointer of the CARRIER LEVEL meter at 1 V (0 dB).

NOTE. Adjustment of the carrier level does not affect the modulation depth.

(2) Set the coarse and fine attenuator controls to obtain the required output. The attenuator settings indicate the signal level across a matched 50 Ω load or alternatively are direct reading in terms of source e.m.f. when the output is connected through the 6 dB pad TM 5573/1 which is stored at the rear of the instrument.

When higher output is required in the c.w. or f.m. modes the 1 V/2 V switch is set at the higher position, the attenuator reading must then be multiplied by two.

Expressed in dB referred to 1 μV

With the 1 V/2 V switch at 1 V and with the pointer of the CARRIER LEVEL meter at 1 V (0 dB) the signal level across 50 Ω referred to 1 μV can be ascertained by adding the dB figures displayed by the attenuator and by the meter: e.g. coarse attenuator reads 50, fine attenuator reads 17, meter reads -1, therefore, output level = 66 dB above 1 μV across a 50 Ω load.

The coarse attenuator allows output adjustments of 0 to 120 dB in steps of 20 dB and the fine attenuator can be adjusted from 0 to 20 dB in steps of 1 dB. Intermediate fine adjustments of less than 1 dB can be obtained by varying the setting of the CARRIER LEVEL control.

Frequency modulated or c.w. outputs up to 126 dB above 1 μV into 50 Ω can be obtained when the 1 V/2 V switch is set at 2 V (this is indicated on the meter).

Under these conditions the output level is still the sum of the attenuator and meter readings, e.g. coarse attenuator reads 100, fine attenuator reads 10 and the meter reads +5 say. This gives an output level of 115 dB above 1 μV across a 50 Ω load.

Expressed in volts

With the CARRIER LEVEL meter at 1 V the voltage applied across a 50 Ω load is indicated on the fine attenuator dial within the decade shown on the coarse attenuator dial. If the CARRIER LEVEL meter is at 2 V the output is twice that indicated by the attenuator voltage scales.

Counter output

For applications such as operating a frequency counter, or driving the digital synchronizer, a separate 50 Ω output is provided. This output is unmodulated and the level which is greater than 100 mV into 50 Ω remains within approximately ±2 dB over the entire frequency range.

2.13 MISMATCHED LOADS

The r.f. output circuit of the signal generator can be regarded as a zero impedance voltage source in series with a resistance of 50 Ω. This is shown in Fig. 2.10 where :

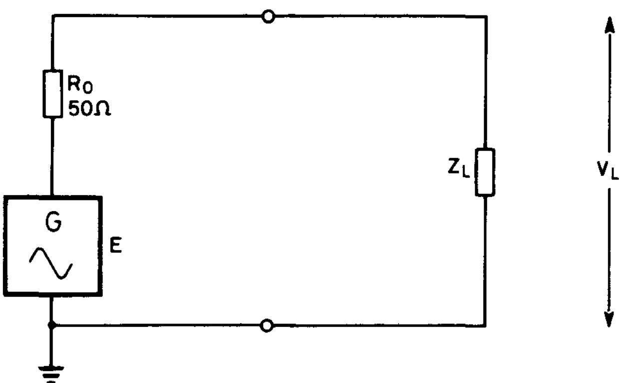


Fig. 2.10 Equivalent output circuit TPA2223

E is the indicated source e.m.f.

R_o is the source resistance

Z_L is the external load impedance

V_L the voltage developed across the load is given by

$$V_L = E \frac{Z_L}{R_o + Z_L}$$

or, for purely resistive loads

$$V_L = E \frac{R_L}{R_o + R_L}$$

Table 2.4 shows the conversion factors for obtaining the load voltage from the indicated e.m.f. at different load impedances.

Table 2.4

To find load voltage :

Load ohms	Multiply e.m.f. by	or subtract dB
10	0.167	15.5
20	0.286	10.9
30	0.375	8.5
40	0.445	7.0
50	0.50	6.0
60	0.55	5.2
70	0.58	4.7
75	0.60	4.4
80	0.62	4.2
90	0.64	3.8
100	0.67	3.5
120	0.71	3.0
150	0.75	2.5
200	0.80	1.9
300	0.86	1.3
500	0.91	0.8
600	0.92	0.7
800	0.94	0.5
1000	0.95	0.4
2000	0.98	0.2
4000	0.99	0.1

When using a correctly matched, i.e. 50 Ω, coaxial output cable its output end can be regarded as an extension to the output socket on the generator, and wide variations of load impedance do not seriously affect the calculated load voltage obtained from Table 2.4. Standing waves produced by the mismatched load can, for most purposes, at lower frequencies be ignored. However, at the higher frequencies where cable lengths can become a significant fraction of a wavelength, extreme mismatches should be avoided as described in the following paragraphs.

For greatest accuracy - if the additional attenuation can be tolerated - use a 20 dB attenuator pad such as Marconi Instruments type TM 5573 between seriously mismatched loads and the output cable. This ensures that the cable is correctly terminated, and also attenuates any extraneous noise.

Matching to high impedance loads

To match a load that is greater than 50 Ω to the output of TF 2002B a resistor R_s is required to be added in series with the generator output as Fig. 2.11. The value of R_s is given by the difference between the load and the generator impedances, i.e.

$$R_s = R_L - R_o$$

in which case the voltage across the load V_L is given by

$$V_L = \frac{E}{2}$$

For the special case of a 75 Ω load, matching pads Marconi Instruments type TM 5569 or TM 6599, are available as accessories and consist basically of a 25 Ω resistor with coaxial connectors for insertion in series with the output lead.

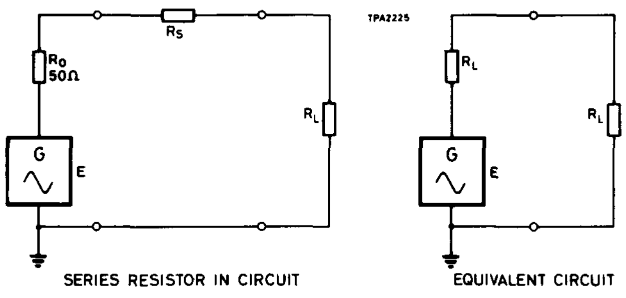


Fig. 2.11 Matching to high impedance loads

Matching to low impedance loads

To match a load that is less than 50 Ω to the output of TF 2002B a resistor R_p is required to be added in parallel with the generator output as Fig. 2.12. The value of R_p is given by

$$R_p = \frac{R_o \quad R_L}{R_o - R_L}$$

The effective source e.m.f. is now different and is given by

$$E_1 = \frac{R_p}{R_o + R_p} \times E$$

and the voltage across the load V_L is then given by

$$V_L = \frac{E_1}{2}$$

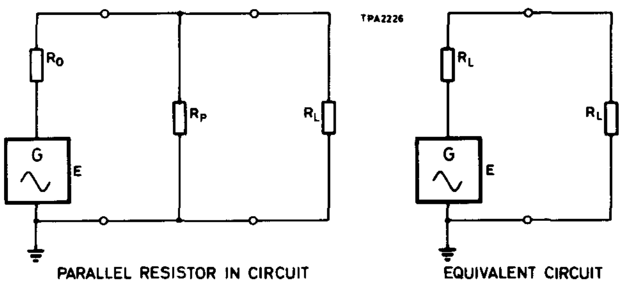


Fig. 2.12 Matching to low impedance loads

If the signal generator is likely to be used regularly with a receiver of different impedance, it is preferable to construct a proper matching pad to provide a voltage reduction of some convenient ratio. This is usually satisfied by a T network as shown in Fig. 2.13.

Providing the attenuation is sufficient to accommodate the change of impedance, a pad of this type can be designed to give a true match; i.e. not only is the output resistance of the pad equal to the required source resistance, but also its input resistance, when correctly terminated, is equal to the R_o of the signal generator. The values of the resistive elements of such pads can be calculated from the following expressions in which

$$N = E_{in}/E_{out} \text{ and } F = R_{in}/R_{out}$$

$$R_3 = \frac{2N}{N^2 - F} \times R_{in}$$

$$R_2 = R_{out}\frac{(N^2 + F)}{(N^2 - F)} - R_3$$

$$R_1 = R_{in}\frac{(N^2 + F)}{(N^2 - F)} - R_3$$

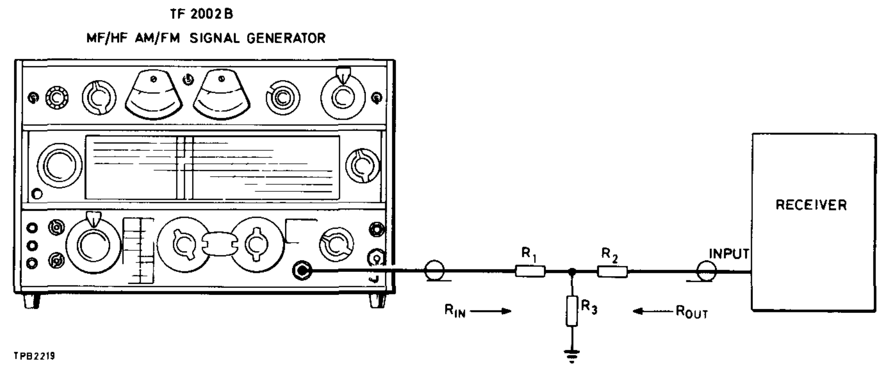


Fig. 2.13 Impedance matching network

Table 2.5 below, gives the values of R_1, R_2 and R_3 for the more commonly used impedance conversions.

Table 2.5

R_{in} Ω	R_{out} Ω	N V_{in} to V_{out}	R_1 Ω	R_2 Ω	R_3 Ω
50	75	$\sqrt{10}$ = 3.162:1	23.2	51.7	33.8
50	75	5:1	32.2	58.5	20.5
50	75	10:1	40.1	65.9	10.1
50	60	$\sqrt{10}$ = 3.162:1	24.5	36.4	34.4
50	60	5:1	30.4	41.0	20.3
50	60	10:1	40.4	50.4	10.1

A 50 Ω to 75 Ω matching pad (TM 5573/3) with a voltage ratio of 2:1 is supplied with the instrument.

Matching to balanced loads

Equipment with an input circuit in the form of a balanced winding can be energized from the generator by using two series resistors as shown in Fig. 2.14. This method makes use of the auto-transformer effect of the centre-tapped winding and is not suitable for resistive balanced loads.

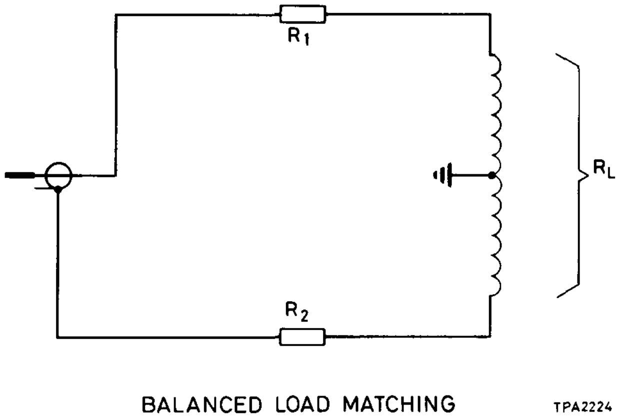


Fig. 2.14 Matching to balanced loads

The values of R_1 (high level) and R_2 (low level/earth) are given by

$$R_1 = \frac{R_L}{2} - 50$$

$$R_2 = \frac{R_L}{2}$$

For use with circuits that have a balanced impedance of 300 Ω a special matching unit is available as an accessory and can be ordered under the type number TM 5955/5. The unit incorporates a wide band transformer with a 4:1 impedance ratio and a resistive pad to give an overall ratio of 1:6. The voltage ratio is 1:0.5 +0.5.

2.14 USE OF DUMMY AERIAL AND DC ISOLATOR

To use the dual-purpose unit, Marconi Instruments TM 6123, Fig. 2.15, as a dummy aerial, connect EMF/10 and EARTH terminals to the receiver under test. The unit then simulates the impedance of an external aerial normally used for receivers operating in the l.f., m.f. and h.f. bands. When using the dummy aerial the voltage input to the receiver will be one tenth (20 dB down) of that indicated by the attenuators.

To use it as an isolator, connect the EMF/2 and EARTH terminals to the equipment under test. This allows the signal generator output to be connected to circuits having a standing d.c. potential up to 350 V. Used in this way, the output voltage is half that indicated by the attenuators.

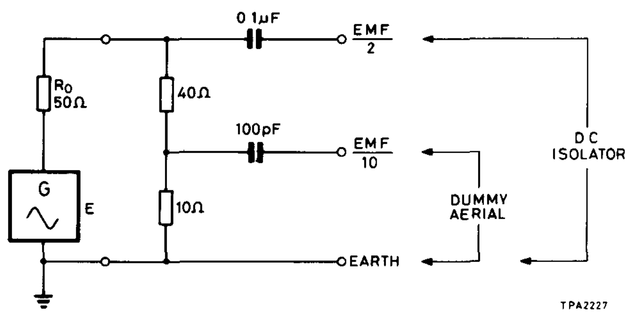


Fig. 2.15 Generator output using TM 6123

2.15 COUPLING TO LOOP AND FERRITE ROD AERIALS

Many receivers operating in the m. f. and h. f. bands are now fitted with internal ferrite rod aerials. Since such aerials normally form part of the input tuned circuit, it is not feasible to connect the signal generator to the receiver directly. The concept becomes rather different, for the signal generator can no longer simulate the aerial system as it does for receivers requiring external aerials. Instead, the operational conditions must be simulated by creating a field of known strength to ascertain the performance of the receiver.

The system recommended by the I. E. C. (publication 69) for use with receivers having frame aerials can also be applied for those with ferrite rod aerials. It utilizes a loop radiator connected to the signal generator in the arrangement shown in Fig. 2. 16.

A circular polarized wave is radiated in the direction coaxial with the loop. As the magnetic field of this wave is in the direction of propagation, it couples to the ferrite rod aerial when it is mounted coaxially with the loop radiator. A voltage is induced in the receiver aerial equal to that produced by an equivalent field strength, which can be calculated from the parameters of the loop radiator and the distance separating it from the receiver aerial.

The equivalent field strength for a frame aerial is given by the formula :

$$e = 188.5 \frac{N.A.^2.I}{D^3}$$

Where

e = equivalent mean field strength in volts per meter.

N = number of turns in loop radiator.

A = radius of radiator coil in metres.

D = distance in metres between the centre of the loop radiator and the periphery of the frame aerial.

I = current in the loop radiator in amperes.

The meaning of distance D is slightly different when applied to a ferrite rod aerial because of the difference in dimensions. The frame aerial is virtually in one plane but is of large diameter, whereas the ferrite rod is of negligible diameter but has an appreciable aerial dimension. The distance D, therefore, must be the distance between the centre of the loop radiator and the mid-point of the ferrite rod.

When the loop radiator is used with a frame aerial, it is necessary to fit the loop into a tubular screen to prevent direct electrostatic coupling. However, the dimensions of the ferrite rod are so small that providing it is mounted truly coaxially with the loop radiator, the direct electrostatic field virtually cancels itself out and screening is not very necessary.

The loop recommended by the I. E. C. comprises three turns of solid copper wire -20 swg - formed into a coil 25 cm in diameter. This loop has low impedance over the frequency range covered by ferrite rod aerials. A series resistor, R_S, whose value is high compared with the impedance of the loop, is connected in series with the signal generator as shown in Fig. 2. 16. The current in the loop is then equal to $E(R_0 + R_S)$, assuming that the inductive impedance of the loop is negligible.

To avoid the necessity for tedious calculation a value for R_s is chosen so that the equivalent field strength in volts/metre is a tenth of the signal generator e. m. f. in volts at a convenient value of D.

The recommended value of D is 60 cm, and this requires a value of 403 Ω for $R_o + R_s$.

For frame aerials the electrostatic screen recommended by the I. E. C. consists of a copper tube 10 to 12 mm in diameter. This tube is bent into the form of a circle having a mean diameter of 25 cm. It is prevented from acting as a shorted turn by connecting one end only to earth and insulating the other end.

Measurements of sensitivity and similar measurements involving low level operation, must be made in a screened room to prevent the receiver picking up unwanted signals. It is also most important that the stray field radiated by the signal generator is very small; otherwise errors of measurement will be introduced. Since radiation from TF 2002B is negligible, radiation errors are much too small to be considered in the measurement.

WARNING

When applying TF 2002B to the testing of transceivers it is recommended that RF FUSE UNIT TM 9884 (optional accessory) be used to ensure protection of the resistors in the attenuator units in case of accidental switching to the transmit mode.

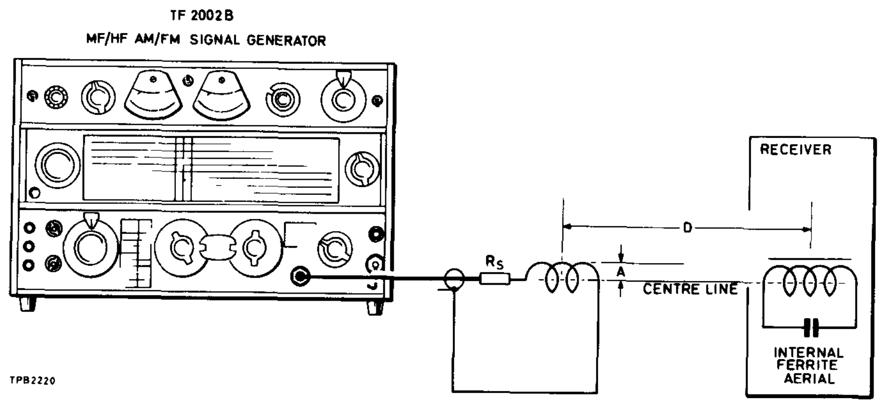


Fig. 2.16 Coupling to a receiver with ferrite-rod aerial

2.16 TYPICAL APPLICATIONS

Applications contained in the sections which follow are given as a guide to the versatility of Signal Generator TF 2002B. Many additional uses are possible and these soon become apparent to the user.

2.17 RECEIVER MEASUREMENTS

Measurement of receiver sensitivity

The sensitivity of a receiver is its ability to receive weak signals. To express this ability in numerical terms we can define the sensitivity as the smallest r.f. input signal necessary to produce an acceptable demodulated output.

To measure the overall sensitivity, TF 2002B is coupled to the receiver input by the appropriate method, i.e. through a suitable dummy aerial, or impedance correcting network, for a receiver requiring an external aerial, or a loop radiator for a receiver with an internal aerial.

The output from the receiver is measured using an a.f. absorption power meter connected to the final output terminals. This type of power meter is designed to load the a.f. amplifier with the correct impedance, so the normally connected loudspeaker is not required for tests.

For a receiver requiring an external aerial, the sensitivity is stated in terms of input e.m.f. for a given power output; e.g. 100 µV for 50 mW. For internal aerial receivers, it is stated in terms of field strength for a given output; e.g. 10 µV/metre for 50 mW.

Measuring ratio of signal + noise + distortion (SINAD)

When the a.f. output from a receiver is measured using a power meter, the meter will indicate a signal level which will include both noise and distortion and the ratio which is usually expressed in dB is determined by

$$\frac{S + N + D}{N + D}$$

The most common method of measuring the true signal level utilizes a signal generator to provide a modulated r.f. input to the receiver with a power meter connected through a band-stop filter to measure the a.f. output as shown in Fig. 2.17.

The power meter should be an instrument which indicates the true power (or r.m.s. voltage) otherwise the indicated power levels will not be correct. When a true power meter is not available an average reading voltmeter calibrated in r.m.s. for a sine wave can be employed. Using this type of meter the power measurement error is not very large (nominally +1.1 dB) and the accuracy is usually acceptable.

The measurement is made at the output of the receiver and the band-stop filter is at the frequency of the desired output signal (e.g. 1 kHz) so when it is switched into circuit, this signal is eliminated and the power meter shows the noise and distortion power only. With the filter switched out the whole of the output is applied to the power meter.

The $\frac{S + N + D}{N + D}$ ratio can be calculated from these two measured powers.

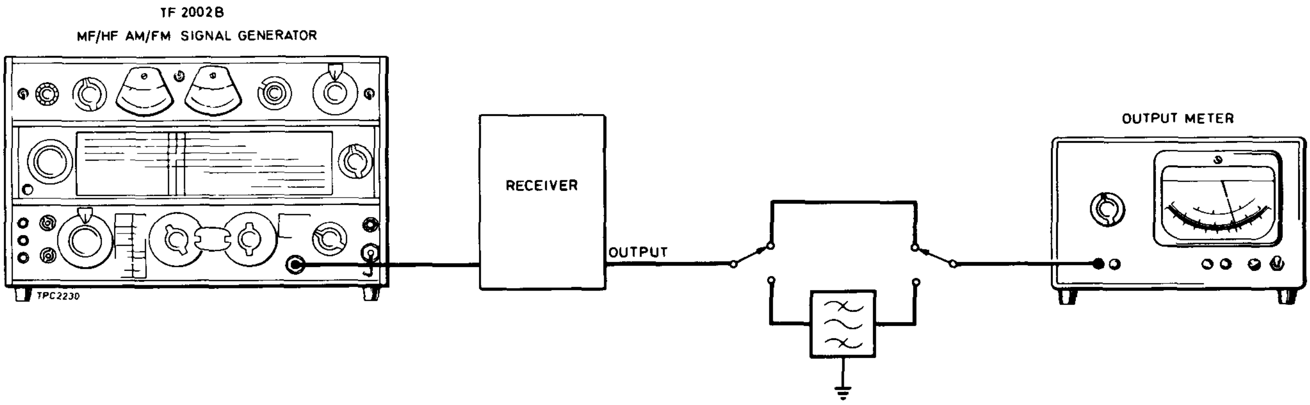


Fig. 2.17 Measurement of $\frac{S+N+D}{N+D}$ *(Sinad)*

The measurement can be simplified by using a Marconi Instruments Distortion Factor Meter, type TF 2331, instead of the filter and power meter. Use of this instrument overcomes the problems associated with using a filter, i.e. insertion loss and selectivity.

Manual measurement of automatic gain control (a.g.c.)

Measurement of the a.g.c. characteristic follows naturally after sensitivity and noise measurement; because the a.g.c. varies the sensitivity of the receiver to cope with the strength of the applied signal.

The arrangement of the test equipment is the same as for sensitivity measurements the standard procedure being as follows :

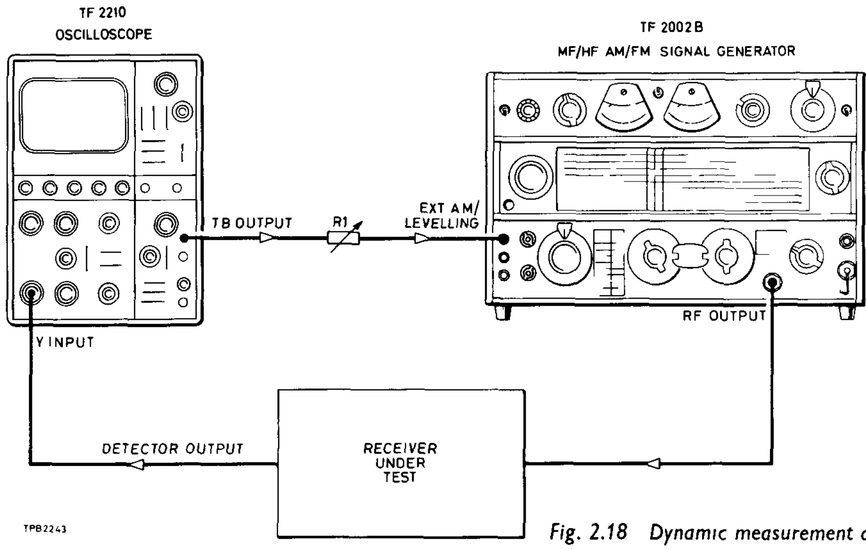
First, an r.f. (carrier) signal modulated at 400 Hz to a depth of 30% is applied to the input of the receiver and the carrier amplitude is adjusted to a typical signal level, such as 5 mV for an a.m. broadcast receiver. The manual a.f. gain control of the receiver is then set to give the standard test output as used for overall gain measurement - usually 50 mW.

With the receiver gain control left fixed, the carrier input level is varied from a level well below the a.g.c. threshold (i.e. the input level at which the a.g.c. begins to operate) up to the maximum input level. (IEC recommend 1 μV to 1 V).

The output power, as read from the output meter, is plotted as a curve showing receiver output as a function of r.f. input voltage. Both of these are expressed in decibels relative to the maximum.

Dynamic measurement of a.g.c.

A dynamic display of a.g.c. characteristics or limiting action can be obtained using TF 2002B as a sweep generator in conjunction with an oscilloscope, see Fig. 2.18 and Section 2.19.



The r.f. level can be varied from approximately 2 V to 0 V p.d. by sweeping the saw-tooth input voltage from -0.75 V to -12.75 V. The horizontal axis of the display then corresponds to the r.f. input voltage to the unit under test and the vertical axis to its audio output voltage.

Fig. 2.18 Dynamic measurement a.g.c. characteristics

The vertical calibration is the direct amplitude calibration of the oscilloscope. To calibrate the horizontal scale in terms of r. f. input voltage, the signal generator attenuator can be used in the following way.

With the attenuator set for a low level, the overall gain of the system is adjusted to produce a readable deflection at the 'high' end of the graticule. This deflection should be noted. The attenuator is then adjusted to increase the signal generator output by an amount equal to the required total sweep, and R1 is adjusted to produce the noted vertical deflection at the 'low' end of the graticule scale. It may be necessary to repeat this procedure several times to compensate for changes in mean level when R1 is adjusted.

Manual measurement of receiver bandwidth and overall response

Ideally, the acceptance band of a receiver should be only just wide enough to accommodate all the sidebands of the transmitted signal. For a. m. receivers, this means that the acceptance band should be just twice the maximum modulation frequency. If it is too narrow the high frequency components of the modulation will be lost and, if it is too wide, not only will the selectivity of the receiver be impaired, but, as the noise interference is directly proportional to bandwidth, the signal-to-noise ratio will also suffer.

A simple statement of the -3 dB bandwidth is meaningful as a measure of the range of modulation frequencies that a receiver will respond to but it does not give any indication of how well it will reject frequencies outside this bandwidth, nor does it show how the response varies over the acceptance band. To obtain a more comprehensive assessment of this aspect of receiver performance, it is better to plot a graph of the frequency response characteristic showing the output level (or gain) as a function of input frequency.

The test gear arrangement is shown in Fig. 2.19 and the procedure is described.

Bandwidth measurements on d.s.b. receivers

With an a. m. output from Signal Generator TF 2002B applied to the input of the receiver and with the a. f. output of the receiver connected to a suitable measuring instrument (preferably with a dB scale) tune the signal generator and the receiver to a reference (centre) frequency Fc and set the output of the receiver to give a datum level on the output meter e. g. 0 dB.

For bandwidth measurements on d. s. b. receivers adjust the incremental controls to a frequency Fc + Δ F to set the pointer of the output meter at -3 dB. Note this frequency then adjust the incremental controls to a frequency Fc - Δ F to again set the pointer at -3 dB, note this frequency. The bandwidth is ascertained by subtracting Fc - Δ F from Fc + Δ F - see Fig. 2.20.

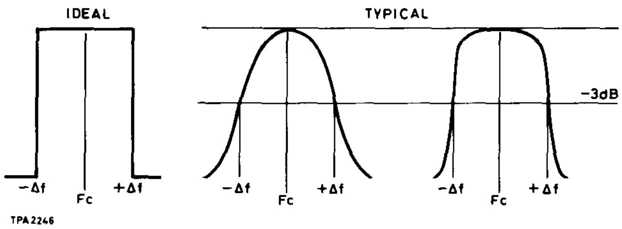


Fig. 2.20 Bandwidth measurements

For quick and accurate manual bandwidth measurement especially on highly selective receivers incorporating crystal filters, Digital Synchronizer TF 2170B can be used in conjunction with TF 2002B to provide very stable frequency shifts in steps of 10 Hz - see Section 2.20.

Overall selectivity of d. s. b. receivers

To ascertain the overall selectivity of a receiver, set up the signal generator, receiver and output meter as for bandwidth measurement, then adjust the incremental controls on TF 2002B to provide small frequency changes above and below Fc.

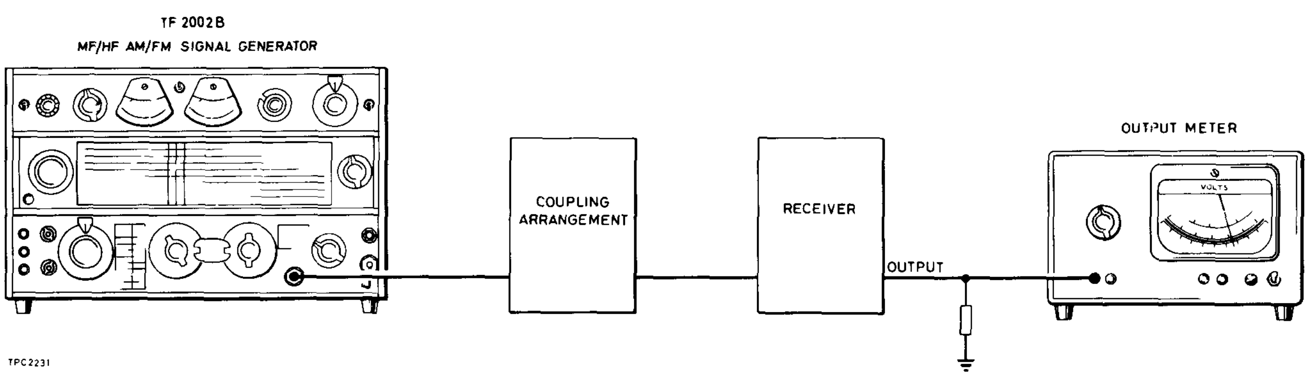


Fig. 2.19 Bandwidth and overall response measurements

Record the output meter readings for each frequency setting then use these to construct a selectivity curve. Two typical response curves are shown in Fig. 2.21.

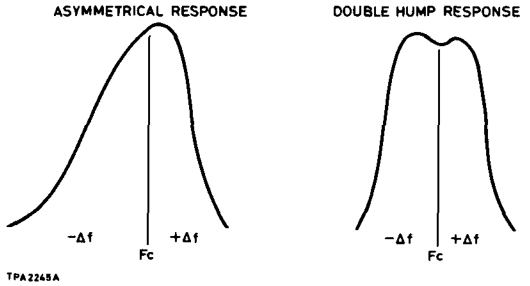


Fig. 2.21 Typical overall response curves

Dynamic measurement of receiver bandwidth or overall response

To determine the selectivity of a receiver using the method described is a tedious procedure and if adjustments are found to be necessary to modify the response it becomes a lengthy exercise calling for some expertise.

However, the selectivity characteristic of most receivers is more quickly and easily checked using a visual (dynamic) method which also offers advantage that results of any correcting adjustments can be immediately observed.

This can be done by using Signal Generator TF 2002B as a sweep generator in conjunction with an oscilloscope, see Section 2.18, to display the selectivity characteristic of the receiver.

The test equipment arrangement which can also be used for r.f. and i.f. alignment is shown in Fig. 2.22.

For the dynamic method of measuring the r.f. bandwidth of an a.m. receiver, an amplitude modulated signal is swept progressively through the pass band and the two frequencies where the a.f. output is 3 dB below the output at the centre frequency are noted. The bandwidth is then given by the difference between these two frequencies.

If, however, the overall resonance characteristic of the tuned amplifiers in the receiver are asymmetric or double-humped there is often difficulty in determining the centre frequency. For practical purposes, this can be accepted as being mid-way between points on the resonance curve which are, say, 14 dB below peak response, i.e. 20% of f.s.d. on linear display.

The TF 2002B is particularly suitable for this type of swept measurement because the full internal a.m. facilities are retained when the instrument is set for external sweep. To use the TF 2002B in this way you also need :

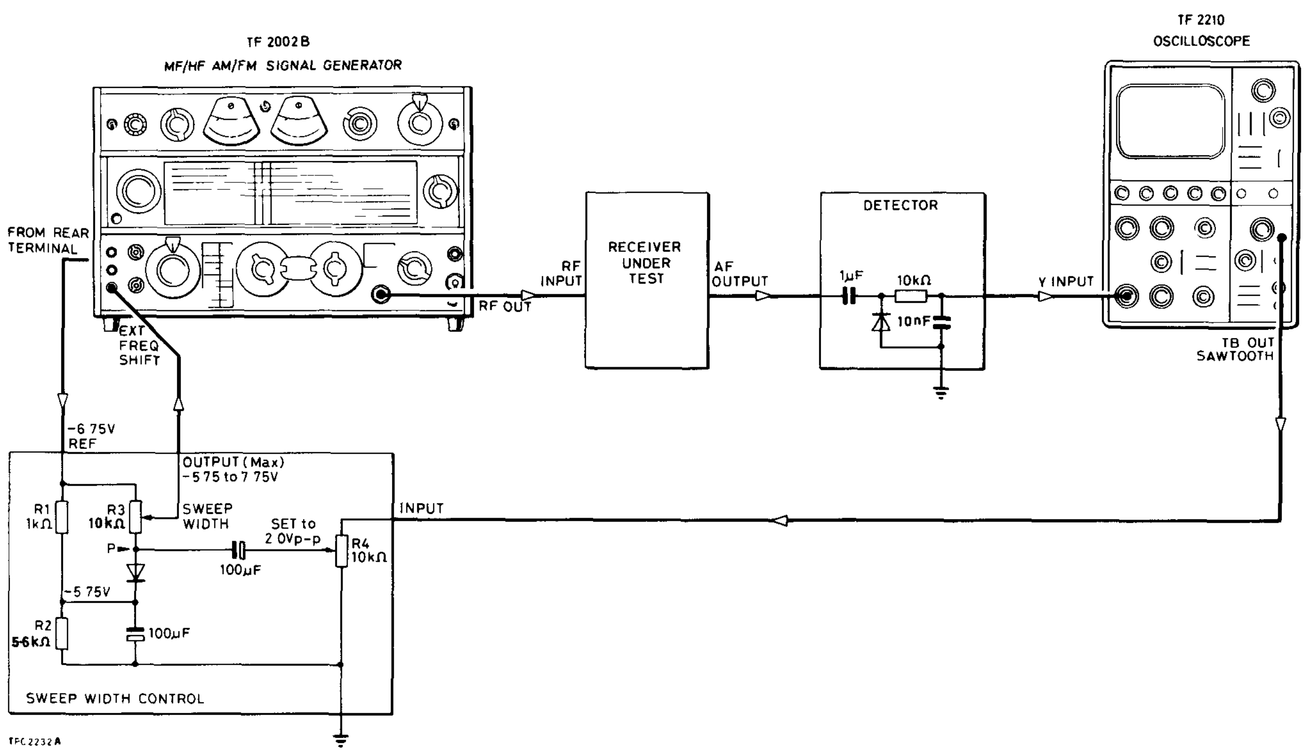


Fig. 2.22 Dynamic method for bandwidth and overall response

1) An oscilloscope with TB output facility (e.g. MI type TF 2210).

2) Audio frequency detector - see diagram.

3) Sweep width control to suit oscilloscope - see diagram.

The sweep width control unit shown in the diagram is suitable for use with most oscilloscopes at sweep speeds down to 10 ms/cm, i.e. 100 ms total sweep duration. Control R4 should be adjusted to give a saw-tooth amplitude of 2 V p-p at point P. The sweep width control, R3, then covers a total variation of sweep width from zero to the maximum available for the TF 2002B frequency range setting.

For bandwidth measurement, first set the function switch to INT AM and adjust the modulation controls to give 30% a.m. depth at 400 Hz. Then set the FUNCTION switch to EXT Δ f. Frequency sweep can then be applied.

To make the measurement, first centre the display using the main FREQUENCY control then adjust the sweep width so that the displayed response fills most of the screen. If the curve is asymmetric, readjust the frequency so that the 14 dB points on the curve (approximately 1/5th of total height from the base line) are spaced symmetrically about the middle of the screen which then indicates the centre frequency.

Note the level 3 dB below the centre frequency level and adjust the FREQUENCY controls to bring each side of the curve in turn to cross the centre line at the -3 dB level, noting the signal generator frequency at each point. The total frequency change is the r.f. bandwidth of the receiver.

Manual measurement of response characteristics of S.S.B. receivers

The response characteristic of an s.s.b. receiver can be measured very easily because the a.f. output is derived from the frequency difference between the input signal and the internally generated carrier. Furthermore, the a.f. amplifier normally forms part of the selective chain; so the response characteristic is usually taken using an r.f. input signal to produce the wanted sideband and an a.f. power meter to measure the receiver output.

The measurements should be made with the a.g.c. switched off - s.s.b. receivers are normally fitted with an a.g.c. on/off switch.

To plot the response characteristic, the signal generator frequency is first adjusted to simulate a sideband separated from the carrier frequency Fc by say, +1 kHz (for upper sideband).

This produces an a.f. output at 1 kHz. The receiver gain controls are then adjusted to produce a convenient deflection on the power output meter and this reading is taken as the reference output level.

Using the incremental control the frequency of the signal generator is then adjusted to provide in turn frequencies Fc + 2 kHz + 3 kHz.....

The output meter reading for each frequency setting is recorded and a graph is constructed to show the response characteristic. It should be added that the frequency response of the a.f. amplifier should be known.

When a Digital Synchronizer TF 2170 or TF 2170B is available this can be used to produce very stable sideband frequencies. The incremental control on TF 2002B is then set at zero and the frequency switches on the synchronizer are stepped in desired increments to provide the required sideband frequencies. See section 2.20.

Dynamic display of response characteristics of S.S.B. receivers

The a.f. response of SSB receivers can be displayed on an oscilloscope using TF 2002B as a sweep generator. The test configuration is as shown in Fig. 2.22 with the sweep width control adjusted to provide a full screen display for the expected a.f. range.

Measurement of spurious responses

Receivers respond to signals other than those for which the tuning is set. Two of the most important of these are the image (second channel) response and the i.f. spurious response.

(1) Image frequency rejection

The image frequency is the frequency spaced one i.f. away from the local oscillator frequency in the opposite direction from the tuned frequency; i.e. if the tuned frequency is the local oscillator frequency minus the i.f., the image frequency is the oscillator frequency plus the i.f. or vice versa.

The image frequency rejection ratio is the ratio in decibels between a tuned and an image frequency signal to produce the same a. f. power output from the receiver.

To measure the rejection ratio TF 2002B and the power meter are connected as for sensitivity measurement.

First the signal generator is tuned to the receiver centre frequency, generally with 400 Hz, 30% modulation. The signal generator carrier level is then set to produce the standard sensitivity test output from the receiver, usually 50 mW, and the TF 2002B attenuator settings are noted.

The signal generator is then tuned to the image frequency and the r. f. input level to the receiver is increased until 50 mW output is again obtained. It is generally necessary to increase the output from the signal generator by 20 to 40 dB in order to ascertain the image response of the receiver. The same tuning procedure should be used as for the tuned frequency; i. e. if the signal generator is adjusted for peak output at the tuned frequency it should be adjusted for peak output at the image frequency.

The image frequency rejection ratio is the ratio between the two input levels. This is normally expressed in decibels and is generally expected to be greater than -40 dB.

(2) Intermediate frequency rejection

Intermediate frequency rejection ratio is a measure of the response of a receiver to an unwanted signal at the intermediate frequency.

The rejection ratio is the ratio in decibels between the r. f. level of an unwanted signal (equal in frequency to the i. f.) and that of the tuned signal when both produce the same a. f. output power.

The method of measurement is similar to that used for image frequency rejection except that the spurious response is at the i. f.

The signal generator is first tuned to the centre frequency of the receiver pass band and with standard modulation applied, the r. f. level is adjusted to produce the standard output power (usually 50 mW) and the attenuator settings are noted.

The signal generator is then tuned to the intermediate frequency and the signal level is increased until the standard output power is again obtained. The ratio between the two attenuator settings is the i. f. rejection ratio. It is normally expected to be greater than -70 dB.

2.18 ADDITIONAL APPLICATIONS

TF 2002B can be used either manually or dynamically (in conjunction with an oscilloscope) to check the response of r. f. amplifiers or r. f. filters, the basic test configuration being the same for both measurements.

Checking r.f. filters

When it is required to adjust a sharp cut-off filter, the sweep frequency method shown in Fig. 2. 23 to display the response characteristic, avoids the tedium and difficulties associated with the manual tuning method. It also prevents errors due to frequency drift because small changes in frequency merely move the displayed characteristic across the screen without affecting its shape. To use the TF 2002B in this way you also need :

1) An oscilloscope with time base output facility.

2) A suitable detector (MI type TF 9651 probe).

3) Sweep width control unit - see diagram.

A logarithmic amplifier can, if desired, be used between the probe and oscilloscope for improved display of the skirts of the response curve.

For sweep frequency tests on high Q resonant devices it is essential that a low sweep speed be used to prevent errors caused by the ringing effect. At very low sweep speeds, phase shift in an a. c. coupled sweep width control circuit causes distortion of the displayed characteristic. Therefore, a d. c. coupled circuit is shown in the diagram giving continuously variable control of the sweep width without variation of the centre frequency.

To set up the control circuit, first adjust R2 to make the saw-tooth at point P exactly symmetrical about -6. 75 V; then adjust R5 to bring the saw-tooth amplitude to 2 V p-p. The sweep width control, R4, can then be used to vary the width from zero to maximum for the carrier frequency used.

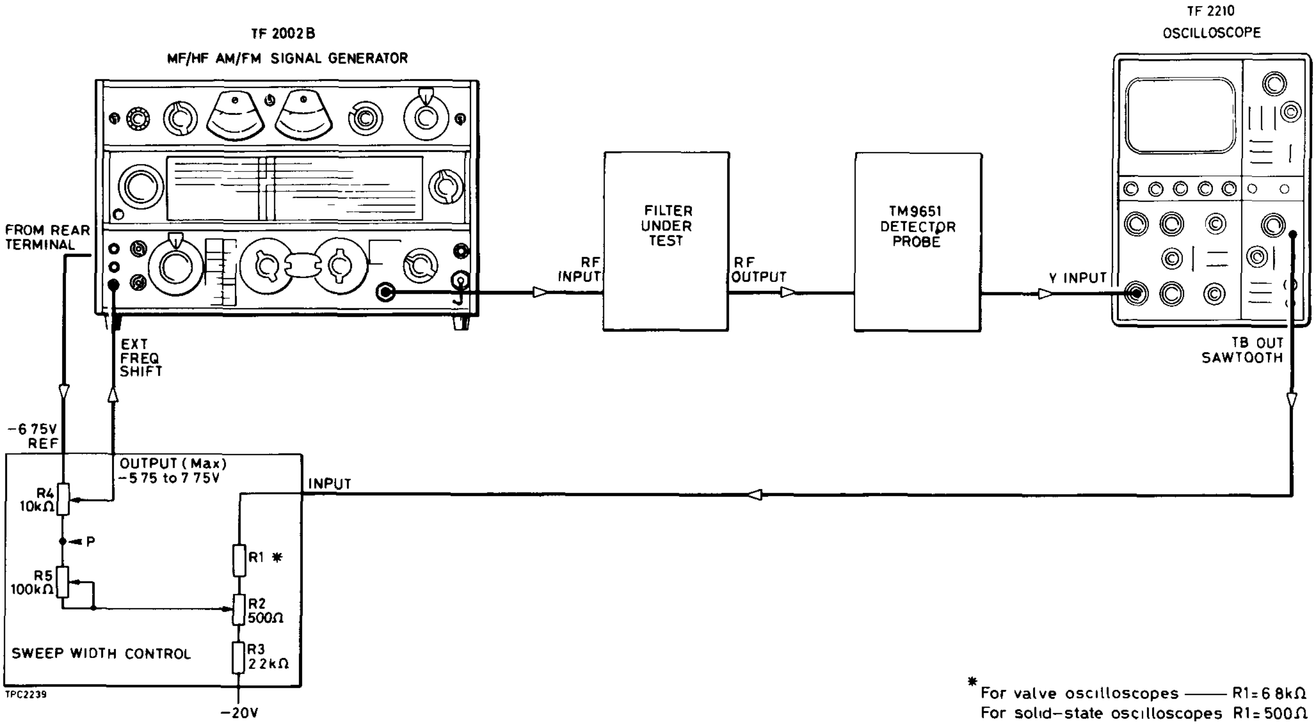


Fig. 2.23 Checking r.f. filters and amplifiers

Wide band f. m.

The cover plate on the rear of the instrument and the associated marking on the r. f. box 'FM Wideband/Normal' is for a special military version of the instrument.

2.19 GENERAL NOTES ON CONNECTING AN OSCILLOSCOPE FOR DYNAMIC DISPLAYS

A negative-going control voltage applied to the external frequency shift terminal of the TF 2002B increases the frequency. For an oscilloscope display with frequency calibration increasing from left to right, a negative-going saw-tooth voltage should, therefore, be applied to the terminal, the maximum linear frequency sweep width occurring when the voltage sweeps from -5. 75 to -7. 75 V.

The majority of oscilloscopes now in use deliver positive-going saw-tooth outputs so the frequency increases from right to left. In practice, this is seldom a disadvantage; however, if desired, the X plate connections to the cathode ray tube can be reversed to position the high frequency end of the scale at the right side of the screen.

Because it is not advisable to allow the input voltage to the signal generator to become positive with respect to the chassis, the positive peaks of the saw-tooth should be held at zero by means of a catching diode in conjunction with a blocking capacitor, C1, as shown in Fig. 2. 24.

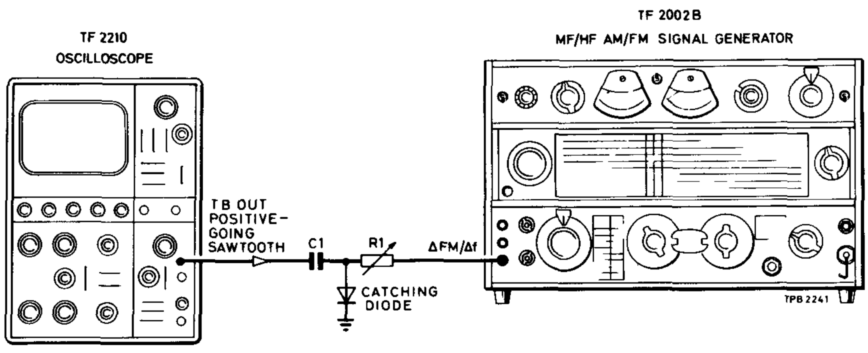


Fig. 2.24 Diode circuit and width control

The input resistance at the EXT Δ f terminals of the TF 2002B is nominally 100 kΩ; and the most convenient way of controlling the input voltage is to use this input resistance as the lower arm of a potential divider, with a variable resistor R1 as the sweep width control, forming the upper arm. The most suitable value for R1 depends upon the saw-tooth output from the oscilloscope, but a 50 kΩ coarse control in series with a 5 kΩ fine control satisfies most requirements.

The optimum value of C1 depends upon the sweep speed and the amount of series resistance. To avoid errors due to phase shift, the time constant of the loop comprising C1, R1 and the respective input and output resistances should be long compared with the sweep time; if the value of C1 is made too high its charging time may encompass several sweeps so that the displayed curve will not remain stationary on the oscilloscope screen. For the common case where the sweep time is about 0.01 second and the total series resistance is of the order of 10 kΩ, a 10 μF, 100 V electrolytic capacitor is usually satisfactory.

With the attenuator set for a low level, the overall gain of the system is adjusted to produce a readable deflection which should be noted. The attenuator is then adjusted to increase the signal generator output by an amount equal to the required total sweep, and R1 is adjusted to produce the noted vertical deflection at the 'low' end of the graticule scale. It may be necessary to repeat this procedure several times to compensate for changes in mean level when R1 is adjusted.

2.20 OBTAINING CRYSTAL STABILITY AND ACCURACY FROM TF 2002B WITH DIGITAL SYNCHRONIZER TF 2170B

When TF 2002B is used in conjunction with TF 2170B or TF 2170 shown in Fig. 2.25 any output frequency in the range 32 kHz to 88 MHz can be held stable to within 1 p.p.m. over an ambient temperature range of +10 °C to +35 °C. Used together, the combination can be considered as a phase locked frequency synthesizer.

None of the facilities of the generator are degraded by connection of the synchronizer.

The synchronizer, which is designed to be fitted on the top of the signal generator, obtains its input from the counter output socket on TF 2002B and the coaxial connector positioned at the rear of the signal generator accepts the phase lock control voltage from TF 2170B. A switch located on the panel of TF 2170B enables the signal generator to be used independently (unlocked condition) without disconnection.

Digital Synchronizer TF 2170 can also be used with TF 2002B but frequency control is limited to 80 MHz and TF 2170 is required to be slightly modified, see Supplement to Manual EB 2170.

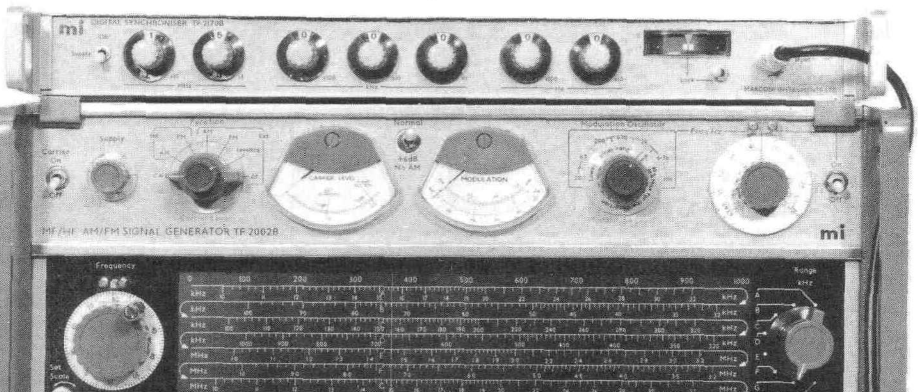


Fig. 2.25 Signal generator TF 2002B with Digital Synchronizer TF 2170B

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

Chapter 3

Technical description

This chapter, which outlines the overall and circuit functions of Signal Generator TF 2002B, is intended to be read with reference to the circuit diagrams and illustrations contained within this manual.

3.1 MECHANICAL CHARACTERISTICS

Signal Generator TF 2002B is constructed and designed to provide easy access to printed circuit boards and sub-assemblies for the purpose of servicing and to enable direct access to the oscillator units and associated circuits, the r. f. compartment can be completely removed without electrical disconnection.

Efficient screening of particular units together with the general design, reduces stray fields to a negligible level whilst temperature rise within the instrument has been kept to a minimum by the consideration given to the positioning of certain circuits and the use of carefully designed heat conducting devices.

Oscillator and associated filter circuits contained within the r. f. compartment are tuned by movable ferrite cores which are driven by a tape attached to a drum as shown in Fig. 3.1. To obtain a continuous frequency scale in the form of a zig-zag pattern, the tapes driving alternate ranges are wound in opposite directions around the drum. In addition, a SET SCALE control is available to move the tuning scale to the left or right by a small amount to correctly position the calibrated scales.

All printed circuit boards and sub-assemblies in the instrument are allocated a unit identification number in the sequence A1 to A31 and where practical the assembly is marked with this number; silk screening is used to identify components on the printed circuit boards.

Inputs and outputs are conveyed through connectors and terminals located on the lower front panel and at the rear of the instrument.

Side handles are fitted to the instrument case and handles are also fitted to the front panel for easy handling when the instrument is rack mounted. These can also be used to provide protection to the front panel controls when the generator is positioned face down for repair.

Since the instrument can, if desired, be rack mounted a modification kit is available.

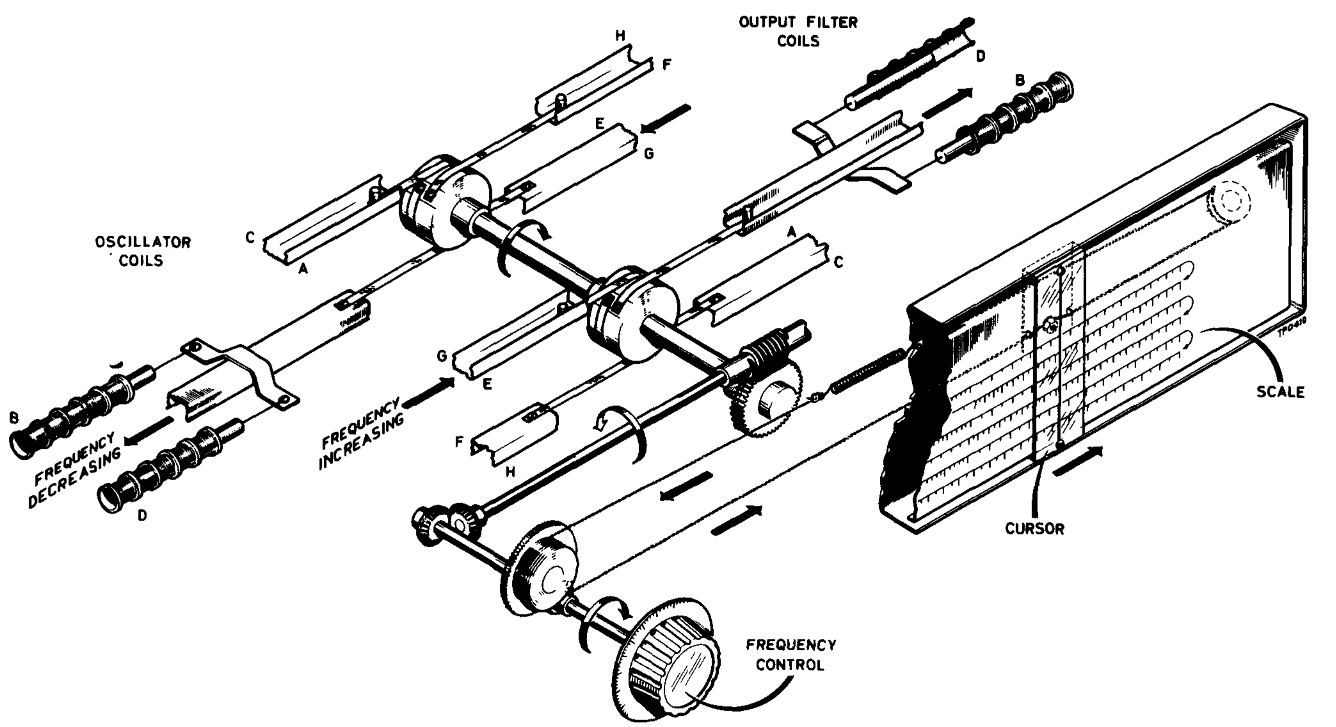


Fig. 3.1 Tuning drive system

3.2 SUMMARIZED OVERALL FUNCTION

Block diagram page 43

The tuned r. f. oscillator signal (10 kHz to 88 MHz) is applied to the input of a wide band amplifier consisting of a pre-amplifier incorporating an automatic gain control circuit, two buffer stages, a modulator and a final amplifier.

Output from the pre-amplifier, which is maintained at 150 mV by action of the a. g. c. circuit is passed to the modulator circuit and also through an emitter follower to two buffer stages which supply signals to the crystal calibrator and counter output socket.

The input circuit of the modulator employs a dual gate field effect transistor (f. e. t.) which accepts the modulating signal, the d. c. instruction voltage from the overall automatic level control circuit, (a. l. c.) and the r. f. signal. From the modulator the signal is passed to the final amplifier at a level which is controlled by the d. c. instruction signal.

The final amplifier consists of an emitter follower and two Class A common emitter amplifiers. Output from the final amplifier is passed to a switch selected filter which applies the a. m. signal to the a. l. c. and envelope detector circuit to produce a signal of constant level and low distortion to the input of the attenuators.

Reactance circuits, using diodes or transistors as variable capacitors, provide incremental tuning (Δ f) which enables the frequency of a selected oscillator to be either precisely set or swept over a band of frequencies above and below the set frequency by the Δ f driver circuit incorporating the panel mounted incremental controls.

For very accurate and stable frequency setting or very accurate frequency shifts (up to ±0. 5% in steps of 10 Hz from the tuned frequency) Digital Synchronizer TF 2170B can be used instead of the incremental controls.

The variable reactance circuits also enable any oscillator B to H inclusive to be dynamically swept over a band of frequencies by application of a varying d. c. voltage or low frequency saw-tooth waveform to the EXT FM/ Δ f terminals.

To enable the frequency of the r. f. signal to be accurately tuned, an internal 1 MHz crystal oscillator with two cascaded decade dividers is used with a 1 kHz filter. The low level r. f. output from the crystal calibrator socket on the wide band amplifier is passed to a mixer circuit to produce a beat frequency which is applied to an a. f. amplifier driving an internal loudspeaker or if preferred, headphones connected to the phone jack on the front panel can be used instead of the loudspeaker.

A Wien bridge oscillator with a continuously variable frequency range from 20 Hz to 20 kHz is used to modulate the r. f. signal and also to provide an a. f. output.

Automatic level control and envelope feedback circuits maintain the set r. f. voltage constant at the input to the attenuators and also operate to ensure minimum envelope distortion. The signal level applied to the attenuators is sampled and compared with an instruction signal for level and modulation and the error signal is used to correct the r. f. signal level and reduce any modulation distortion.

Modulated r. f. signal levels up to 1 V into the attenuator are obtained when the 1 V/2 V switch is positioned at 1 V and this can be increased to 2 V for c. w. or f. m. signals by setting the switch at 2 V. The -1 dB and +5 dB calibrations on the meter scale enables interpolation of the 1 dB attenuator steps.

To ensure that f. m. deviation is maintained acceptably constant over each carrier frequency range, tracking circuits which operate in conjunction with the frequency range switch and main tuning control, are incorporated.

Provision is made for both amplitude modulation and frequency modulation by an external source and if desired, the level of the carrier signal can be controlled from a remote d. c. source.

3.3 SUMMARIZED CIRCUIT FUNCTIONS

Block schematic diagram Fig. 3. 2 details the various circuits employed in TF 2002B whilst the sections which follow briefly explain the operation of each circuit.

3.3.1 R.F. oscillators

Circuit diagrams Figs 7. 2 and 7. 4

All the r. f. oscillators use a modified Colpits circuit with tuning achieved by variation of inductance. The principal inductor in each circuit has a ferrite core which is positioned by operation of the main tuning control to provide the required frequency.

Range A

Range A uses a bipolar transistor TR1 for the oscillator circuit with regenerative feedback obtained from the tuned circuit and applied to emitter of the transistor : base bias is provided by resistors R1 and R2 and resistor R3 shunts the tuned circuit to reduce its Q to maintain an acceptable signal level over the frequency range. The emitter input signal is developed across R4 whilst R5 serves to return the collector to the negative supply. The tuned circuit consists of C2 and C3 in parallel with L1 and L2. Capacitor C5 is selected to set the low frequency end of the range and L2 is pre-adjusted to set the high frequency end and consequently the overall frequency coverage.

Range B

Range B also uses a bipolar transistor TR2 for the oscillator circuit with transistor TR1 as a variable capacitor across the tuned circuit, its value being determined by the base voltage which is established by the output from the f. m. or Δ f driver circuits or externally applied signal levels.

Range C

Range C is similar to range B, a bipolar transistor TR2 is used for the oscillator circuit with transistor TR1 as the variable capacitor.

In this circuit C3 is selected to set the modulation frequency response.

Range D

Range D is, in outline, similar to range B. It uses the same type of transistors and differs only with respect to the value of components.

Ranges E and F

Ranges E and F are similar and differ only with respect to component values. Both use a field effect transistor (f. e. t.) for the oscillator circuit and buffer circuit respectively and a bipolar transistor as the variable capacitor.

Range G

Range G also uses field effect transistors for the oscillator and buffer circuits, with a diode D1 as the variable capacitor operating in conjunction with the series connected capacitor C2 to provide the desired range of deviation.

To obtain the required output from the oscillator circuit it was necessary to give R6 a value of 1 kΩ and to overcome the loading which would be imposed upon the tuned circuit by using this value of resistor, a choke L2 is connected in series with the resistor.

Range H

Range H is similar to range G with the addition of choke L4 which isolates earth currents to reduce carrier distortion.

Capacitors C3, C4, C6 are positioned very close to the tuning coil to keep stray inductance at a minimum.

A series trimmer inductor is not provided on this range but a selected capacitor C7 is included to enable the low frequency end of the range to be correctly set.

3.3.2 Wideband amplifier

Circuit diagram Fig. 7.5 Board A25

The wide band amplifier consists of a pre-amplifier, two buffer stages, a modulator circuit and a final amplifier.

Pre-amplifier

The primary function of the pre-amplifier is to maintain a constant 150 mV to the modulator circuit but it also serves, through transistors TR5 and TR6, to supply a constant signal voltage to the crystal calibrator circuit and the counter output socket.

Input impedance of the amplifier which is set by resistor R1 is nominally 50 Ω and outputs from the selected oscillator unit, which are expected to vary between approximately 50 and 200 mV, are developed across this resistor and then applied to g1 of the dual gate field effect transistor TR1.

The constant 150 mV output is obtained by automatically controlling the gain of the amplifier; the gain of the amplifier is dependent upon the voltage applied to g2, TR1 and this is determined by the automatic gain control (a. g. c.) circuit which operates as follows :

Output signals from TR3 are rectified by D1 which is connected to the inverting input of the error amplifier IC1. A bias voltage determined by the resistor network R15, 16, 17, 53 and 54 is also applied to D1 across the decoupling capacitor C8.

The variable resistor R16 provides the input bias for the non-inverting input to IC1, so enabling the voltage at the output of the IC to be set to a datum required for 150 mV output from the pre-amplifier. Diode D4 provides compensation for the temperature coefficient of D1.

High level r. f. input signals cause the voltage at g2, TR1 to be more negative than the datum level so the amplifier gain is reduced to re-establish the 150 mV output.

Low level r. f. signals cause the voltage at g2 to go more positive than the datum level and consequently the amplifier gain is increased proportionally.

Transistor TR2 is incorporated to hold the TR1 source voltage constant and it also serves to provide a stable bias to g1, TR2.

The filter L1, C1 is included to ensure that interfering r. f. signals are not introduced by the 15 V supply.

Buffer circuits

The two buffer circuits, TR5 and TR6, serving the crystal calibrator circuit and the counter output socket respectively, receive their inputs from the pre-amplifier through the emitter follower TR4.

Negative feedback for each circuit is obtained by the emitter resistors R21 and R24. Both buffers are designed for low gain and to provide an output impedance of approximately 50 Ω.

Modulator

The modulator circuit employs two dual gate field effect transistors, TR7 and TR10, together with bipolar transistors TR8 and TR9.

Output from the pre-amplifier is applied to g1, TR7 and the modulating signal together with a d. c. instruction signal from the automatic level control circuit is applied to g2, TR7.

Large a. f. signals at g2, TR7 such as are necessary for deep modulation would normally appear across R37 and this would produce unacceptable distortion of the a. m. envelope. To cancel out such distortion the a. f. (modulating) signal is applied to g2, TR10. This transistor amplifies and pre-distorts the modulating signal by a factor set by pre-adjustment of R33. Output from TR10 is inverted by transistor TR9 and then applied to the output of TR7. Circuit TR8 is incorporated to maintain the source voltage of TR7 and TR10 at a constant level and also to establish the bias on g1, TR7 and g1, TR8.

Final amplifier

The final amplifier uses an emitter follower, TR11, which serves a two stage common emitter amplifier, TR12-TR13.

Negative feedback is introduced into the circuit of TR12 by resistor R44 whilst L6 provides a high impedance collector load at all frequencies to ensure maximum efficiency.

L7, C25, R42, C29, R55 determine the higher frequency response.

Collector load for TR13 is provided by the selected tuned output filter in the r. f. compartment and the collector current passes through the first choke of the selected unit. Zener diode D3 is incorporated in the collector circuit to limit the excursion of TR13 in the event of high amplitude ringing transients occurring under fault conditions.

Diode D2 is employed to ensure that a forward voltage is not applied to D3.

3.3.3 Tuned output filters

Circuit diagram Fig. 7.7, Boards A17 to A24

The eight tuned output filters are contained in separate cast aluminium compartments which are housed in the r. f. box.

All filters are similar in that a π tuned circuit is used to cover the same frequency range as the associated oscillator. The filter is selected by the range switch and tuned by the main frequency control as shown in Fig. 3.1.

Each filter provides a variable low-pass section (dependent on the tuning), a fixed high-pass section (dependent on C5 and L4) and second harmonic rejection (dependent on C3).

Output from the selected tuned filter is applied through a pair of normally closed relay contacts to the r. f. detector (part of the automatic level control circuit) and to the attenuators through the source resistor R42.

3.3.4 ALC and envelope feedback circuits

Circuit diagram Fig. 7.9

The a. l. c. and envelope feedback circuits operate to maintain a constant r. f. input level to the attenuators and to achieve minimum a. m. envelope distortion. The circuits compare the output from the selected tuned filter with a reference or 'instruction' voltage obtained from the a. m. driver.

The unbalanced instruction voltage is applied to a phase splitter (IC2) which produces balanced negative and positive potentials at TP1 and TP2 respectively. These are applied to temperature compensating emitter followers TR4 and TR5 to produce a voltage across R29 which is the reference for the comparator bridge.

The modulated r. f. signal from the selected output filter is applied through contacts of RL1 to the detector circuit D5 and D6 forming the other input to the bridge. The detector circuit provides a balanced output across R36, R37 with a d. c. component proportional to the carrier level and an a. f. component commensurate with modulation depth.

A small forward bias current is applied to D5 and D6 which brings the diodes to the knee of their characteristic to ensure minimum distortion of the modulated signal. The diodes are matched by a corresponding temperature coefficient in TR4 and TR5 on the opposite side of the comparator bridge so that variation of diode characteristic with temperature is balanced out.

When the input to the attenuators is at the required level and the modulation envelope is at minimum distortion, the difference between the detected r. f. signal and the reference signal will be zero. With these conditions there is no differential output from the bridge to the error amplifier IC1.

If the frequency of the generator is changed, the level of the detected signal may momentarily differ from the reference. The bridge then produces a composite (d. c. + a. f.) error signal which is proportional to the difference in level and envelope shape of the two signals.

The error signal is applied to a long tailed pair, IC1a3 which is initally balanced by the preset a. l. c. threshold control R3.

The amplified error signal is developed across R12 and this is passed to a common emitter amplifier TR1. Phase correction circuits are included at this stage and these are selected by the range switch to satisfy the stability requirements of each frequency band.

Capacitors C3 and C17 with resistor R43 are included for r. f. decoupling.

Output from TR1 is applied via emitter follower IC1b3 to one input of the summing amplifier IC1c3. This connection is d. c. coupled but the amplitude of the a. c. component of the feedback error signal is controlled by adjustment of R52.

The purposes of the summing amplifier is to add together the amplified error signal and a 'direct' modulating voltage which is derived from TP1 through the predistorting diode network D7 - D10. The degree of predistortion approximately matches the non-linearity of the dual gate f. e. t. modulator TR7 on board A25, thus minimizing the correction signal necessary from the envelope feedback circuit. R14 permits the amplitude of the direct feed to be adjusted.

With R18 set at the -15 V end, the a. c. component of the feedback is turned 'off' and the error signal on TP6 may be minimized by adjusting the level of the direct modulating voltage with R14. The feedback is then increased with R52 until optimum loop bandwidth and stability is obtained.

Output from the summing amplifier is passed directly to TR7 in the modulator circuit on board A25.

The carrier level meter is connected to the comparator bridge through two star networks R23, R28, R39 and R24, R31, R35. The meter indicates the sum of the instruction voltage (via R23, R24) and the error (via R28, R29, R31 and R35).

The relay RL1 and associated driver circuits TR2 and TR3 are included to enable the measurement of signal to noise ratio. With normal operating conditions, both transistors are non-conducting, relay RL1 is not operated, contacts 1 and 4 are closed, and the output between the junction C14 R42 and earth appears as a zero impedance giving the signal generator a source impedance of 50 Ω (R42).

With the carrier off, the polarity of the voltage across TP1 and TP2 is reversed causing TR2 and TR3 to conduct and operate RL1. Since contacts 4 and 7 are then closed, R42 is connected to earth again providing a 50 Ω source impedance.

3.3.5 Modulation oscillator

Circuit diagram Fig. 7.11

Internal modulation signals from 20 Hz to 20 kHz are provided by a Wien bridge oscillator with six switched ranges. Three transistors are used in the oscillator circuit. The input of TR1 is connected across the shunt arm of the bridge and its output is passed to the amplifier circuit TR2. Output from TR2 is applied to an emitter follower. The oscillator output signal is across R14 and it is applied to the top of the Wien bridge network to enable positive feedback. To cover the frequency range the parallel arm of the bridge has six switched capacitors C1 to C6 and variable resistor R25A with preset trimmer R8. The series arm consists of six switched capacitors C7 to C12 with variable resistor R25B and preset trimmer R7. R25A and R25B are ganged.

During the non-oscillating condition prior to 'switch on' the negative feedback thermistor R13 is cold and its resistance high, therefore the amplifier gain is high. At 'switch on' oscillation commences readily, causing the resistance of R13 to fall and the gain of the amplifier to stabilize at a value just sufficient to maintain oscillation.

The low distortion is minimized by R2 which biases TR1. To reduce amplitude bounce to a minimum the resistive arms of the bridge are finally balanced by a small adjustment of R7 or R8. Spurious oscillation of the amplifier is prevented by C4 and R12.

Output from the oscillator for a. f. tests is available through R1 at the modulation oscillator output terminals TP3-TP8 located on the rear panel of the generator.

3.3.6 A.M. driver circuit

Circuit diagram Fig. 7.13

The a. f. modulating signal obtained from either the internal modulation oscillator, or an external source, through the function switch and modulation level control, is applied together with a d. c. signal to one input of a current summing amplifier IC1a2 (tag 8).

Amplitude of the a. f. signal is fixed by the setting of the modulation level control, whilst the d. c. input is preset by R6 to determine the mean d. c. output.

The a. f. gain of the amplifier is independent of the setting of R6, adjustment of this control varies the ratio of a. c. to d. c. at the output; R6 therefore, enables the mean carrier level to be adjusted so that the available a. f. produces the correct a. m. depth as indicated by the modulation meter.

The level of both the a. f. and d. c. output forming the composite instruction signal from IC1a2 (tag 13) is dictated by the carrier level control and, since this is incorporated in the negative feedback loop, the modulation depth is independent of carrier level. The instruction signal is then passed to the input of the automatic level control and envelope feedback circuit on board A26 through R19.

The non-inverting input of IC1a2 (tag 9) is set at 7.5 V by R10 and R11.

External levelling is achieved by application of d. c. voltages to IC1a2 (tag 9) through the function switch and terminals provided. Resistors R27, R2 and R28 ensure that the standing voltage on the external levelling terminal is at 6.75 V whilst R12 and C3 are included as stabilizing components.

The 1 V/2 V switch enables the mean carrier level to be doubled by short circuit of R19; at the same time preventing amplitude modulation by earthing the a. f. input.

3.3.7 Monitor amplifier

Circuit diagram Fig. 7.13

The amplifier provides a low impedance source of up to 7 V p-p modulating signals about a stable mean of -6.75 V d. c. The amplifier is used to drive the monitor circuit for both a. m. and f. m. and its output is also passed to the f. m. range attenuator when using the f. m. function. Resistors R26 and R25 set the gain of the amplifier and R34 increases the current of the emitter follower output of IC3b2 to improve its signal handling capability.

Resistors R20 and C4, C2, C5 are included to prevent amplifier instability whilst permitting optimum bandwidth.

3.3.8 Monitor circuit

Circuit diagram Fig. 7.13

Both modulation depth and f. m. deviation is indicated by modulation meter ME2.

D5, D6, C8 and C11 constitute a full-wave peak detector which is driven by IC2. The gain of

IC2 is adjusted by the feedback network including R18 which enables the sensitivity of the circuit to be preset. D3 and D4 provide compensation for the temperature coefficient of D5 and D6.

To permit a reasonable discharge time for the peak reading meter the time constant of the detector components has to be made smaller than is required for accurate operation down to 20 Hz. Therefore, to overcome this problem R15, R16 and C2 are used to provide a small amount of correction at 20 Hz to maintain the monitor accuracy at the low modulation frequencies.

3.3.9 FM and Δf systems

Circuit diagram Fig. 7.13

The f.m./Δ f system is shown in the block diagram, Fig. 3.2 and the circuits employed are summarily described.

Δ f control supply

This circuit provides an output of -6.75 V ±3.5 V (depending on the setting of the Δ f control) through a 5 kΩ source resistor, R30, which passes the output to the Δ f attenuator.

The d.c. output level is determined by the incremental frequency control R30 which forms part of the potentiometer network R3, R36, R4 and R37, with R36 and R37 selected to apply -6.75 V to the input of the amplifier when the scale of the incremental frequency control is set at centre zero.

To obtain the required ±3.5 V swing, the gain of the amplifier IC3a2 is set by pre-adjustment of the negative feedback circuit incorporating R32, whilst resistor R35 is included to increase the current in the output circuit of the emitter follower in the i.c. package to improve the signal handling ability of the amplifier.

Resistor R9 and capacitor C1 are incorporated to prevent oscillation occurring in the amplifier.

FM and Δ f attenuators and FM/Δ f cal control

The f.m. attenuator, R12 to R17, sets the range of f.m. deviation which is then adjusted by the modulation level control and indicated by the modulation meter.

The Δ f attenuator R6 to R11 sets the Δ f range and is relative to the ranges shown on the incremental frequency control.

Both attenuators are stepped to provide increments of 10 dB and the outputs are paralleled and passed through a series resistor, R31, to the tracking network. Resistor R31 is also located on the front panel and this serves as a fine attenuator for both a.c. (f.m.) and d.c. (Δ f) to accurately calibrate the incremental frequency control against the crystal calibrator.

FM driver and predistortion resistor board A31

Input voltages about a mean of -6.75 V from the tracking network are applied to one input of amplifier IC1b2 which provides a gain of six and a maximum output of 7 V p-p at a low impedance.

The circuit incorporating TR4 forms a 'boot strap' stage which augments the emitter follower within IC1b2 whilst feedback resistor R13 controls the gain.

Potentiometer R29 and resistor R5 provide a small amount of bias shift to enable very fine frequency adjustment for the set zero control which is used in conjunction with the Δ f dial, capacitors C4, C5 with R14 ensure amplifier stability.

Diodes D9 and D10 in conjunction with the resistors on board A31 predistort the output waveform of the f.m. driver to reduce second harmonic distortion of the final f.m. Only one diode is used per range of the instrument depending whether it is the positive or negative half of the waveform that requires shaping. When a diode conducts it shunts R13 with the appropriate resistor on board A31 and so reduces the amplifier gain on one half of the a.c. waveform only.

Diodes D1 and D2 offset the voltage drop across D9 and D10 to ensure that conduction occurs at the correct part of the waveform.

The output of the amplifier is passed through source resistor R18 to the f.m. supply filter contained on boards A7 and A8 then to the oscillator boards.

3.3.10 Crystal calibrator

Circuit diagram Fig. 7.15

A crystal controlled 1 MHz oscillator is used as the fundamental standard to produce a series of harmonics and sub-harmonics which can be compared with an unknown radio frequency.

Output from the oscillator is applied to an amplifier and limiter circuit and then to two cascaded divide-by-ten circuits to produce subfrequencies at 100 kHz and 10 kHz. For generation of harmonics, the output from the crystal oscillator is also passed to a Schmitt trigger circuit and then to a pulse shortener.

Both the outputs from the dividers and the pulse shaper are applied to a mixer which also accepts the r. f. from the wide band amplifier.

The mixer output is passed through filters to an a. f. amplifier which is arranged to drive the internal loudspeaker or external headphones.

The 1 MHz standard frequency is produced by a crystal controlled modified Colpitts circuit using transistor TR1. Trimmer capacitor C30 enables the frequency to be adjusted to 1 MHz ±1 Hz. Output from TR1 is taken via a π filter circuit which is tuned to 1 MHz by L1. TR2 is a common base, class C amplifier producing a large output signal. Its output circuit is adjusted to 1 MHz by L2. D1 and D2 form a limiter which clips the 1 MHz signal. When the crystal calibrator selector is in the 100 kHz position, the 100 kHz storage counter operates. TR4 and TR5 are biased non-conducting by R11 and R13. A positive-going pulse edge charges C14 (C15) and C16 and the voltage developed across D3 holds TR3 off. The negative-going pulse edge turns on TR3 allowing C14 (C15) to discharge, but since there is no discharge path for C16 this is charged in a series of steps by the successive pulses. The value of C15 is selected to give voltage steps so that when ten pulses have been received the potential across C16 is just sufficient to turn on TR4. A cumulative switching action through the regenerative coupling between TR4 and TR5 occurs, both transistors are rapidly turned on and C16 is discharged. When C16 is discharged, a similar switching action turns both transistors off again. The counter produces an output pulse for every ten input pulses and so, for a 1 MHz input, gives a 100 kHz pulse train output.

The 10 kHz storage counter operates in exactly the same way with C22 being charged in steps through C18 (C19) and D5, then discharged every tenth step through TR7 and TR8. By applying a small part of the 100 kHz signal through C21 and R14 to the 10 kHz counter, the switching points of the counter are brought into exact synchronism.

Output from the crystal oscillator, through C25, to the Schmitt trigger TR9 and TR10, produces a sharp edged pulse to drive TR11. Transistor TR11 operates in the class C mode and conducts for part of the positive-going half of the input waveform. L3 resonates with stray capacitance at 50 MHz and tries to ring at this frequency whenever TR11 conducts. D7 damps this so that only one negative-going half cycle is produced. The output from TR11 thus consists of a train of 10 ns pulses at a frequency of 1 MHz, to produce a spectrum of 1 MHz harmonics of approximately equal amplitude throughout the range of the signal generator.

The r. f. signal from the wide band amplifier is applied through C29 to the emitter resistors R31 of TR12. Mixing occurs in TR12 between the r. f. carrier and the 1 MHz, 100 kHz and 10 kHz pulse trains applied to the base of TR12. Audio frequency beat signals from the collector of TR12 are switched by SA2 to the crystal calibrator amplifier, which is contained on board A5.

In the 1 kHz (filter) position of the crystal calibrator selector, SA2, routes the a. f. signal through a 1 kHz band-stop filter consisting of C9, C10 and L1 to a three stage a. f. amplifier TR1, TR2, TR3 to bring the beat note to a suitable level to drive headphones or the loudspeaker LS1. The frequency response of the crystal calibrator a. f. system is limited to 1.5 kHz by the filter on boards A7 and A8 and by C6 in the collector circuit of TR2. The crystal calibrator level control is a potentiometer, R32, interposed between TR1 and TR2. Its configuration has been chosen to ensure that TR2 is always fed from a high impedance source.

In the OFF position of the crystal calibrator selector, C2 is effectively connected between collector and base of TR1 to reduce its gain by negative feedback, to prevent unwanted audio frequencies being heard.

3.3.11 Attenuators

Circuit diagram Fig. 7.16

Two stepped attenuators are fitted to the instrument, a coarse attenuator giving up to 120 dB loss in 20 dB steps and a fine attenuator giving up to 20 dB in 1 dB steps.

Both attenuators are of similar construction and operation. The pad sections consist of resistive networks with a characteristic impedance of 50 Ω. The body is divided into compartments to achieve maximum shielding between pad sections. Pads are brought into circuit by microswitches housed inside the screened compartments and operated in pairs by leaf springs which are actuated by cams on the control spindles to depress miniature plungers on the microswitches.

Semi-rigid coaxial cable is used between the r. f. box, attenuators and front panel to overcome r. f. leakage.

3.3.12 Supply filters

Circuit diagram Fig. 7.17

Seven of the ten supply filters are of the same circuit design and differ only with respect to the value of components. The filters which are connected in the supply lines to various units to remove any r.f. are basically π section types with half sections positioned on separate boards.

The crystal calibrator amplifier filter incorporating inductors A7 L4, A8 L4, provides a cut-off frequency approximating 2 kHz whilst the a.m. (three section) and f.m. (two section) filters have cut-off frequencies of 20 kHz. It should be added that modulation response of TF 2002B is largely dependent upon the characteristics of the a.m. and f.m. filters, hence the inductors are adjusted to precise values.

3.3.13 —13.5 V regulator

Circuit diagram Fig. 7.18

This is a series regulator circuit employing an i.c. package.

A long tail differential pair contained in IC1b2 is used in conjunction with the potentiometer network R27, R28, R29/31 to compare part of the -13.5 V with a reference (datum) voltage set by R13 and Zener diode D1.

Deviations of the -13.5 V output either towards positive or negative causes the voltage developed across R22 to vary and consequently the current through transistor TR1. This varies the current in transistor 9-10-11 in IC1a2 in the appropriate direction to restore the -13.5 V output.

The circuit consisting of R1, R5, R6 and a transistor 12-13-14 in IC1a2 is incorporated to prevent damage should a short circuit be presented to the output of the regulator. A short circuit will reduce the negative voltage at the junction of R1 and R5 and this causes the base of transistor 12-13-14 in IC1a2 to go towards positive so that it conducts to take the base of transistor 9-10-11 to -15 V causing this transistor to be cut off.

3.3.14 6.75 V regulator

Circuit diagram Fig. 7.18

The function of the -6.75 V regulator circuit is basically the same as that described in section 3.3.13 with the exception that the reference (datum) voltage is obtained through the potentiometer network R14 R15 from the -13.5 V regulator and the output voltage is sampled directly by the long tailed pair. The lower output-voltage enables the protection transistor 12-13-14 in IC2a2 to be connected directly across the series regulator transistor 9-10-11.

3.3.15 Power unit —15 V

Circuit diagram Fig. 7.18

The power unit which operates by switch selection from a.c. supplies of 95 to 130 V or 190 to 264 V, 45 to 500 Hz consists basically of a mains transformer, T1, a full-wave rectifier circuit D3, D4, C1 and a voltage regulator circuit on board A1.

Connection to the a.c. supply is made through a three pin connector and the a.c. input circuit includes an ON/OFF switch SD2F and fuses FS1 and FS2.

Output from the rectifier circuit is passed through a second fuse, FS3, to the series regulator which stabilizes the -15 V output.

The circuit of the regulator follows that commonly adopted for a series stabilizer in which R12 is adjusted to set the -15 V output and R11 is adjusted for optimum regulation with C2 incorporated to minimize ripple.

When an external battery 19 to 32 V is connected to terminals TP1 and TP2 to power TF 2002B, the battery supply is switched by SD1F. Diode D2 is incorporated to protect the power unit against reversed battery polarity.

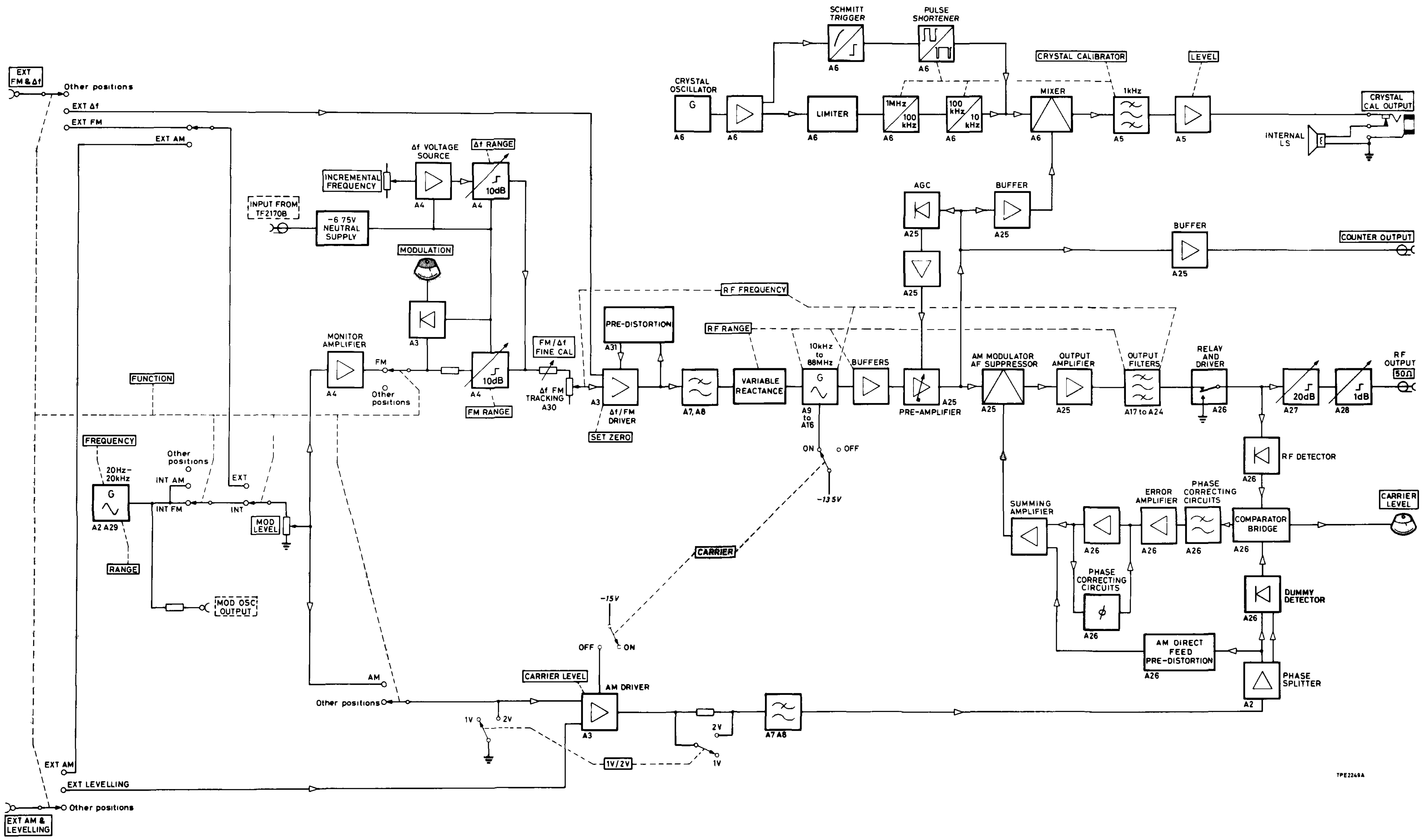


Fig 3.2 Simplified block diagram

Chapter 4 Maintenance

4.1 INTRODUCTION

This chapter which should be read with reference to Chapter 3 and the drawings, illustrations and circuit diagrams contained within this manual is primarily concerned with functional checks of various circuits employed in the instrument to localize the cause of any malfunction and thereby effect adjustment or repair.

CAUTION

> The MOS field effect transistors used in this instrument have extremely high input resistance and can be damaged by accumulation of static charges.

Avoid possible damage to the devices when handling, testing or replacing, by following the precautions given below :

1. To avoid build up of static charge, the leads should remain shorted together using a metal ring until the device is required to be tested or used.

2. Handle the device by the case <u>not</u> by the leads.

3. Before removing or replacing these devices ensure that the power supplies are switched OFF.

4. When replacing or removing the devices the soldering iron used MUST BE EARTHED.

4.2 SCREW FASTENERS

Screw threads used in this instrument are all BA sizes.

Ensure that screws removed are refitted in original positions.

4.3 ACCESS TO SUB-ASSEMBLIES AND COMPONENTS

All sub-assemblies and components can be accessed by following the procedure given.

Removal of case

To remove the outer case of the instrument, extract the four coin-slotted screws at the rear and slide the instrument forward out of the case. With the case off, the following boards are accessible, A1, A2, A3, A4, A5, A29; for the location of these boards and other components see Fig. 4.1 and Fig. 4.2 (shown with r.f. compartment removed).

Removal of the r.f. unit

Extract the eight screws (four on each side) that secure the screening case of the r.f. unit on the side frames of the main chassis. Disconnect the 18-way plug, PL1, from SKT3 on the top cross-member of the chassis and disconnect the two snap-on BNC plugs and sockets on the front bulkhead of the r.f. unit. The unit can then be removed by sliding it out of the back of the instrument.

With r.f. unit removed, switch wafers SG0 and SG1, the tracking assembly including the potentiometer R9 and board A30 are accessible. If it is necessary, for test purposes, to operate the instrument with the r.f. unit removed and lying alongside the chassis, this is possible if the 18-way plug is reconnected with a temporary connection made between the r.f. unit and main structure. The output can then be taken direct from SKT10.

To remove the r.f. unit cover, unscrew the two hexagon socket cap screws at the back of the unit and slide the cover off rearwards. A hexagon wrench to fit these screws is clipped to the top cross-rail of the chassis.

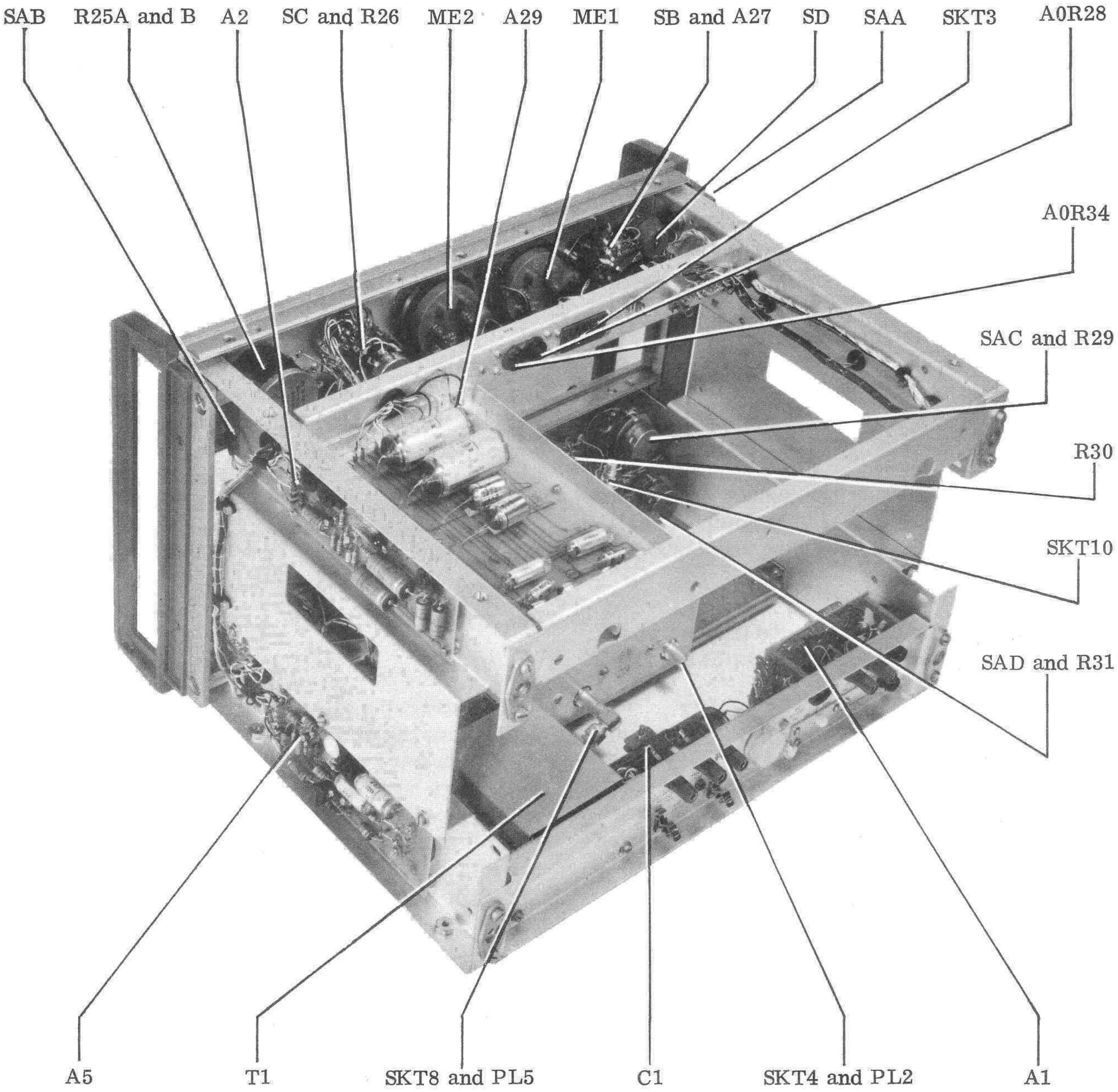


Fig. 4.1 Top view with r.f. unit removed

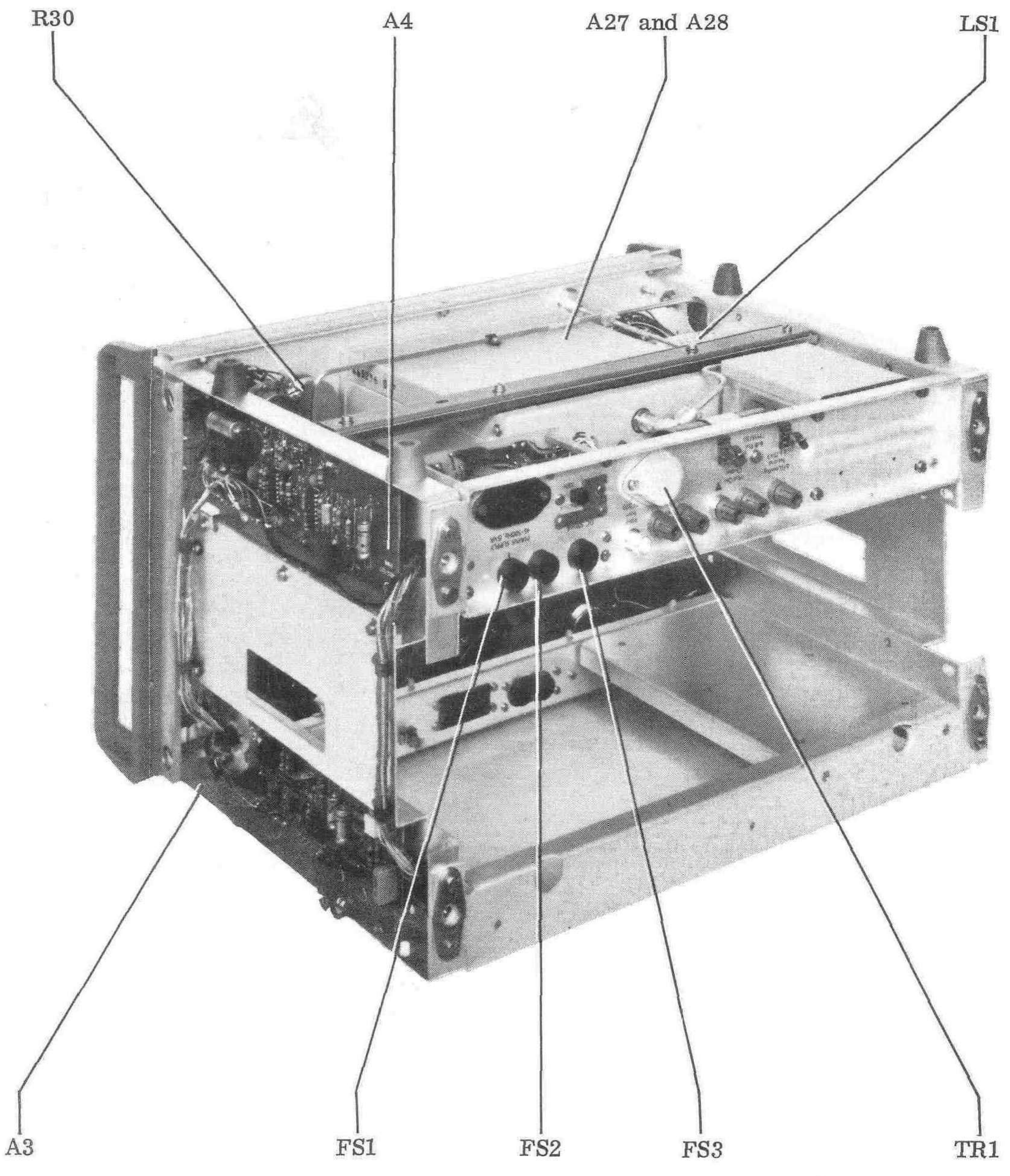


Fig. 4.2 Bottom view with r.f. unit removed

Boards A6, A7 and A8

These boards are located at the rear of the r.f. unit; see Fig. 4.3 to enable access, unscrew the two screws that secure the rear cover plate and lift it off.

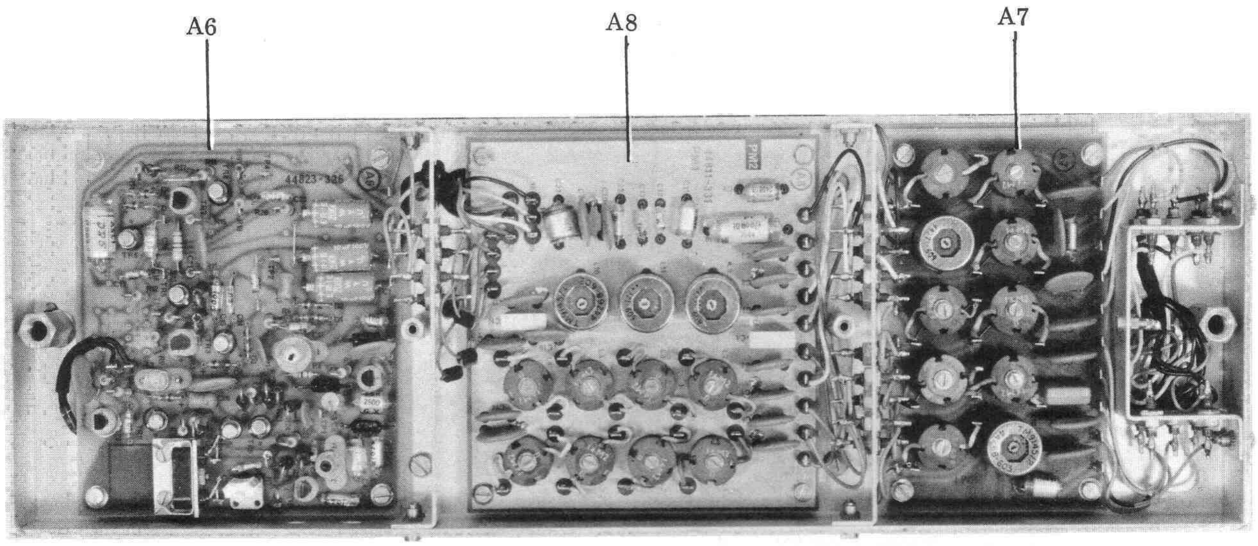


Fig. 4.3 R.F. unit with covers removed—rear

Boards A25 and A26

These boards are, together with section 2 of switch SG, mounted between the oscillators - see Fig. 4.4. Extract the six screws holding the upper central cover plate and remove it. Board A26 is then accessible. Remove the lower central cover plate in a similar manner to reveal section 2 of switch SG.

To replace components on board A25 it must be removed. Do this as follows :

a) With the r.f. unit right way up, extract the two screws that secure the support brackets to the top edge of board A25.

b) Withdraw the two screws that secure the brackets on the bottom edge of board A25 to the main drive shaft rear support plate.

The board may now be pulled out through the bottom of the r.f. unit. There is sufficient length of lead to allow the board to be pulled clear of the surrounding metalwork.

Be re-arranging the fixing bracket adjacent to TR3, the board can be fitted to the outside of the r.f. box for easy access to components.

Oscillators and output filters, boards A9 to A24 : these boards are contained in pairs, in cast boxes bolted on either side of the r.f. unit; oscillators on the left and output filters on the right. See Figs. 4.4 and 4.5. Access to the component side of each board may be obtained by removing the cover plate (secured by three screws) on the outside face of the appropriate box, as marked. To obtain access to the print side of a board, remove the screw and the two nuts that hold the board in position and swing it up and clear of the box. For oscillator, range H, also unsolder leads on tags.

Attenuator unit,, boards A27 and A28

To remove the attenuator unit :

a) Remove the attenuator scale plate (held by two screws).

b) Slacken the hexagon socket screws securing the attenuator knobs and pull them off.

c) Remove the four screws securing the attenuator box, two under each dial.

d) Disconnect the snap-on BNC plugs and sockets at the rear of the attenuator. The nut securing the 50 Ω output socket on the front panel should be loosened to avoid bending the stiff output cable.

e) Remove cleat securing counter output cable.

f) If the r.f. unit has already been removed from the chassis, the attenuator unit will be freed by extracting the two screws at each end which secure the bottom cross-rail of the chassis.

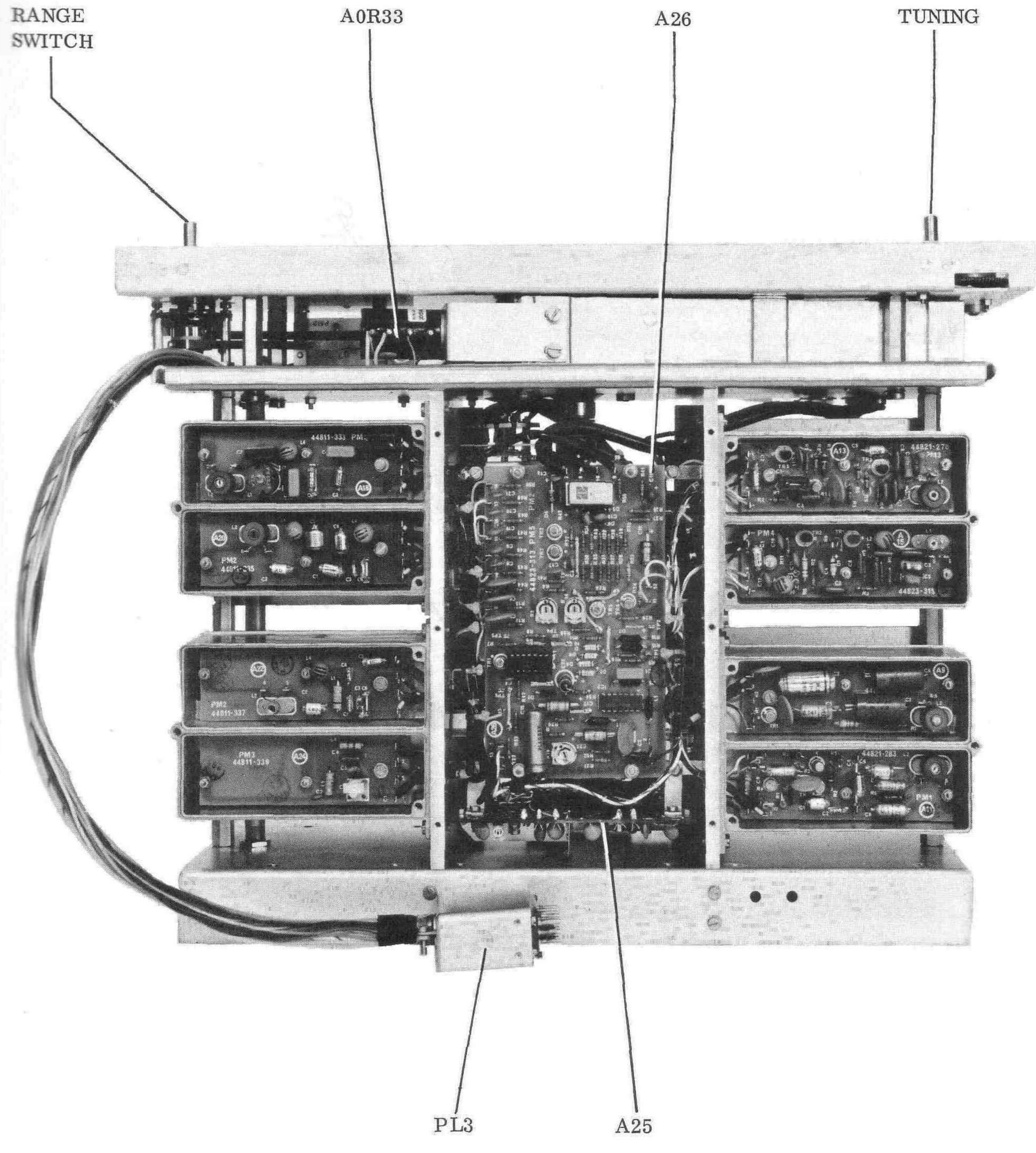


Fig. 4.4 R.F. unit with covers removed—top

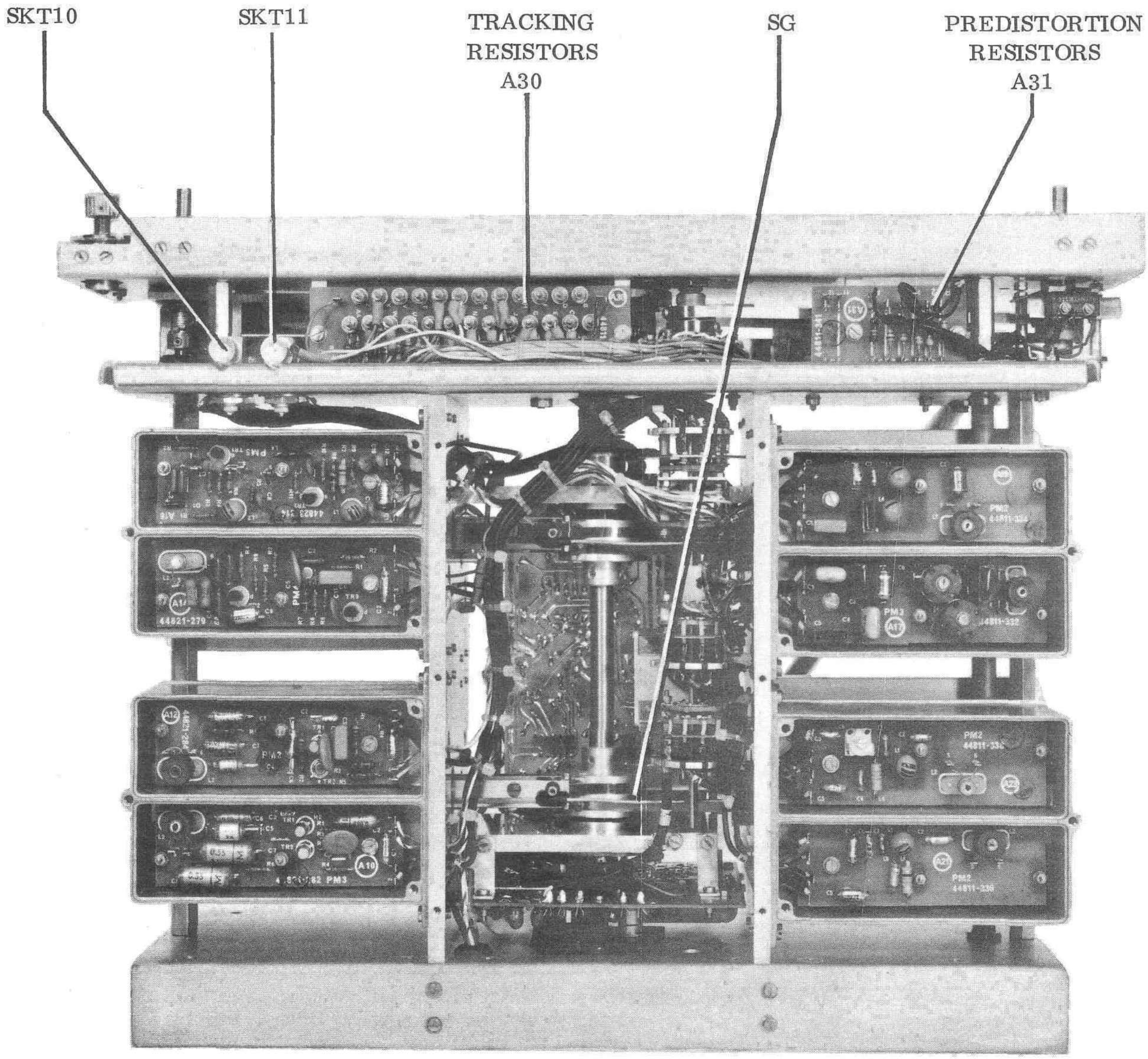


Fig. 4.5 R.F. unit with covers removed—bottom

To open the attenuator unit :

a) Slacken the four screws in slots at the rear of the side of the attenuator unit, and pull off rear cover.

b) Remove the six screws from the front of the attenuator unit and lift the coarse and fine attenuators out of the case.

c) Access to the individual attenuator components can be obtained by removing the twenty screws that secure the rectangular cover plate of each attenuator.

4.4 PRELIMINARY CHECKS

1) Check to ensure that all switches are undamaged and operating correctly and verify that connectors are securely mated.

2) Check that fuses are of the correct rating and type, not open circuit, and fit correctly in the holders.

3) Check using the multimeter (a) on low ohms range that electrical connections to chassis and earth points have low contact resistance.

4.5 TEST EQUIPMENT

The test equipment required for maintenance and repair of the instrument is listed in Table 4.1.

Table 4.1

Item	Description	Recommended model
a	Multimeter	Avo meter model 8 or GEC Selectest.
b	Oscilloscope	MI TF 2210 or equivalent.
c	Input Probes (2 off)	MI TM 8110, switchable x1 or x10.
d	Frequency Counter	Range up to 100 MHz, MI TF 2410 or equivalent.
e	Distortion Factor Meter	MI TF 2331 or equivalent.
f	AF Generator	Frequency range : up to 20 kHz. Output : up to 2 V. MI TF 1107 or equivalent.
g	Digital Voltmeter (DVM)	Range to 25 V - resolution 1 part 10^3.
h	Wave Analyser	MI TF 2330 or equivalent.
i	RF Voltmeter	MI TF 2603 (50 kHz to 1.5 GHz). MI TF 2600 (10 Hz to 500 kHz).

4.6 CIRCUIT PERFORMANCE

To ensure that the performance of TF 2002B is maintained, functional checks as given below, should be made to ascertain correct operation of the various circuits and where necessary adjustments, as given, should be made to obtain the required performance.

NOTE. If the results quoted in the following sections are not obtainable, refer to the related section in Chapter 5.

4.6.1 Power supply −15 V Board A1

1) With TF 2002B connected to the a.c. supply and switched on, connect the digital voltmeter (g) between tag 3 (negative) and chassis (positive) and check that the meter indicates 15 V ±150 mV. If necessary adjust R12 to obtain this requirement.

2) Apply the a.c. input through a variable voltage transformer and check that with inputs to the power supply of between 190 and 260 V the voltage between tag 3 and chassis is maintained to within ±20 mV.

If necessary, adjust R11 to obtain this requirement. If a substantial alteration of R11 has been necessary, recheck procedure (1).

3) Disconnect the digital voltmeter (g) and connect the wave analyser (h) between tag 3 and chassis, and check that at 100 Hz the ripple is not greater than 50 μV r.m.s.

Refer to Section 5.2.4.

4.6.2 –13.5 V Regulator Board A4

Connect the d.v.m. between tag 17 (negative) and pin 16 (positive) and check that the meter indicates 13.5 ±100 mV. If necessary, adjust R28 to obtain this requirement.

Remove the d.v.m. and connect the wave analyser between tag 17 and tag 16 and check that at 100 Hz the ripple is not greater than 10 μV r.m.s.

Refer to Section 5.2.5.

4.6.3 –6.75 V Regulator Board A4

Connect the d.v.m. between tag 6 (negative) and tag 16 (positive) and check that the meter indicates a voltage which is half (±60 mV) that at tag 17.

Refer to Section 5.2.6.

4.6.4 CW output checks

1) With TF 2002B connected to the a.c. supply and switched ON and with the CARRIER switch ON and the MODULATION switch at OFF, set the FUNCTION switch at CW and the CARRIER LEVEL at 1 V.

2) Connect the counter (d) to the COUNTER OUTPUT socket, check that the CRYSTAL CALIBRATOR selector is at OFF, then by switching to each frequency range in turn, check by counter indication and tuning that outputs are produced at several selected frequencies throughout each band.

Refer to Section 5.2.7.

3) With the INCREMENTAL FREQUENCY control and SET SCALE control centralized, check by counter indication that the frequency calibrations on MAIN TUNING scale are correct at the low and high frequency ends on each frequency range.

Refer to Section 5.2.8.

4) With the counter (d) connected, tune the signal generator in turn to frequencies 50 kHz, 200 kHz, 500 kHz, 2 MHz, 5 MHz, 20 MHz and 50 MHz (ranges B to H) then, using the appropriate Δf range, check that the INCREMENTAL FREQUENCY control provides the expected deviations at each set frequency.

Refer to Section 5.2.9.

4.6.5 RF output level

1) Using the r.f. voltmeter (i) connected to the 50 Ω output, set the attenuators at 0 dB, the 1 V/2 V switch at 1 V, the FUNCTION switch at CW and the CARRIER LEVEL control to position the pointer of the CARRIER LEVEL meter at 1 V.

2) Set the signal generator frequency in turn to 20 kHz, 50 kHz, 200 kHz, 500 kHz, 2 MHz, 5 MHz, 20 MHz and 50 MHz (ranges A to H) and check that the r.f. voltmeter (i) indicates 1 V at each frequency.

Refer to Section 5.2.10.

4.6.6 Crystal calibrator Board A6

Correct operation of the crystal calibrator can be proved as follows :

1) Centralize INCREMENTAL FREQUENCY control.

2) Connect the counter (d) to the counter output, set the CRYSTAL CAL selector at 1 MHz and tune the signal generator to obtain a null at 1 MHz. The counter should indicate 1 MHz ±100 Hz

3) Set the CRYSTAL CAL selector at 100 kHz and tune the signal generator between 1 MHz and 2 MHz and check that 10 marker pips are heard.

4) Set the CRYSTAL CAL selector at 10 kHz and tune the signal generator between 100 kHz and 200 kHz and check that 10 marker pips are heard.

Refer to Section 5.2.11.

4.6.7 Crystal calibrator amplifier and 1 kHz filter Board A5

The 1 kHz filter and the amplifier can be checked together using the internal a.f. oscillator as the signal source.

1) Connect a pair of headphones to the jack socket on front panel and the counter (d) to the MOD OSC OUTPUT terminals at the rear of the instrument.

2) Remove the plug from SKT3 and connect a 2.2 kΩ resistor between tags 4 and 10 and a 470 Ω resistor between pin 4 and chassis.

3) Tune the internal a.f. oscillator to 1 kHz using the counter as an indicator then check by listening with the headphones and by advancing the amplifier level control that the filter is tuned to provide a null.

Confirm this by varying the 1 kHz signal by ±100 Hz. The filter is designed to give a sharp null at 1 kHz; if this is not obtained, slightly adjust R13, R14 and L1 to obtain this requirement.

4) Remove resistors, counter and headphones and refit the plug to SKT3.

4.6.8 Modulation oscillator Boards A2 and A29

1) Connect the counter (d) to the MOD OSC OUTPUT terminals (rear of instrument).

2) Set the MODULATION switch at ON, the FREQUENCY selector at 200 - 630 and the MODULATION FREQUENCY scale at 20. The counter should then display 200 Hz.

3) If the frequency is incorrect adjust MODULATION FREQUENCY control by counter indication for 200 Hz then slacken the set screws securing the scale to the drive spindle and turn the scale until the 20 mark is under the cursor line.

4) Tighten the set screws and advance the MODULATION FREQUENCY control to set the scale at 63.

The counter should now indicate 630 Hz ±10%.

5) Remove the counter and connect the distortion factor meter (e) to the MOD OSC OUTPUT terminals. Set the oscillator at 400 Hz and check that signal distortion is not greater than 0.04%.

Refer to Section 5.2.12.

4.6.9 Checking a.m. depth

Amplitude modulation depth can be checked, with limitations, using an oscilloscope to measure the peak and trough amplitudes of the modulation envelope.

The procedure is given below and the results obtained are then applied to calculate the percentage by :

$$\%\,AM = \frac{Vp - Vt}{Vp + Vt} \times 100$$

Where Vp and Vt are the measured peak-to-peak and trough-to-trough amplitudes :

1) Connect the channel A input of the oscilloscope (b) to the 50 Ω output of TF 2002B, set the CARRIER and MODULATION switches at ON and the FUNCTION switch at INT. AM.

2) Tune TF 2002B to 1 MHz. Set the MODULATION OSCILLATOR at 400 Hz, the CARRIER LEVEL at 1 V, the MODULATION LEVEL at 50% and the TF 2002B attenuator to provide a suitable input to the oscilloscope.

3) Measure the peak-to-peak and trough-to-trough amplitudes, then use the formula given to check that the calibration accuracy of the modulation meter is within ±5% of the calculated result.

4) When making the above checks verify that the a.m. envelope is free of discernible distortion.

Refer to Section 5.2.13.

4.6.10 Checking f.m. deviation

FM deviation is preferably proved using a modulation meter, e.g. MI FM/AM Modulation Meter TF 2300.

However, for a quick performance check the disappearing carrier method (Bessel zero technique) which is given below, can be used.

1) Connect the counter (d) to the MOD OSC OUTPUT terminals (rear of instrument). Set the CARRIER switch at ON, the MODULATION switch at OFF, the FUNCTION switch at CW and the CARRIER LEVEL at 1 V.

2) With the INCREMENTAL FREQUENCY control, the SET ZERO and the FM/ Δ f FINE CAL controls centralized, tune the signal generator to approximately 6 MHz using the 1 MHz CRYSTAL CAL marker to provide, in conjunction with the CRYSTAL CAL LEVEL control, an audible beat tone of about 1 kHz.

3) Set the FUNCTION switch at INT FM, the MODULATION switch at ON, the MODULATION LEVEL control fully counter-clockwise and the FM

RANGE switch at 3 then, by counter indication, set the MODULATION OSCILLATOR at 4 kHz precisely.

4) Slowly advance the MODULATION LEVEL control until the beat tone disappears (i.e. a null point is obtained) the meter should then read 0.962 (top scale) which for f.m. range 3 indicates a deviation of 9.62 kHz.

5) If the INCREMENTAL FREQUENCY scale is standardized (Sect. 2.9) a deviation accuracy of better than ±5% can be obtained.

Refer to Section 5.2.14.

NOTE. To avoid distortion and consequent masking of the null point, the CRYSTAL CAL LEVEL control should not be advanced further than is necessary to provide an audible signal.

4.6.11 Checking f.m. tracking

Table 5.1 lists the r.f. check points and the following procedure which is given for RANGE B should be repeated for ranges C to H.

1) Connect the counter (d) to the COUNTER OUTPUT on TF 2002B.

2) Set the FUNCTION switch at CW, the CARRIER switch at ON, the MODULATION switch at OFF and the CARRIER LEVEL at 1 V.

3) Set the INCREMENTAL FREQUENCY control at 0, the Δf RANGE switch at 3 and the FINE CAL control (red knob) central (white mark up).

4) Set the r.f. by counter indication at 32 kHz then set the INCREMENTAL FREQUENCY control in turn, at +5 and -5.

The counter should indicate frequencies 32 kHz +500 Hz (±15%) and 32 kHz -500 Hz (±15%) respectively.

(5) Reset the INCREMENTAL FREQUENCY control at 0 then tune the generator to set the cursor at 500 on the top scale and note the frequency displayed by the counter.

6) Set the INCREMENTAL FREQUENCY control in turn, at +5 and -5 and check that the frequencies indicated by the counter are respectively 500 Hz (±15%) above and 500 Hz (±15%) below the noted frequency.

7) Reset the INCREMENTAL FREQUENCY control at 0, set the r.f. by counter indication at 100 kHz then set the INCREMENTAL FREQUENCY control in turn at +5 and -5.

The counter should indicate frequencies 100 kHz +500 Hz (±15%) and 100 kHz -500 Hz (±15%) respectively.

8) Reset the INCREMENTAL FREQUENCY control at 0 then proceed with checks on ranges C to H.

Refer to Section 5.2.15.

4.6.12 Checking a.l.c. system Board A26

Correct operation of the a.l.c. system can be quickly proved as follows :

1) Set the FUNCTION switch at CW and the CARRIER LEVEL at 1 V.

2) Switch to each FREQUENCY range in turn and tune the signal generator through each frequency band.

The indicated carrier level should be within ±0.5 dB of the 1 V mark on the carrier level meter at all frequencies.

Refer to Section 5.2.16.

4.6.13 External a.m. (a.c.) Board A3

Check as follows :

1) With the FUNCTION switch at EXT AM and with the CARRIER switch at ON and the MODULATION switch at OFF, set the CARRIER LEVEL at 1 V.

2) Using the external a.f. generator (f) apply a 1.2 V (maximum) 1 kHz signal between terminals EXT AM/LEVELLING and EARTH and check by varying the MODULATION LEVEL control that the modulation depth (indicated by the modulation meter) can be adjusted to 30% and 100%.

Refer to Section 5.2.13.

4.6.14 External levelling Board A3

To quickly prove the external levelling function proceed as follows :

Set the FUNCTION switch at EXT LEVELLING and the CARRIER LEVEL at 0.25 V (nominal) then temporarily short circuit the EXT AM LEVELLING terminal to EARTH terminal. The pointer of the CARRIER LEVEL meter should go to full-scale.

4.6.15 Attenuators (A27 and A28)

Provided the attenuator pads have not been damaged (see Sect. 2.15) it is only necessary to prove correct operation of the associated micro-switches and this can be satisfied by making a series of resistance measurements as follows :

1) With the CARRIER switch at OFF, connect the multimeter (a) set at low ohms range, to the 50 Ω output socket.

2) Set both attenuators at 0 dB and check that the multimeter indicates a resistance of 50 Ω ±2%.

3) Position the FINE ATTENUATOR in turn to each dB setting and check that the measured resistance at each setting is 50 Ω ±2%.

4) Return the FINE ATTENUATOR to 0 dB and repeat (3) for the COARSE ATTENUATOR, checking that the measured resistance at each setting is 50 Ω ±2%.

Refer to Section 5.2.17.

4.7 CLEANING ROTARY SWITCHES

These should be cleaned two or three times a year depending upon use. Only benzine or white spirit (not carbon tetrachloride) should be used. After cleaning, carefully wipe the contacts with a lubricant of 1% solution petroleum jelly in white spirit.

Chapter 5 Repair

5.1 INTRODUCTION

Since the functional checks given in Chapter 4 serve to localize the cause of incorrect performance of the instrument, this chapter contains information intended to assist to systematically trace the fault to the particular part of the suspect circuit.

The information given should be studied with reference to the circuit diagrams and illustrations contained within this manual, and it must be stated that any figures given in this chapter are for guidance only and are not intended to be accepted as true performance figures unless they are quoted in the Data Summary, Section 1.2.

5.2 FAULT LOCATION

5.2.1 Circuit voltages

Voltages given on the circuit diagrams, except when marked *, are those which can be expected using a 20 kΩ/V meter on a typical TF 2002B connected to an a.c. supply of 240 V, 50 Hz and set up as follows :

Frequency	1.8 MHz
Carrier level	1 V
AM frequency	1 kHz
AM depth	80%

Voltage levels marked * must be measured using a high impedance voltmeter, e.g. digital voltmeter (g).

5.2.2 Fault charts

The fault charts included in this chapter should be studied conjunctively, e.g. to trace an f.m. fault it is necessary to have proved correct operation of the Δf, crystal calibrator and c.w. circuits.

5.2.3 Waveforms

The test waveforms may vary slightly from the typical waveforms given for guidance and shown in Figs. 5.6 to 5.19.

5.2.4 Power supply –15 V

Circuit diagram Fig. 7.18, Board A1

a) Symptom : fuse FS1 or FS2 blows when instrument is switched on.

i) Check a.c. input circuit.

ii) Check unregulated d.c. circuit especially C1 (on chassis) for short circuit.

b) Symptom : no –15 V ±150 mV at tag 3.

i) Check a.c. input circuit especially FS1 and FS2 for open circuit.

ii) Check FS3 for continuity and D3, D4 for rectification.

iii) Check TR1 (rear panel) for open circuit and C3 (board 1) for short circuit.

c) Symptom : inability to correctly set 15 V ±150 mV.

i) Check TR1 and TR2 on board A1.

ii) Check R9, R12, R8, R11, R6.

iii) Check C1 for short circuit and then D1 for operation.

d) Symptom : 100 Hz ripple greater than 50 μV.

i) Check C1 (on chassis) for open circuit or low capacitance.

ii) Check C2, C3 on board A1 for open circuit or low capacitance.

5.2.5 –13.5 V regulator

Circuit diagram Fig. 7.18, Board A4.

a) Symptom : no –13.5 V or very low voltage at tag 17.

i) Using d.v.m. (g) check for 15 V ±150 mV at tag 18.

ii) Check C10 for short circuit.

iii) Check R1 and transistors in ICa2.

b) Symptom : inability to correctly set –13.5 V ±100 mV.

i) Check transistors in ICa2, ICb2 and transistor TR1.

ii) Check R27, R28, R29, R13 and D1.

iii) Check C3 for short circuit.

iv) If necessary change value of SIC resistor R31 (18 kΩ - 47 kΩ) to obtain required output.

5.2.6 -6.75 V regulator

Circuit diagram Fig. 7.18, Board A4.

a) Symptom : no -6.75 V or incorrect voltage at tag 6.

i) Using d.v.m. (g) verify d.c. levels ±5% as given on circuit diagram.

ii) Check C9 for short circuit.

iii) Check IC2a2, IC3b2 and transistor TR2.

5.2.7 CW outputs

NOTE. If the r.f. box is removed from the main structure but remains electrically connected for purpose of test and repair, a wired connection (earth return) must be made between the r.f. chassis and the instrument frame and SKT10 must be loaded with 50 Ω.

a) Symptom : unsatisfactory c.w. operation

Refer to fault finding chart Fig. 5.1.

5.2.8 Incorrect frequency coverage

Symptom : calibrations main tuning scale incorrect at low or high frequency ends of any selected range.

i) Set :

FUNCTION switch at CW.
INCREMENTAL FREQUENCY control at 0.
SET SCALE control at centre position (dot uppermost).

ii) With the counter (d) connected to TF 2002B adjust the FREQUENCY control to set the cursor coincident with the lowest frequency calibration on the selected range, then select a value for the related SIC capacitor (C5, C6 or C7 as appropriate) to correct the calibration.

iii) Adjust the FREQUENCY control to set the cursor coincident with the highest calibrated frequency on the selected range, then carefully adjust trimmer inductor (L1 or L2 as appropriate) to correct the calibration.

iv) Disconnect the counter and use the internal crystal calibrator to check the calibration accuracy at other points in the range.

5.2.9 Unsatisfactory Δf operation

Symptom : inability to obtain accurate frequency shifts.

Refer to fault finding chart Fig. 5.2.

5.2.10 Incorrect r.f. output level

Symptom : measured output voltage greater or less than 1 V with 1 V/2 V switch at 1 V and meter pointer at 1 V.

Refer to fault finding chart Fig. 5.1.

5.2.11 Unsatisfactory operation crystal calibrator, associated amplifier and 1 kHz filter

Symptoms : no marker pips, incorrect number of marker pips, incorrect operation 1 kHz filter.

Refer to fault finding chart Fig. 5.3.

5.2.12 Unsatisfactory operation of modulation oscillator

a) Symptom : calibration set correctly at 200 Hz (Sect. 4.6.8) but incorrect at 630 Hz.

With counter (d) connected to MOD OSC OUTPUT terminal, carefully adjust R7 and R8 in small equal steps for a frequency indication of 630 Hz ±10%. After setting the frequency, check that the adjustment has not impaired the amplitude bounce; if this has occurred slightly re-adjust R7 or R8 to minimize.

b) Symptom : signal distortion greater than 0.04% at 500 Hz.

With the distortion meter (e) connected to MOD OSC OUTPUT terminals, carefully adjust R2 for minimum distortion at 500 Hz.

c) See also fault finding chart Fig. 5.4.

5.2.13 Unsatisfactory a.m. function

Refer to fault finding chart Fig. 5.4.

5.2.14 Unsatisfactory f.m. function

Refer to fault finding chart Fig. 5.5.

5.2.15 Unsatisfactory f.m. tracking - Range B

a) Symptom : incorrect Δ f at 32 kHz.
i) Disconnect the WHITE lead (SG0f9) from board A30 then connect to any contact A to AA on A30 to obtain the required result.

b) Symptom : incorrect Δ f when cursor is set at 500 on top scale.

i) Disconnect the BLUE lead (SG1b8) from board A30 then connect to any contact A to AA on A30 to obtain the required result.

c) Symptom : incorrect Δ f at 100 kHz.

i) Disconnect the YELLOW lead (SG0b8) from board A30 then connect to any contact A to AA on A30 to obtain the required result.

Ranges C to H

Repeat a, b, c using Table 5.1 for identification of lead colour.

5.2.16 Unsatisfactory operation of a.l.c. system and/or envelope feedback circuit on Board A26

The cause of incorrect operation of the a.l.c. system can be localized using the oscilloscope (b) to check for expected waveforms at various points of the circuit.

i) Set the frequency of TF 2002B at 1.8 MHz and the carrier level at 1 V.

ii) Set the FUNCTION switch at INT AM, the MODULATION OSCILLATOR at 1 kHz and the a.m. depth at 80%, then proceed as follows :

a) Using probe (c - x10) connect the channel 1 input of the oscilloscope between the junction R36-D5 and earth and the channel 2 input between the junction R37-D6 and earth, and check that the waveforms are as Fig. 5.15 respectively.

b) Using probe (c - x1) connect the oscilloscope in turn to :

TP5 for waveform Fig. 5.16
TP6 for waveform Fig. 5.17
Tag 13 for waveform Fig. 5.18

c) Set the frequency of TF 2002B at 88 MHz then with the carrier level at 1 V and modulation as in (ii) check that the waveform is as Fig. 5.19.

5.2.17 Replacing attenuator resistors

If the attenuator resistors are required to be replaced, dismantle the attenuator unit by following the instructions given in Sect. 4.3, carefully fit the replacement resistors then check the attenuator units by following the procedure given in Sect. 4.6.15.

5.3 ADDITIONAL INFORMATION

If further information is required please write or telephone Marconi Instrument Limited, Service Division - see address on back cover - or contact nearest representative, quoting the type and serial number on the data plate on rear of instrument.

If the instrument is being returned for repair please indicate clearly the nature of the fault or the work you require to be done.

Table 5.1

Range	Freq/position	Switch tag	Lead colour
B	32 kHz	SG0f 9	WHITE
B	500 divs	SG1b 8	BLUE
B	100 kHz	SG0b 8	YELLOW
C	100 kHz	SG0b 6	ORANGE/BROWN
C	500 divs	SG1b 6	ORANGE/RED
C	320 kHz	SG0f 7	ORANGE
D	320 kHz	SG0f 5	WHITE/ORANGE
D	500 divs	SG1b 4	WHITE/RED
D	1000 kHz	SG0b 4	WHITE/BROWN
E	1 MHz	SG0b 2	GREEN/BROWN
E	500 divs	SG1b 2	GREEN/RED
E	3.2 MHz	SG0f 3	GREEN/ORANGE
F	3.2 MHz	SG0f 1	BLUE/ORANGE
F	500 divs	SG1b 21	BLUE/RED
F	10 MHz	SG0b 21	BLUE/BROWN
G	10 MHz	SG0b 19	BROWN
G	500 divs	SG1b 19	BLACK/RED
G	32 MHz	SG0f 22	BLACK/ORANGE
H	32 MHz	SG0f 20	GREY/ORANGE
H	500 divs	SG1b 17	GREY/RED
H	88 MHz	SG0b 17	GREY/BROWN

Leads to the wipers

SG0f 18	ORANGE
SG1b 13	RED
SG0b 13	BROWN

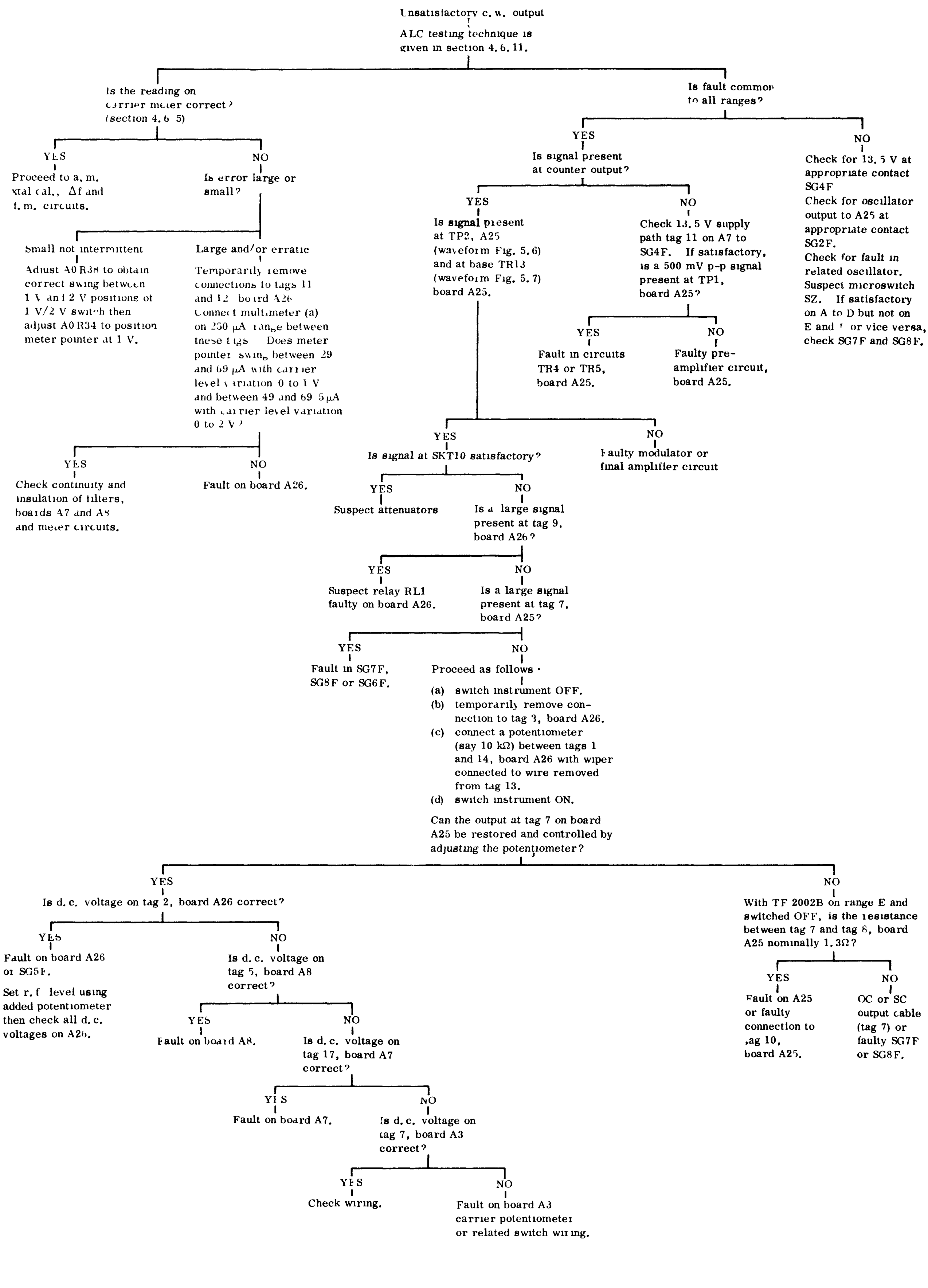


Fig. 5.1 Fault location in the c.w. signal path

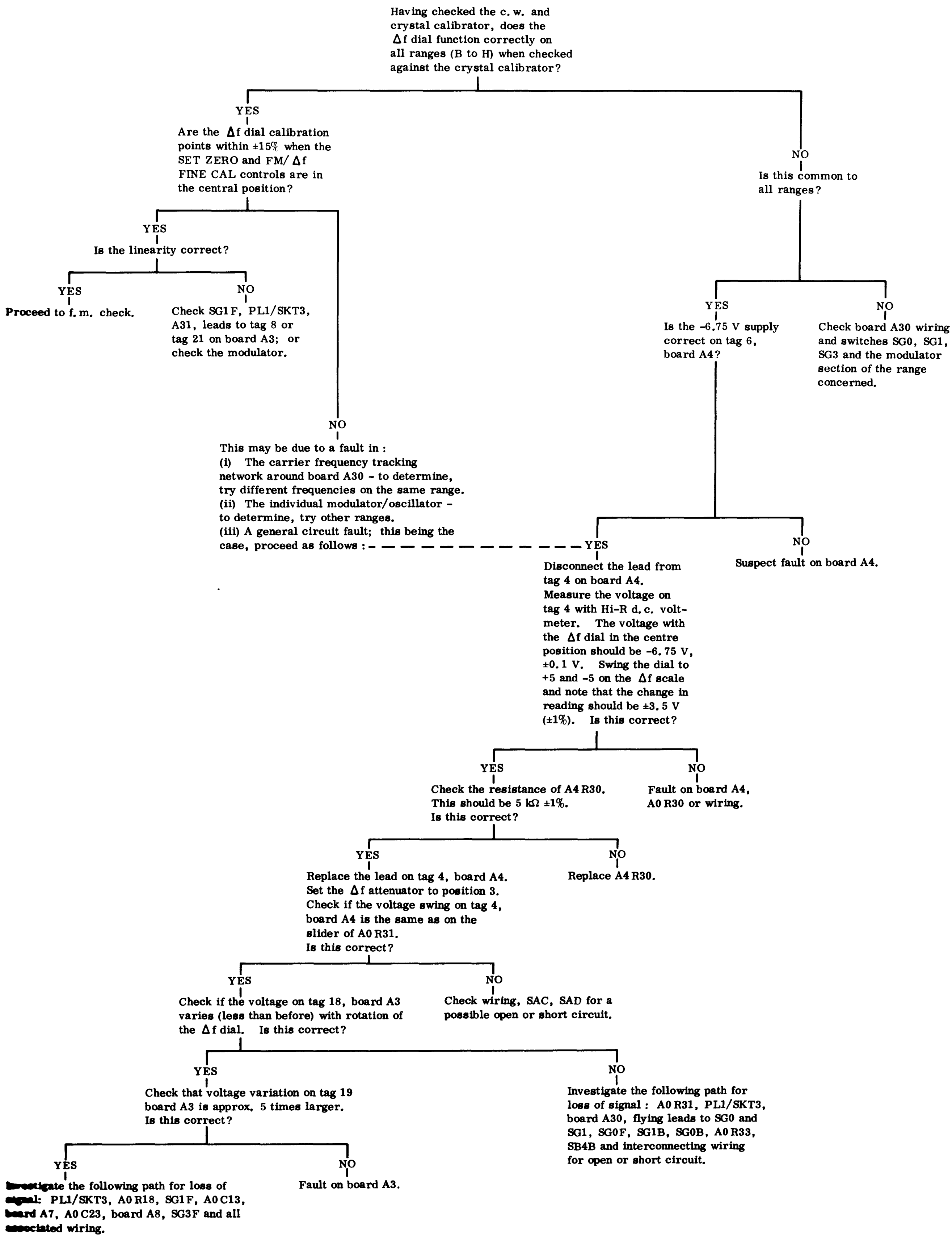


Fig. 5.2 Fault location in the Δf circuits

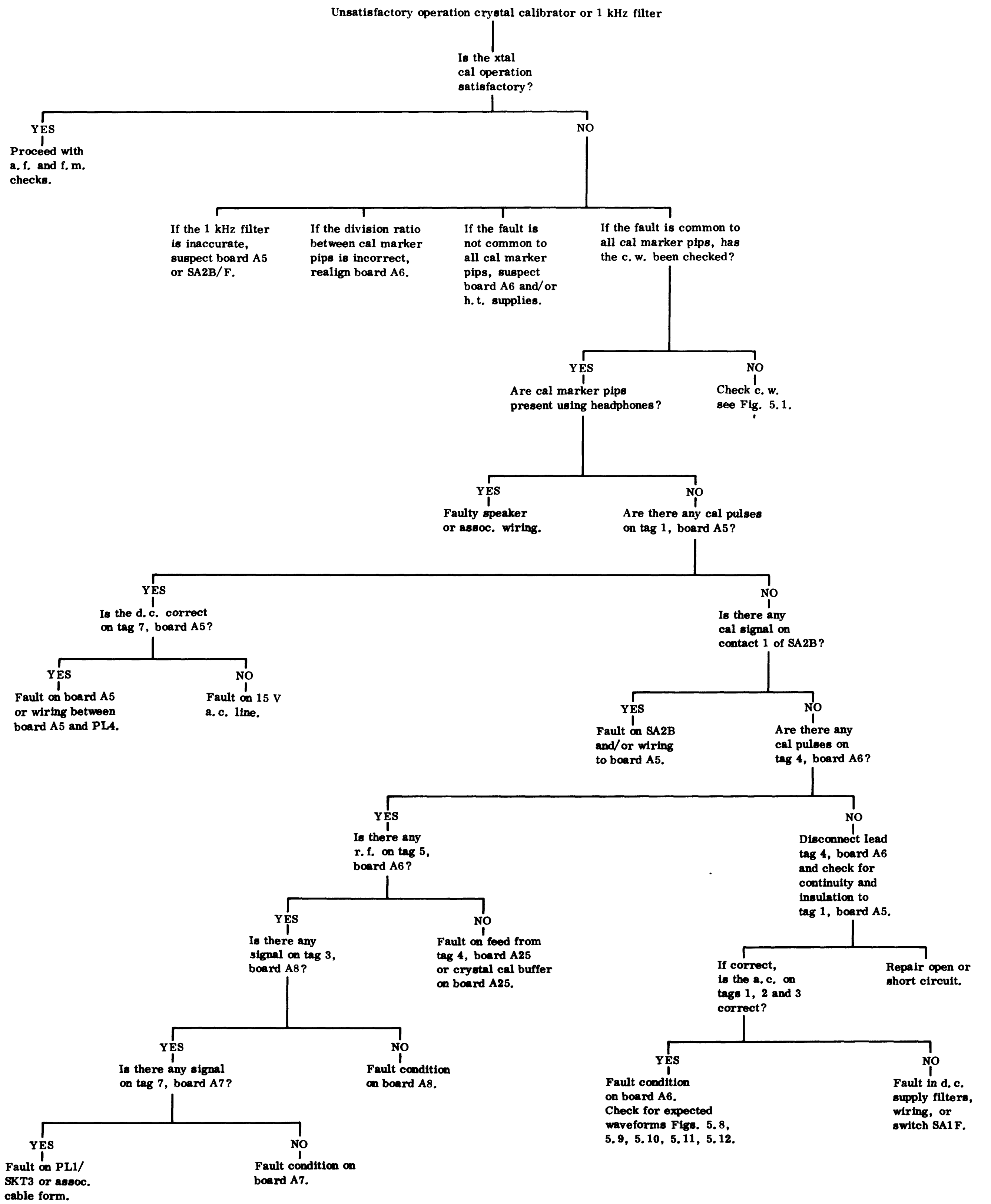


Fig. 5.3 Fault location in the crystal calibration circuits

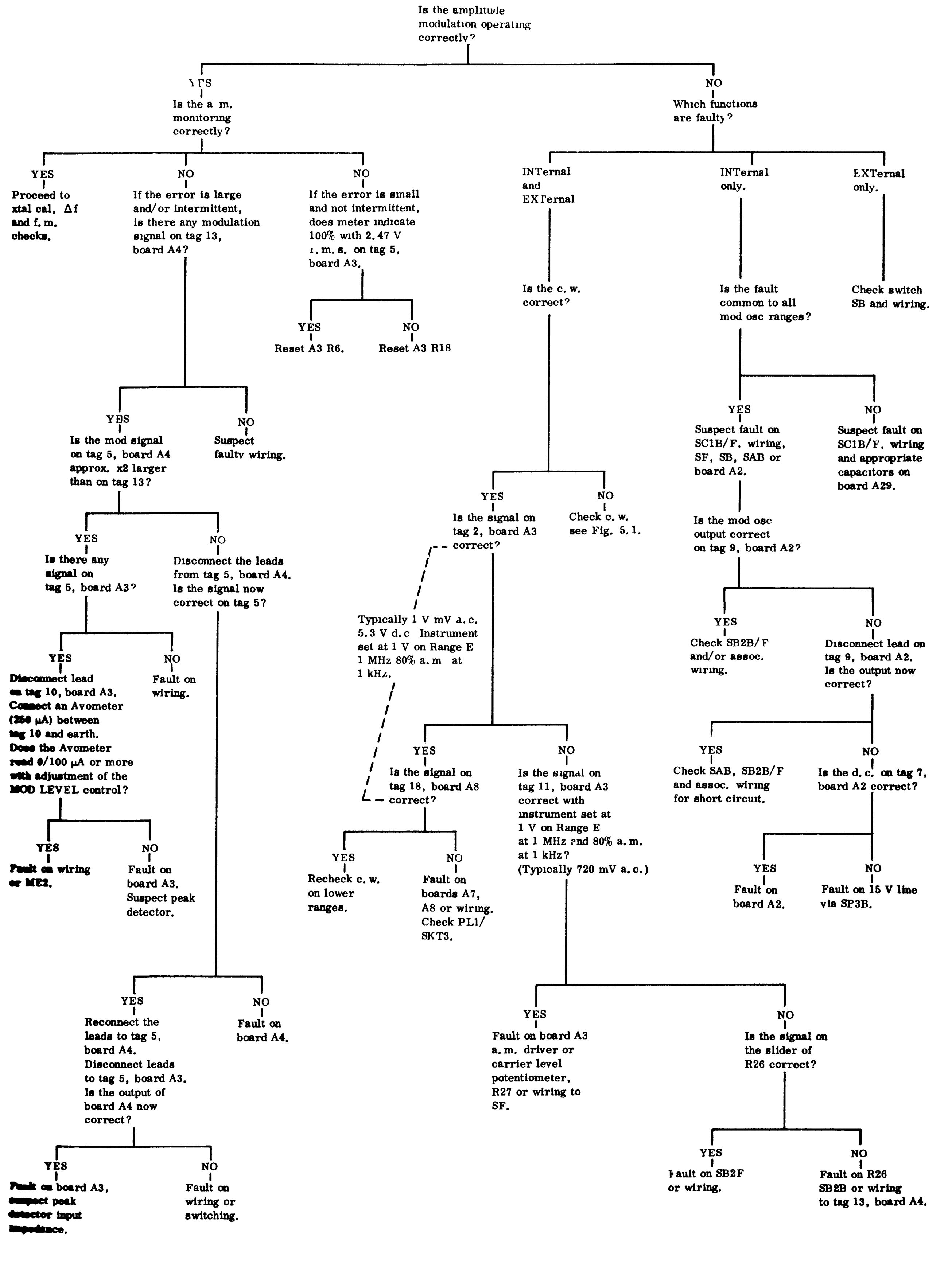


Fig. 5.4 Fault location in the a.m. circuits

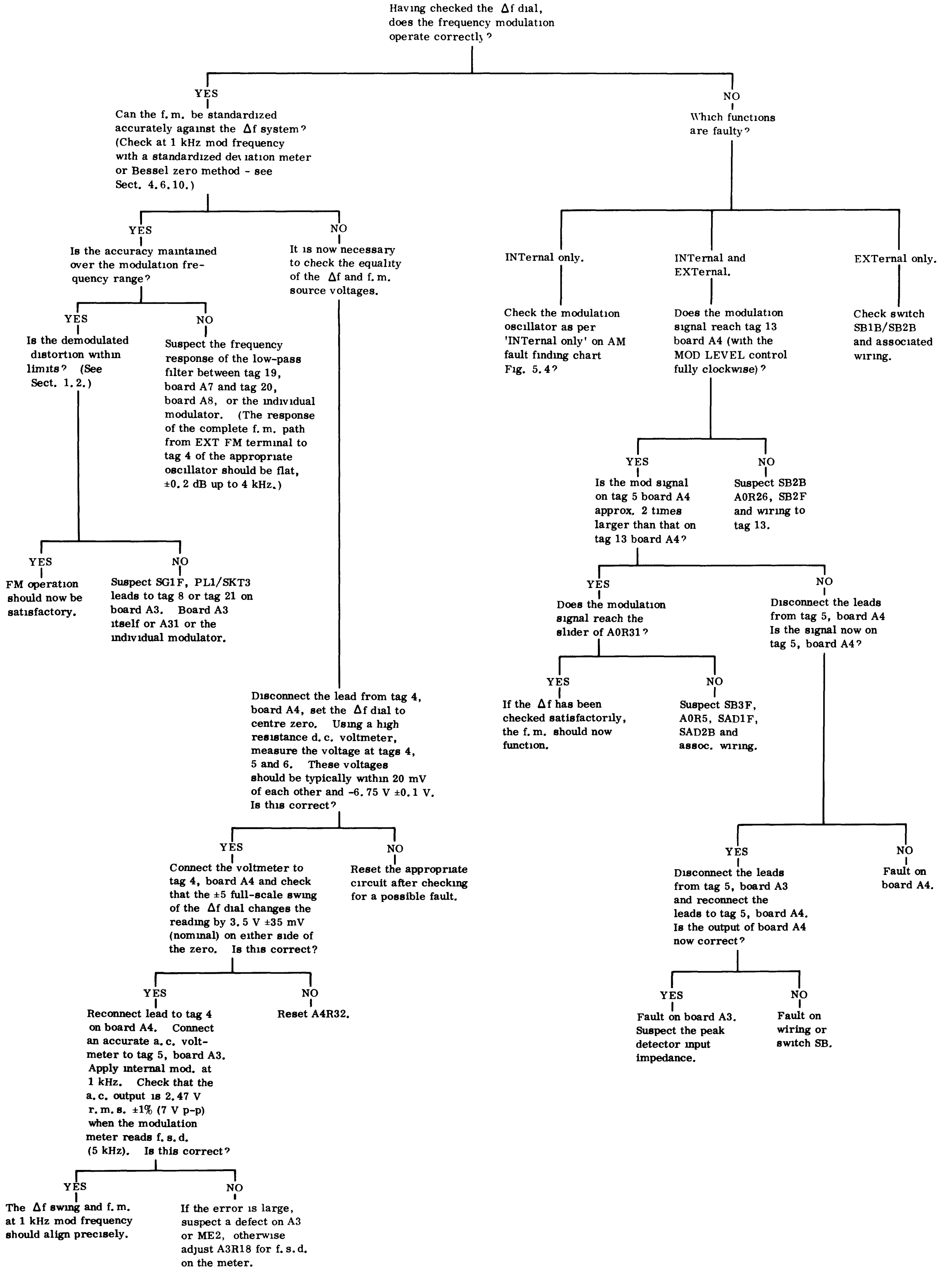


Fig. 5.5 Fault location in the f.m. circuits

WAVEFORMS

The waveforms shown in Figs. 5.6 to 5.19 were taken on a typical TF 2002B using a M.I. Oscilloscope type TF 2210 with an appropriate probe (see Chapter 6).

Test waveforms may vary slightly from the typical waveforms shown.

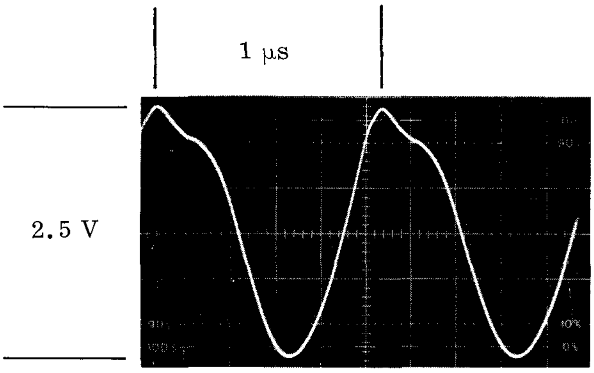


Fig. 5.6 A6—TP1

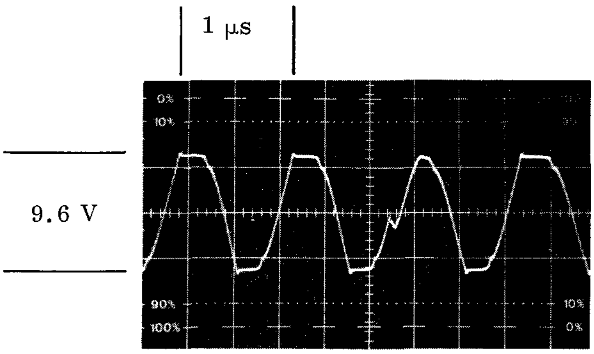


Fig. 5.7 A6—TP2

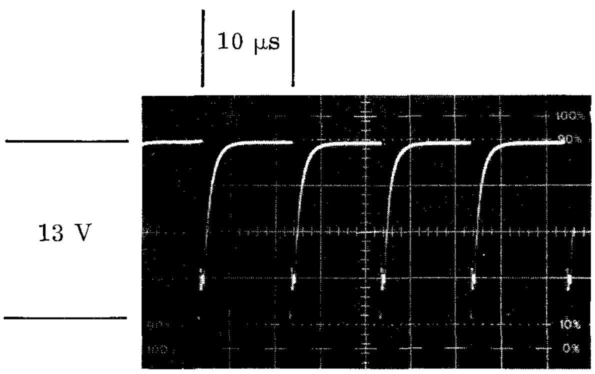


Fig. 5.8 A6—TP3

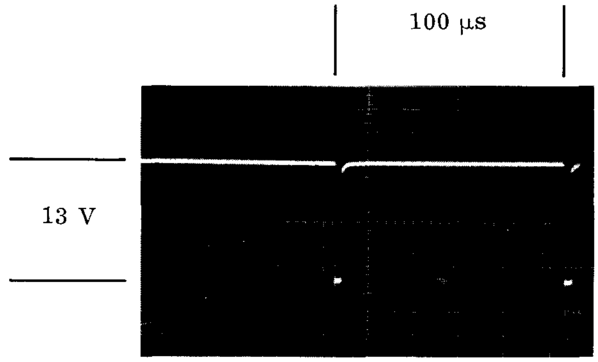


Fig. 5.9 A6—TP4

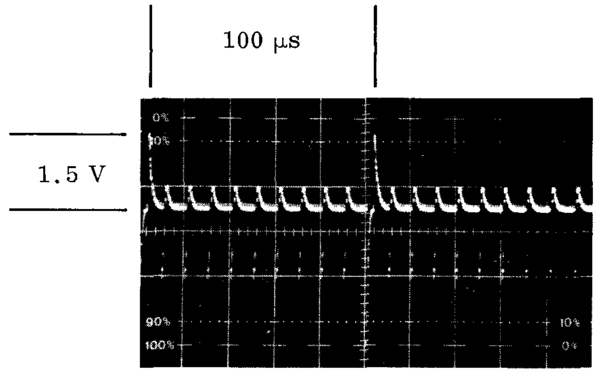


Fig. 5.10 A6 TR12 base

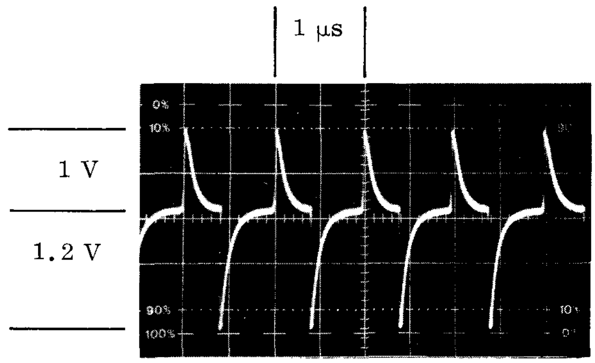


Fig. 5.11 A6 TR11 base

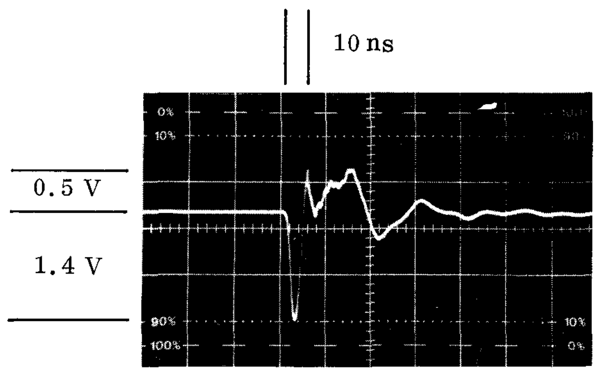


Fig. 5.12 A6 across L3

150 mV

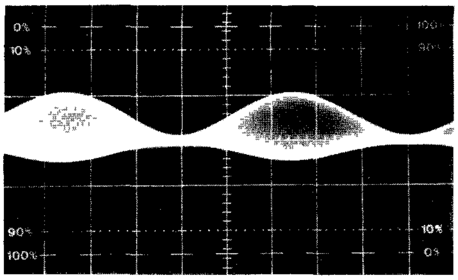


Fig. 5.13 A25—TP2

200 mV

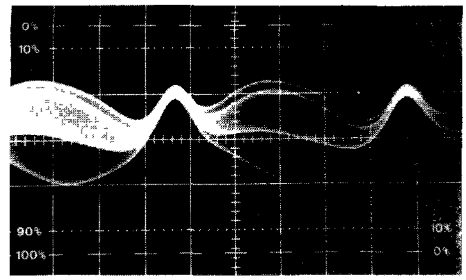


Fig. 5.17 A26—TP6

1.9 V

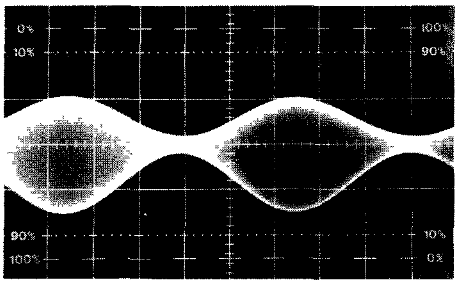


Fig. 5.14 A25—TR13 base

900 mV

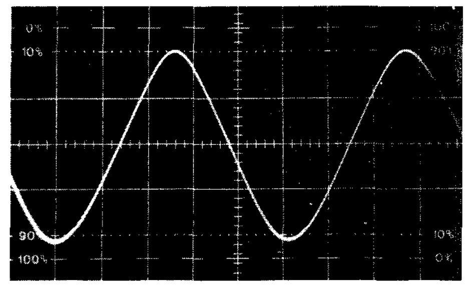


Fig. 5.18 A26—Tag 13

2.8 V

2.8 V

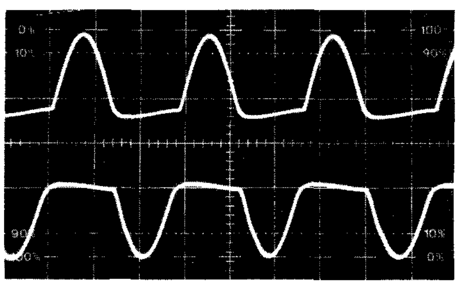


Fig. 5.15 A26 Junction R36—D5 (top)
Junction R37—D6 (bottom)

125 mV

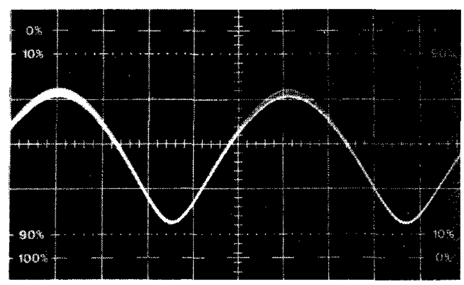


Fig. 5.19 A26—Tag 13 (TF 2002B at 88 MHz)

2.2 V

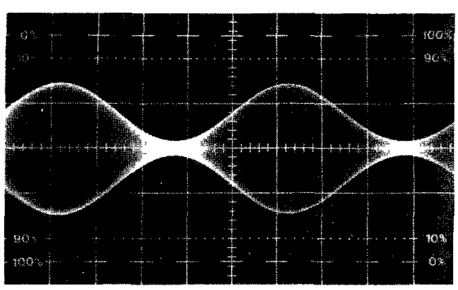


Fig. 5.16 A26—TP5

Unless stated otherwise the measurement was made between the point given and the related earth connection.

Except for waveform Fig. 5.19 all measurements were made with TF 2002B at 1.8 MHz. For modulated waveforms use 1 kHz at 80% depth.

Chapter 6 Replaceable parts

Introduction

Each sub-assembly or printed circuit board in this instrument has been allocated a unit identification in the sequence A0 to A31.

The complete component reference carries its unit number as a prefix e.g. A1C1 but for convenience in the text and on circuit diagrams the prefix is not used.

However, when ordering replacements or in correspondence the complete component reference must be quoted.

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

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

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

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

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

When ordering replacements, address the order to our Service Division (address on rear cover) or nearest agent and specify the following for each component required.

(1) Type* and serial number of instrument

(2) Complete circuit reference

(3) Description

(4) M.I. code number

* as given on the serial 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.

COMPONENT REFERENCES

The components are listed in alphanumerical order and the following abbreviations are used:

C	: capacitor
Carb	: carbon
Cer	: ceramic
Cerm	: cermet
D	: semiconductor diode
Elec	: electrolytic
FS	: fuse
IC	: integrated circuit (package)
L	: inductor
Max	: maximum
ME	: meter
Met	: metal
Mic	: mica
Min	: minimum value
Ox	: oxide
PL	: plug
PLAS	: plastic dielectric
R	: resistor
S	: switch
SK	: socket
T	: transformer
TP	: terminal
TR	: transistor
WW	: wirewound
X	: crystal oscillator
†	value selected during test; nominal value listed
∅	: feed-through component
W	: watts at 70°C
W*	: watts at 55°C
W**	: watts at 40°C
W***	: watts at 20°C
W°	: watts at unspecified temperature
⚠	: static sensitive device

Circuit reference	Description	M.I. code

Unit A0

When ordering, prefix circuit reference with A0.

C1	Elec 3600µF -20+50% 50V	26427-134
C3	Elec 4.7µF 20% 35V	26486-219
C4 to C11	Cer ∅ 0.0047µF -20+80% 500V	26373-665
C12	Cer ∅ 39pF 20% 500V	26333-308
C13	Cer ∅ 500pF 25% 500V	26373-609
C14 to C21	Cer ∅ 0.0047µF -20+80% 500V	26373-665

Circuit reference	Description	M.I. code
C22	Cer ∅ 39pF 20% 500V	26333-308
C23	Cer ∅ 500pF 25% 500V	26373-609
C24 to C27	Cer ∅ 0.0047μF -20+80% 500V	26373-665
D1	1N4148	28336-676
FS1	160mA 230V	23411-054
FS2	350mA 115V	23411-055
FS3	500mA	23411-056
JKA	Crystal cal output	23421-662
L2	Inductor assembly	44223-801
L3	Inductor assembly	44223-801
L4	Inductor assembly	44223-801
L5	Inductor assembly	44223-801
L7	Ferrite beads	23635-833
L8	Ferrite beads	23635-833
L51	70Ω	23646-103
ME1	100μA	44572-228
ME2	100μA	44579-003
PL7	Panel plug	23423-159
R1	Met ox 560Ω 2% ½W	24573-067
R2	Met ox 82kΩ 2% ½W	24573-119
R4	Met ox 100kΩ 2% ½W	24573-121
R5	Met ox 5kΩ 0.5% ½W	24753-878
R6	Carb 6.111kΩ 1% ¼W	24138-724
R7	Carb 9.625kΩ 1% ¼W	24138-734
R8	Carb 7.115kΩ 1% ¼W	24138-728
R9	Carb 2.475kΩ 1% ¼W	24138-785
R10	Carb 9.625kΩ 1% ¼W	24138-734
R11	Carb 6.111kΩ 1% ¼W	24138-724
R12	Carb 6.111kΩ 1% ¼W	24138-724
R13	Carb 9.625kΩ 1% ¼W	24138-734
R14	Carb 7.115kΩ 1% ¼W	24138-728
R15	Carb 24.75kΩ 1% ¼W	24138-785
R16	Carb 9.625kΩ 1% ¼W	24138-734
R17	Carb 6.111kΩ 1% ¼W	24138-724
R18	Met film 1.15kΩ 0.5% ½W	24755-481
R19	Met ox 5kΩ 0.5% ½W	24753-878
R20	Met ox 220Ω 2% ½W	24573-054
R21	Met ox 10kΩ 2% ½W	24573-097
R22	Met ox 820kΩ 2% ½W	24573-143
R24	Met ox 15kΩ 2% ½W	24573-101
R25a	Var WW 16kΩ 2% 4W	25874-578

Circuit reference	Description	M.I. code
R25b	Var WW 16kΩ 2% 4W	25874-578
R26	2.5kΩ part of switch assy SC	44324-716
R27	1kΩ part of switch assy SB	44340-016
R28	Var carb 4.7kΩ 20% ¼W	25611-176
R29	50kΩ part of switch assy SAC	44322-131
R30	WW 2.5kΩ 10% 3W	44371-247
R31	2.2kΩ part of switch assy SAD	44322-419
R32	100kΩ part of switch assy SA	44324-219
R33	WW 100kΩ 5% 1½W	44372-015
R34	Var carb 47kΩ 20% ¼W	25611-182
SA	Switch assy including R32	44324-219
SB	Switch assy including R27	44340-016
SC	Switch assy including R26	44324-716
SD	Switch assy	44321-406
SE	Switch slider	23467-155
SF	Switch DPDT	23462-258
SG	Switch assy	44325-609
SAA	Switch DPDT	23462-258
SAB	Switch SPDT	23462-252
SAC	Switch assy including R29	44327-131
SAD	Switch assy including R31	44322-419
SK3	18 way	23435-293
SKT10	Bulkhead elbow socket	23445-273
SKT11	Bulkhead elbow socket	23445-273
SKT12	Receptacle BNC 50Ω	23443-443
TP1	Terminal miniature	23235-176
TP2	Terminal miniature	23235-176
TP3	Terminal miniature	23235-176
TP4	Terminal miniature	23235-179
TP5	Terminal miniature	23235-176
TP8	Terminal miniature	23235-177
TP9	Terminal miniature	23235-176
TP10	Terminal miniature	23235-176
T1	Mains transformer	43456-006
TR1	MJ491	28435-876

Unit A1 — Power supply —15 V

When ordering, prefix circuit reference with A1.

Circuit reference	Description	M.I. code
C1	Elec 100μF -20+100% 40V	26415-814
C2	Elec 100μF -20+100% 25V	26415-813
C3	Elec 100μF -20+100% 25V	26415-813
C4	Plas 0.1μF 10% 100V	26582-211
C5	Plas 0.1μF 10% 100V	26582-211
C6	Cer 0.1μF -25+50% 30V	26383-031

Circuit reference	Description	M.I. code
D1	Z5B 7.5V Zener	28371-603
D2	1N404	28357-028
D3	1N404	28357-028
D4	1N404	28357-028
R1	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R2	WW 1.5Ω 5% 1$\frac{1}{2}$W	25123-002
R3	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R4	Met ox 6.8kΩ 2% $\frac{1}{2}$W	24573-093
R5	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R6	Met ox 3.9kΩ 2% $\frac{1}{2}$W	24573-087
R7	Met ox 1.8kΩ 2% $\frac{1}{2}$W	24573-079
R8	Met ox 75kΩ 2% $\frac{1}{2}$W	24573-118
R9	Met ox 2.2kΩ 2% $\frac{1}{2}$W	24573-081
R10	Met ox 2.7kΩ 2% $\frac{1}{2}$W	24573-083
R11	Var carb 220kΩ 20% $\frac{1}{4}$W	25611-086
R12	Var carb 470Ω 20% 1W	25811-012
TR1	2N2905	28434-879
TR2	2N2905	28434-879
	Bead insulator	23213-146

Unit A2 —Modulation Oscillator

When ordering, prefix circuit reference with A2.

C1	Elec 47μF -20 +100% 40V	26415-810
C2	Elec 47μF -20 +100% 40V	26415-810
C3	Elec 470μF -20 +100% 25V	26415-822
C4	Plas 1000pF 2% 125V	26516-481
C5	Elec 47μF -20 +100% 40V	26415-810
C6	Elec 470μF -20 +100% 25V	26415-822
R1	Met ox 10kΩ 2% $\frac{1}{2}$W	24573-097
R2	Var carb 100kΩ 20% $\frac{1}{4}$W	25611-084
R3	Met ox 47kΩ 2% $\frac{1}{2}$W	24573-113
R4	Met ox 22kΩ 2% $\frac{1}{2}$W	24573-105
R5	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R6	Met ox 5.6kΩ 2% $\frac{1}{2}$W	24573-091
R7	Var carb 2.2kΩ 20% $\frac{1}{4}$W	25611-074
R8	Var carb 2.2kΩ 20% $\frac{1}{4}$W	25611-074
R9	Met ox 5.1kΩ 2% $\frac{1}{2}$W	24573-090
R10	Met ox 10kΩ 2% $\frac{1}{2}$W	24573-097
R11	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R12	Met ox 33Ω 2% $\frac{1}{2}$W	24573-037
R13	Thermistor 10kΩ 20%	25683-389
R14	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R15	Met ox 47Ω 2% $\frac{1}{2}$W	24573-041
R16	Met ox 100kΩ 2% $\frac{1}{2}$W	24573-121
R17	Met ox 5.1kΩ 2% $\frac{1}{2}$W	24573-090
TR1	BF244B	28459-011
TR2	BCY71	28435-235
TR3	BC108	28452-787

Unit A3 —A.M./F.M. Drive and Monitor

When ordering, prefix circuit reference with A3.

C1	Elec 47μF -20 +100% 40V	26415-810
C2	Plas 1μF 10% 63V	26582-414
C3	Cer 0.047μF -25 +50% 30V	26383-018
C4	Cer 0.1μF -25 +50% 30V	26383-031
C5	Cer 22pF 20% 500V.	26343-134
C6	Cer 0.1μF -25 +50% 30V	26383-031
C7	Elec 220μF -20 +100% 10V	26415-817
C8	Elec 10μF 20% 20V	26488-212
C9	Elec 4.7μF 20% 35V	26486-219
C10	Cer 0.1μF -25 +50% 30V	26383-031
C11	Elec 10μF 20% 20V	26488-212
D1	1N4148	28336-676
D2	1N4148	28336-676
D3	1N4148	28336-676
D4	1N4148	28336-676
D5	1N4148	28336-676
D6	1N4148	28336-676
D9	1N4148	28336-676
D10	1N4148	28336-676
IC1	μA739	28461-312
IC2	μA741C	28461-304
R1	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R2	Met ox 2.7kΩ 2% $\frac{1}{2}$W	24573-082
R3	Met ox 2kΩ 2% $\frac{1}{2}$W	24573-080
R4	Met ox 2.2kΩ 2% $\frac{1}{2}$W	24573-081
R5	Carb 2.2MΩ 10% 1/6W	24322-974
R6	Var WW 4.7kΩ 10% 1W	25811-023
R7	Met ox 8.2kΩ 2% $\frac{1}{2}$W	24573-095
R8	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R9	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R10	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R11	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R12	Met ox 10Ω 2% $\frac{1}{2}$W	24573-025
R13	Met ox 13kΩ 2% $\frac{1}{2}$W	24573-100
R14	Met ox 150Ω 2% $\frac{1}{2}$W	24573-053
R15	Met ox 16kΩ 2% $\frac{1}{2}$W	24573-102

Circuit reference	Description	M.I. code
R16	Met ox 16kΩ 2% $\frac{1}{2}$W	24573-102
R17	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R18	Var carb 470Ω 20% $\frac{1}{4}$W	25611-070
R19	Met ox 3.3kΩ 2% $\frac{1}{2}$W	24573-085
R20	Met ox 47kΩ 2% $\frac{1}{2}$W	24573-113
R24	Met ox 22kΩ 2% $\frac{1}{2}$W	24573-105
R25	Met ox 220kΩ 2% $\frac{1}{2}$W	24573-129
R26	Met ox 150Ω 2% $\frac{1}{2}$W	24573-053
R27	Met ox 24kΩ 2% $\frac{1}{2}$W	24573-106
R28	Met ox 27kΩ 2% $\frac{1}{2}$W	24573-107
R29 †	Met film 100kΩ 2% $\frac{1}{4}$W	24773-321
R30 †	Met film 220kΩ 2% $\frac{1}{4}$W	24773-324
TR4	BC109	28452-777

Unit A4 ΔF Control Supply and Monitor Amp.

When ordering, prefix circuit reference with A4.

Circuit reference	Description	M.I. code
C1	Cer 0.01μF -20+80% 100V	26383-055
C2	Cer 22pF 20% 500V	26343-134
C3	Elec 47μF -20+100% 63V	26415-801
C4	Cer 0.1μF -20+50% 30V	26383-031
C5	Cer 18pF 20% 500V	26343-129
C6	Cer 0.1μF -20+50% 30V	26383-031
C7	Cer 0.1μF -20+50% 30V	26383-031
C8	Elec 10μF -20+100% 63V	26415-802
C9	Elec 1000μF -20+100% 10V	26415-824
C10	Elec 100μF -20+100% 25V	26415-813
C12	Cer 820pF -20+40% 400V	26383-142
D1	1N825	28371-494
D2	1N4148	28336-676
D3	1N4148	28336-676
D4	OA95	28323-287
D5	OA95	28323-287
IC1	CA3046	28461-901
IC2	CA3046	28461-901
IC3	μA739	28461-312
R1	Met ox 8.2Ω 5% $\frac{1}{2}$W	24552-018
R2	Met ox 18Ω 2% $\frac{1}{2}$W	24573-031
R3	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R4	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R5	Met ox 330Ω 2% $\frac{1}{2}$W	24573-061
R6	Met ox 22kΩ 2% $\frac{1}{2}$W	24573-105
R7	Met ox 5.6 kΩ 2% $\frac{1}{2}$W	24573-091
R8	Met ox 390Ω 2% $\frac{1}{2}$W	24573-063
R9	Met ox 18Ω 2% $\frac{1}{2}$W	24573-025
R10	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R11	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R12	Met ox 10kΩ 2% $\frac{1}{2}$W	24573-097
R13	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R14	Met film 10kΩ 0.5% $\frac{1}{2}$W	24753-893
R15	Met film 10kΩ 0.5% $\frac{1}{2}$W	24753-893
R16	Met ox 8.2kΩ 2% $\frac{1}{2}$W	24573-095
R17	Met ox 33kΩ 2% $\frac{1}{2}$W	24573-109
R18	Met ox 8.2kΩ 2% $\frac{1}{2}$W	24573-095
R19	Met ox 33kΩ 2% $\frac{1}{2}$W	24573-109
R20	Met ox 470Ω 2% $\frac{1}{2}$W	24573-065
R21	Met ox 33kΩ 2% $\frac{1}{2}$W	24573-109
R22	Met ox 15kΩ 2% $\frac{1}{2}$W	24573-101
R23	Met ox 33kΩ 2% $\frac{1}{2}$W	24573-109
R24	Met ox 15kΩ 2% $\frac{1}{2}$W	24573-101
R25	Met ox 22kΩ 2% $\frac{1}{2}$W	24573-105
R26	Met ox 8.2kΩ 2% $\frac{1}{2}$W	24573-095
R27	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R28	Var WW 220Ω 20% 1W	25811-015
R29	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R30	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R31 †	Met ox 27kΩ 2% $\frac{1}{2}$W	24573-107
R32	Var WW 1kΩ 20% 1W	25811-109
R33	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R34	Met ox 6.8kΩ 2% $\frac{1}{2}$W	24573-093
R35 †	Met ox 4.7kΩ 2% $\frac{1}{2}$W	24573-089
R36 †	Met ox 680kΩ 2% $\frac{1}{2}$W	24573-141
R37	Met ox 680kΩ 2% $\frac{1}{2}$W	24573-141
R38 †	Met film 100kΩ 2% $\frac{1}{4}$W	24773-321
TR1	BCY72	28433-487
TR2	BCY72	28433-487

Unit A5 —Crystal Calibrator Amplifier

When ordering, prefix circuit reference with A5.

Circuit reference	Description	M.I. code
C1	Elec 4.7μF -20 +100% 63V	26415-801
C2	Elec 4.7μF -20 +100% 63V	26415-801
C3	Elec 4.7μF -20 +100% 63V	26415-801
C4	Elec 100μF -20 +100% 25V	26415-813
C5	Elec 4.7μF -20 +100% 63V	26415-801
C6	Plas 0.47μF 10% 63V	26582-410
C7	Elec 47μF -20 +100% 10V	26415-809
C8	Elec 22μF -20 +100% 25V	26415-805
C9	Plas 0.047μF 0.5% 125V	26516-820
C10	Plas 0.047μF 0.5% 125V	26516-820
L1	Coil assy	44273-607

Circuit reference	*Description*	*M.I. code*
R1	Met ox 47kΩ 2% $\frac{1}{2}$W	24573-113
R2	Met ox 47kΩ 2% $\frac{1}{2}$W	24573-113
R3	Met ox 10kΩ 2% $\frac{1}{2}$W	24573-097
R4	Met ox 10kΩ 2% $\frac{1}{2}$W	24573-097
R5	Met ox 3.3kΩ 2% $\frac{1}{2}$W	24573-085
R6	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R7	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R8 †	Met ox 470kΩ 2% $\frac{1}{2}$W	24573-137
R9	Met ox 1kΩ 2% $\frac{1}{2}$W	24573-073
R10	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R11	Met ox 22kΩ 2% $\frac{1}{2}$W	24573-105
R12	Met ox 330Ω 2% $\frac{1}{2}$W	24573-061
R13	Var carb 4.7k 20% $\frac{1}{4}$W	25611-076
R14	Var carb 470Ω 20% $\frac{1}{4}$W	25611-070
TR1	BCY72	28433-487
TR2	BSX20	28452-197
TR3	BCY71	28435-235

Unit A6 —Crystal Calibrator

When ordering, prefix circuit reference with A6.

Circuit reference	*Description*	*M.I. code*
C1	Elec 10μF -20 +100% 63V	26415-802
C2	Plas 27pF ±2pF 125V	26516-108
C3	Plas 470pF 2% 125V	26516-406
C4	Plas 0.0022μF 2% 125V	16516-564
C5	Plas 470pF 2% 125V	26516-406
C6	Plas 22pF ±2pF 125V	26516-088
C7	Plas 0.0028pF 2% 125V	26516-591
C8	Plas 0.01μF 10% 630V	26555-463
C9	Cer 0.1μF -25 +50% 30V	26383-031
C10	Plas 180pF 2% 125V	26516-303
C11	Cer 0.01μF -20 +80% 100V	26383-055
C12	Plas 150pF 2% 125V	26516-287
C13	Cer 22pF ±0.25pF 750V	26324-715
C14	Plas 82pF ±2pF 125V	26516-108
C15	Plas 22pF ±2pF 125V	26516-088
C16	Plas 0.001μF 2% 125V	26516-481
C17	Plas 110pF 2% 125V	26516-254
C18	Plas 0.001μF 2% 125V	26516-481
C19	Plas 390pF 2% 125V	26516-387
C20	Elec 10μF -20 +100% 63V	26415-802
C21	Cer 0.1μF -25 +50% 30V	26383-031
C22	Plas 220pF 2% 125V	26516-718
C23	Plas 220pF 2% 125V	26516-327
C24	Elec 10μF -20 +100% 63V	26415-802
C25	Cer 0.01μF -20 +80% 100V	26383-055
C26	Cer 22pF 0.25pF 750V	26324-715
C27	Cer 0.1μF -25 +50% 30V	26383-031
C28	Plas 120pF 2% 125V	26516-264
C29	Cer 0.1μF -25 +50% 30V	26383-031
C30	Var air 3-14.5pF	26816-236
D1	1N916	28336-466
D2	1N916	28336-466
D3	1N916	28336-466
D4	1N916	28336-466
D5	1N916	28336-466
D6	1N916	28336-466
D7	1N916	28336-466
L1	63.5 μH	44264-210
L2	237μH	44266-217
L3	Coil	44227-019
L4	470μH	23642-565
L5	470μH	23642-565
L6	470μH	23642-565
L7	470μH	23642-565
R1	Met ox 24kΩ 2% $\frac{1}{2}$W	24573-106
R2	Met ox 9.1kΩ 2% $\frac{1}{2}$W	24573-096
R3	Met ox 2kΩ 2% $\frac{1}{2}$W	24573-080
R4	Met ox 47Ω 2% $\frac{1}{4}$W	24511-537
R5	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R6	Met ox 560Ω 2% $\frac{1}{2}$W	24573-067
R7	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R8	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R9	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R10	Met ox 10Ω 2% $\frac{1}{2}$W	24573-025
R11	Met ox 3.9kΩ 2% $\frac{1}{2}$W	24573-087
R12	Met ox 4.7kΩ 2% $\frac{1}{2}$W	24573-089
R13	Met ox 470Ω 2% $\frac{1}{2}$W	24573-065
R14	Met ox 1Ω 10% $\frac{3}{8}$W	24582-555
R15	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R16	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R17	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R18	Met ox 470Ω 2% $\frac{1}{2}$W	24573-065
R19	Met ox 3.9kΩ 2% $\frac{1}{2}$W	24573-087
R20	Met ox 4.7kΩ 2% $\frac{1}{2}$W	24573-089
R21	Met ox 5.1kΩ 2% $\frac{1}{2}$W	24573-090
R22	Met ox 330Ω 2% $\frac{1}{2}$W	24573-061
R23	Met ox 180Ω 2% $\frac{1}{2}$W	24573-055
R24	Met ox 5.1kΩ 2% $\frac{1}{2}$W	24573-090
R25	Met ox 560Ω 2% $\frac{1}{2}$W	24573-067

Circuit reference	Description	M.I. code
R26	Met ox 680Ω 2% $\frac{1}{2}$W	24573-069
R27	Met ox 220Ω 2% $\frac{1}{2}$W	24573-057
R28	Met ox 2.2kΩ 2% $\frac{1}{2}$W	24573-081
R29	Met ox 100Ω 2% $\frac{1}{2}$W	24573-049
R30	Met ox 470Ω 2% $\frac{1}{2}$W	24573-065
R31	Met ox 47Ω 2% $\frac{1}{2}$W	24573-041
TR1	BC239C	28452-771
TR2	2N3904	28454-786
TR3	BSX20	28452-197
TR4	2N3702	28433-488
TR5	BSX20	28452-192
TR6	BSX20	28452-197
TR7	2N3702	28433-488
TR8	BSX20	28452-197
TR9	BC108	23452-787
TR10	BC108	28452-787
TR11	BSX20	28452-197
TR12	MPS3640	28431-766
XL1	1MHz +100 -0 ppm	28311-703
	Crystal holder	28313-604

Unit A7 —Filters

When ordering, prefix circuit reference with A7.

Circuit reference	Description	M.I. code
C1	Cer 0.1µF -25 +60% 30V	26383-031
C2	Cer 0.1µF -25 +60% 30V	26383-031
C3	Cer 0.1µF -25 +60% 30V	26383-031
C4	Plas 0.047µF 10% 250V	26582-206
C5	Cer 0.1µF -25 +50% 30V	26383-031
C6	Cer 0.1µF -25 +50% 30V	26383-031
C7	Cer 0.1µF -25 +50% 30V	26383-031
C8	Cer 0.1µF -25 +50% 30V	26383-031
C9	Plas 820pF 2% 125V	26516-462
C10	Plas 0.00366µF 1% 125V	26516-620
L1	Coil assy	44267-603
L2	Coil assy	44267-603
L3	Coil assy	44267-603
L4	Coil assy	44271-604
L5	Coil assy	44245-003
L6	Coil assy	44245-003
L7	Coil assy	44267-603
L8	Coil assy	44267-603
L9	Coil assy	44271-609
L10	Coil assy	44268-603

Unit A8 —Filters

When ordering, prefix circuit reference with A8.

Circuit reference	Description	M.I. code
C1	Cer 0.1µF -25 +50% 30V	26383-031
C2	Cer 0.1µF -25 +50% 30V	26383-031
C3	Cer 0.1µF -25 +50% 30V	26383-031
C4	Plas 0.1µF 10% 250V	26582-208
C5	Cer 0.1µF -25 +50% 30V	26383-031
C6	Cer 0.1µF -25 +50% 30V	26383-031
C7	Cer 0.1µF -25 +50% 30V	26383-031
C8	Cer 0.1µF -25 +50% 30V	26383-031
C9	Plas 0.0024µF 0.5% 125V	26516-574
C10	Plas 0.0108µF 1% 125V	26516-901
C11	Plas 0.0024µF 0.5% 125V	26516-574
C12	Plas 39pF 2pF 125V	26516-145
C13	Plas 12pF 1pF 125V	26516-014
C14	Cer 0.1µF -25 +50% 30V	26383-031
C15	Cer 0.1µF -25 +50% 30V	26383-031
C16	Cer 0.1µF -25 +50% 30V	26383-031
C17	Plas 0.1µF 10% 250V	26582-208
C18	Cer 0.1µF -25 +50% 30V	26383-031
C19	Cer 0.1µF -25 +50% 30V	26383-031
C20	Cer 0.1µF -25 +50% 30V	26383-031
C21	Cer 0.1µF -25 +50% 30V	26383-031
C22	Plas 0.0011µF 1% 125V	26516-495
C23	Plas 0.0075 1% 125V	26516-689
L1	Coil assy	44267-603
L2	Coil assy	44267-603
L3	Coil assy	44267-603
L4	Coil assy	44271-604
L5	Coil assy	44245-003
L6	Coil assy	44245-003
L7	Coil assy	44267-603
L8	Coil assy	44267-603
L9	Coil assy	44271-608
L10	Coil assy	44268-602
L11	Coil assy	44271-609

Unit A9 —Range A Oscillator

When ordering, prefix circuit reference with A9.

Circuit reference	Description	M.I. code
C1	Cer 0.1µF -25 +50% 30V	26383-031
C2	Plas 0.11µF 2% 125V	26518-293
C3	Plas 1µF 5% 160V	26511-382
C5 †	Plas 0.047µF 5% 160V	26511-337

Circuit reference	Description	M.I. code
C6	Plas 1μF 5% 160V	26511-382
C7	Cer 0.1μF -25 +50% 30V	26383-031
L1	Coil assy	44265-208
L2	Coil assy	44264-205
R1	Met ox 3.3kΩ 2% ½W	24573-085
R2	Met ox 1kΩ 2% ½W	24573-073
R3	Met ox 1kΩ 2% ½W	24573-073
R4	Met ox 910Ω 2% ½W	24573-072
R5	Met ox 100Ω 2% ½W	24573-049
TR1	BCY71	28435-235

Unit A10 —Range B Oscillator

When ordering, prefix circuit reference with A10.

C1	Cer 0.1μF -20+50% 30V	26383-031
C2	Elec 22μF -20+100% 25V	26415-805
C3 †	Plas 18pF ±2pF 160V	26516-028
C4	Cer 0.1μF -25 +50% 30V	26383-031
C5 †	Plas 0.0033μF 2% 125V	26516-609
C6	Plas 0.01μF 5% 400V	26511-316
C7	Plas 0.33μF 5% 160V	26511-367
C8	Plas 0.33μF 5% 160V	26511-367
L1	Coil assy	44267-001
L2	Coil assy	44264-205
R1	Met film 47kΩ 2% ¼W	24773-313
R2	Met film 6.2kΩ 2% ¼W	24773-292
R3	Met film 1kΩ 2% ¼W	24773-273
R4	Met film 3.3kΩ 2% ¼W	24773-285
R5	Met film 1kΩ 2% ¼W	24773-273
R6	Met film 1.5kΩ 2% ¼W	24773-277
TR1	BC108	28452-787
TR2	BC108	28452-787

Unit A11 —Range C Oscillator

When ordering, prefix circuit reference with A11.

C1	Plas 0.0028μF 2% 125V	26516-591
C2	Plas 100pF 2pF 125V	26516-241
C3 †	Plas 0.015μF 5% 160V	26511-319
C4	Plas 0.003μF 2% 125V	26516-597
C5	Cer 0.1μF -25 +50% 30V	26383-031
C6 †	Plas 0.001μF 2% 125V	26516-481
C7	Plas 0.033μF 5% 160V	26511-330
C8	Plas 0.1μF 5% 160V	26511-349

Circuit reference	Description	M.I. code
C9	Plas 0.0068μF 5% 160V	26511-164
L1	Coil assy	44265-208
L2	Coil assy	44257-211
R1	Met ox 13kΩ 2% ½W	24573-100
R2	Met ox 6.8kΩ 2% ½W	24573-093
R3	Met ox 1kΩ 2% ½W	24573-073
R4	Met ox 3.3kΩ 2% ½W	24573-085
R5	Met ox 1.5kΩ 2% ½W	24573-077
R6	Met ox 1.5kΩ 2% ½W	24573-077
R7	Met ox 82kΩ 2% ½W	24573-119
TR1	BSX20	28452-197
TR2	BSX20	28452-197

Unit A12 —Range D Oscillator

When ordering, prefix circuit reference with A12.

C1	Plas 0.001μF 2% 125V	26516-481
C2	Plas 68pF 2% 125V	26516-201
C3	Plas 0.033μF 10% 280V	26582-205
C4	Plas 0.001μF 2% 125V	26156-481
C5	Cer 0.1μF -25 +50% 30V	26383-031
C6 †	Plas 560pF 2% 125V	26516-423
C7	Plas 0.01μF 5% 400V	26511-316
C8	Plas 0.033μF 5% 160V	26511-330
L1	Coil assy	44263-047
L2	Coil assy	44247-010
R1	470Ω 2% ½W	24573-065
R2	4.7kΩ 2% ½W	24573-089
R3	1kΩ 2% ½W	24573-073
R4	3.3kΩ 2% ½W	24573-085
R5	1.5kΩ 2% ½W	24573-077
R6	1.5kΩ 2% ½W	24573-077
TR1	BSX20	28452-197
TR2	BSX20	28452-197

Unit A13 —Range E Oscillator

When ordering, prefix circuit reference with A13.

C1	Plas 0.068μF 10% 250V	26582-207
C2	Plas 0.001μF 2% 125V	26516-481
C3	Mica 33pF 1pF 350V	26272-391
C4	Cer 22pF 5% 750V	26324-807
C5	Cer 0.1μF -25 +50% 30V	26383-031
C6 †	Cer 68pF 2% 750V	26324-868

Circuit reference		Description	M.I. code
C7		Mica 560pF 2% 350V	26272-107
C8		Mica 560pF 2% 350V	26272-107
C9		Plas 0.0018μF 2% 125V	26516-543
C10		Mica 47pF ±1pF 350V	26272-387
C11		Cer 0.01μF -20 +80% 100V	26383-055
L1		Coil assy	44255-005
L2		Coil assy	44233-014
R1		Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R2		Met ox 47Ω 2% $\frac{1}{4}$W	24511-537
R3		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R4	†	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R6		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R7		Met ox 300kΩ 2% $\frac{1}{2}$W	24573-132
R8		Met ox 680Ω 2% $\frac{1}{4}$W	24511-576
R9		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
TR1		BSX20	28452-197
TR2		BF246	28459-024
TR3		BF246	28459-024

Unit A14 —Range F Oscillator

When ordering, prefix circuit reference with A14.

C1		Plas 0.047μF 10% 250V	26582-206
C2		Plas 0.001μF 2% 125V	26516-481
C3		Mica 15pF 1pF 350V	26272-020
C4		Cer 15pF 5% 750V	26324-795
C5		Cer 0.1μF -25 +50% 30V	26383-031
C6	†	Cer 68pF 2% 750V	26324-868
C7		Mica 560pF 2% 350V	26272-107
C8		Mica 560pF 2% 350V	26272-107
C9		Plas 0.0033μF 2% 125V	26516-609
C10		Mica 47pF ±1pF 350V	26272-387
C11		Cer 0.01μF -20 +80% 100V	26383-055
L1		Coil assy	44237-003
L2		Coil assy	44223-405
R1		Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R2		Met ox 47Ω 2% $\frac{1}{4}$W	24511-537
R3		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R4	†	Met ox 3.9kΩ 2% $\frac{1}{4}$W	24511-596
R6		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R7		Met ox 300kΩ 2% $\frac{1}{2}$W	24573-132
R8		Met ox 680Ω 2% $\frac{1}{4}$W	24511-576
R9		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
TR1		BSX20	28452-197
TR2		BF246	28459-024
TR3		BF246	28459-024

Unit A15 —Range G Oscillator

When ordering, prefix circuit reference with A15.

C1		Plas 0.001μF 2% 125V	26516-524
C2		Mica 47pF 1pF 350V	26272-387
C3		Cer 4.7pF 0.5pF 750V	26324-055
C4		Cer 0.001μF -20 +80% 500V	26383-242
C5	†	Cer 10pF 0.25pF 750V	26324-709
C6		Mica 100pF 2% 350V	26272-315
C7		Mica 100pF 2% 350V	26272-315
C8		Mica 0.001μF 2% 350V	26272-150
C9	†	Mica 47pF ±1pF 350V	26272-387
C10		Cer 0.001μF -20 +80% 500V	26383-242
C11		Cer 0.001μF -20 +80% 500V	26383-242
C12		Cer 0.001μF -20 +80% 500V	26383-242
D1		V47	28381-135
L1		Coil assy	44223-203
L2		Choke	23642-325
L3		Coil assy	44233-901
L4		Choke	23642-325
R1		Met ox 4.7kΩ 2% $\frac{1}{4}$W	24511-600
R2		Met ox 12kΩ 2% $\frac{1}{4}$W	24511-612
R3		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R5		Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R6	†	Met ox 560Ω 2% $\frac{1}{4}$W	24511-572
R8		Met ox 150kΩ 2% $\frac{1}{2}$W	24573-125
R9		Met ox 300kΩ 2% $\frac{1}{2}$W	24573-132
R10		Met ox 22Ω 2% $\frac{1}{4}$W	24511-528
R11		Met ox 680Ω 2% $\frac{1}{4}$W	24511-576
TR1		BF246	28459-024
TR2		BF246	28459-024

Unit A16 —Range H Oscillator

When ordering, prefix circuit reference with A16.

C1		Plas 0.0015μF 2% 125V	26516-524
C2		Mica 47pF ±1pF 350V	26272-387

Circuit reference	Description	M.I. code
C3	Mica 27pF 1pF 350V	26272-044
C4	Mica 220pF 2% 350V	26272-073
C5	Mica 22pF 1pF 350V	26272-036
C6	Mica 27pF 1pF 350V	26272-044
C7 †	Cer 15pF 0.25pF 750V	26324-712
C8	Cer 0.001μF -20 +80% 500V	26383-242
C9	Cer 0.001μF -20 +80% 500V	26383-242
C10	Cer 0.001μF -20 +80% 500V	26383-242
C11	Cer 0.001μF -20 +80% 500V	26383-242
C12	Cer 68pF 20% 500V	26343-163
D1	BA111	28381-201
L1	Choke	23642-325
L2	Choke	23642-325
L3	Coil assy	44123-901
L4	Choke	23642-549
R1	Met ox 4.7kΩ 2% $\frac{1}{4}$W	24511-600
R2	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R3 †	Met ox 1.5kΩ 2% $\frac{1}{4}$W	24511-584
R4	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R5	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R7	Met ox 150kΩ 2% $\frac{1}{2}$W	24573-125
R8	Met ox 300kΩ 2% $\frac{1}{2}$W	24573-132
R9	Met ox 22Ω 2% $\frac{1}{4}$W	24511-528
R10	Met ox 680Ω 2% $\frac{1}{4}$W	24511-576
R11	Met film 33Ω 2% $\frac{1}{4}$W	24773-237
TR1	BF246	28459-024
TR2	BF246	28459-024

Unit A17 —Range A Output Filter,

When ordering, prefix circuit reference with A17.

Circuit reference	Description	M.I. code
C1	Plas 0.15μF 10% 250V	26582-212
C2	Plas 0.22μF 10% 63V	26582-406
C3	Plas 0.015μF 10% 250V	26582-203
C4	Plas 0.1μF 10% 250V	26582-208
C5	Plas 0.23μF 10% 63V	26582-406
C6 †	Plas 0.0047μF 2% 125V	26516-646
L1	Coil assy	44265-212
L2	Coil assy	44264-205
L3	Coil assy	44267-001
L4	Coil assy	44265-402
R1	Met film 330Ω 2% $\frac{1}{4}$W	24773-261

Unit A18 —Range B Output Filter,

When ordering, prefix circuit reference with A18.

Circuit reference	Description	M.I. code
C1	Plas 0.047μF 10% 250V	26582-206
C2	Plas 0.015μF 10% 250V	26582-203
C3	Plas 0.001μF 2% 125V	26516-481
C4	Plas 0.033μF 10% 250V	26582-205
C5	Plas 0.068μF 10% 250V	26582-207
C6 †	Plas 820pF 2% 125V	26516-462
L1	Coil assy	44264-205
L2	Coil assy	44265-402
L3	Coil assy	44267-001
L4	Inductor	23642-337

Unit A19 —Range C Output Filter,

When ordering, prefix circuit reference with A19.

Circuit reference	Description	M.I. code
C1	Plas 0.01μF 10% 400V	26582-232
C2	Plas 0.0047μF 2% 125V	26516-646
C3	Plas 330pF 2% 125V	26516-369
C4	Plas 0.01μF 10% 400V	26582-232
C5	Plas 0.022μF 10% 400V	26582-234
C6 †	Plas 330pF 2% 125V	26516-369
L1	Choke	23642-331
L2	Coil assy	44257-211
L3	Coil assy	44265-208
L4	Choke	23642-331

Unit A20 —Range D Output Filter,

When ordering, prefix circuit reference with A20.

Circuit reference	Description	M.I. code
C1	Plas 0.0033μF 2% 125V	26516-609
C2	Plas 0.0018μF 2% 125V	26516-543
C3	Plas 200pF 2% 125V	26516-315
C4	Plas 0.0033μF 2% 125V	26516-609
C5	Plas 0.01μF 10% 250V	26582-202
C6 †	Plas 68pF 2pF 125V	26516-201
L1	Choke	23642-331
L2	Coil assy	44247-010
L3	Coil assy	44263-047
L4	Choke	23642-325

Unit A21 —Range E Output Filter,

When ordering, prefix circuit reference with A21.

Circuit reference	Description	M.I. code
C1	Plas 0.001μF 2% 125V	26516-481

Circuit reference		Description	M.I. code
C2		Plas 510pF 2% 125V	26516-416
C3		Plas 56pF 2% 125V	26516-181
C4		Plas 0.001μF 2% 125V	26516-481
C5		Plas 0.0022μF 2% 125V	26516-564
C6	†	Plas 22pF 2pF 125V	26516-088
L1		Choke	23642-325
L2		Coil assy	44233-014
L3		Coil assy	44255-005
L4		Choke	23642-490

Unit A22 —Range F Output Filter

When ordering, prefix circuit reference with A22.

C1		Plas 330pF 2% 125V	26516-369
C2		Plas 0.0028μF 2% 125V	26516-591
C3		Plas 56pF 2% 125V	26516-181
C4		Plas 330pF 2% 125V	26516-369
C5		Plas 680pF 2% 125V	26516-444
C6	†	Plas 12pF 1pF 125V	26516-014
L1		Choke	23642-490
L2		Inductor assy	44290-011
L3		Coil assy	44237-003
L4		Choke	23642-313

Unit A23 —Range G Output Filter

When ordering, prefix circuit reference with A23.

C1	Plas 100pF 2pF 125V	26516-241
C2	Plas 180pF 2pF 125V	26516-303
C3	Plas 10pF 1pF 125V	26516-009
C4	Plas 100pF 2pF 125V	26516-241
C5	Plas 220pF 2% 125V	26516-327
C6	Var air 2.5-13.4pF	26817-238
L1	Choke	23642-555
L2	Coil assy	44223-405
L3	Coil assy	44233-901
L4	Choke	23642-485

Unit A24 —Range H Output Filter

When ordering, prefix circuit reference with A24.

Circuit reference	Description	M.I. code
C1	Cer 27pF 5% 63V	26343-470
C2	Cer 47pF 20% 500V	26343-160
C3	Var air 2.5-13.4pF	26817-238
C4	Mica 33pF 1pF 350V	26272-391
C5	Cer 68pF 20% 500V	26343-163
L1	Inductor	23642-485
L3	Coil assy	44123-901
L4	Inductor	23642-480

Unit A25 —Wide Band Amplifier

When ordering, prefix circuit reference with A25.

C1	Elec 4.7μF 20% 35V	26486-219
C2	Cer 0.01μF -20 +80% 100V	26383-055
C3	Cer 0.001μF -20 +80% 500V	26383-242
C4	Elec 4.7μF 20% 35V	26486-219
C5	Cer 0.01μF -20 +80% 100V	26383-055
C6	Cer 0.01μF -20 +80% 100V	26383-055
C7	Elec 4.7μF 20% 35V	26486-219
C8	Cer 0.01μF -20 +80% 100V	26383-055
C9	Cer 0.01μF -20 +80% 100V	26383-055
C10	Cer 330pF -20 +40% 500V	26383-136
C11	Elec 4.7μF 20% 35V	26486-219
C12	Elec 4.7μF 20% 35V	26486-219
C13	Cer 10pF 20% 500V	26343-120
C14	Cer 0.01μF -20 +80% 100V	26383-055
C15	Elec 4.7μF 20% 35V	26486-219
C16	Cer 0.01μF -20 +80% 100V	26383-055
C17	Elec 4.7μF 20% 35V	26486-219
C18	Cer 0.001μF -20 +80% 500V	26383-242
C19	Cer 0.01uF -20 + 80% 100V	26383-055
C20	Elec 4.7μF 20% 35V	26486-219
C21	Elec 4.7μF 20% 35V	26486-219
C22	Cer 0.001μF -20 +80% 500V	26383-242
C23	Elec 4.7μF 20% 35V	26486-219
C24	Elec 4.7μF 20% 35V	26486-219
C25	Cer 330pF -20 +40% 500V	26383-136
C26	Elec 4.7μF 20% 35V	26486-219
C27	Elec 4.7μF 20% 35V	26486-219
C28	Elec 4.7μF 20% 35V	26486-219
C29	Cer 100pF 20% 500V	26343-167
C30	Elec 4.7μF 20% 35V	26486-219
C31	Cer 0.01μF -20 +80% 100V	26383-055
C32	Cer 0.01μF -20 +80% 100V	26383-055
C33	Elec 4.7μF 20% 35V	26486-219
D1	1N916	28336-466
D2	1N4148	28336-676
D3	Z5B15	28372-303
D4	1N916	28336-466
IC1	SN741P	28461-304

Circuit reference	*Description*	*M.I. code*
L1	Inductor	23642-325
L2	Inductor	23642-325
L3	Inductor	23642-325
L4	Inductor	23642-325
L5	Inductor	23642-325
L6	Inductor	23642-343
L7	Inductor	23642-549
R1	Met ox 51Ω 2% $\frac{1}{4}$W	24511-539
R2	Carb 1mΩ 5% 1/8W	24311-945
R3	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R4	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R5	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R6	Met ox 32kΩ 2% $\frac{1}{4}$W	24511-588
R7	Met ox 220Ω 2% $\frac{1}{4}$W	24511-558
R8	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R9	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R10	Met ox 12kΩ 2% $\frac{1}{4}$W	24511-612
R11	Met ox 12kΩ 2% $\frac{1}{4}$W	24511-612
R12	Met ox 430Ω 2% $\frac{1}{4}$W	24511-567
R13	Met ox 22Ω 2% $\frac{1}{4}$W	24511-528
R14	Met ox 100Ω 2% $\frac{1}{4}$W	24511-550
R15	Met ox 4.7kΩ 2% $\frac{1}{4}$W	24511-600
R16	Var carb 470Ω 20% $\frac{1}{2}$W	25541-214
R17	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R18	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R19	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R20	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R21	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R22	Met ox 51Ω 2% $\frac{1}{4}$W	24511-539
R23	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R24	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R25	Met ox 51Ω 2% $\frac{1}{4}$W	24511-539
R26	Carb 1mΩ 5% 1/8W	24311-945
R27	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R28	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R29	Met ox 2.2kΩ 2% $\frac{1}{4}$W	24511-588
R30	Met ox 330Ω 2% $\frac{1}{4}$W	24511-563
R31	Met ox 3.3kΩ 2% $\frac{1}{4}$W	24511-594
R32	Met ox 12kΩ 2% $\frac{1}{4}$W	24511-612
R33	Var cerm 470Ω 10% $\frac{1}{2}$W	25711-502
R34	Carb 1mΩ 5% 1/8W	24311-945
R35	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R37	Met ox 330Ω 2% $\frac{1}{4}$W	24511-563
R39	Met ox 2kΩ 2% $\frac{1}{4}$W	24511-587
R40	Met ox 5.1kΩ 2% $\frac{1}{4}$W	24511-602
R41	Met ox 330Ω 2% $\frac{1}{4}$W	24511-563
R42	Met film 5.6Ω 2% $\frac{1}{4}$W	24773-219
R43	Met ox 75Ω 2% $\frac{1}{4}$W	24511-544
R44	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R45	Carb 470kΩ 5% 1/8W	24311-937
R46	Carb 470kΩ 5% 1/8W	24311-937
R47	Met ox 330Ω 2% $\frac{1}{4}$W	24511-563
R48	Met ox 1.8kΩ 2% $\frac{1}{4}$W	24511-586
R49	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R50	Met ox 100Ω 2% $\frac{1}{4}$W	24511-550
R51	Met ox 39Ω 2% $\frac{1}{4}$W	24511-535
R52	Met ox 10Ω 2% $\frac{1}{4}$W	24511-520
R53	Met ox 150Ω 2% $\frac{1}{4}$W	24511-554
R54	Met ox 390Ω 2% $\frac{1}{4}$W	24511-565
R55	Met film 33Ω 2% $\frac{1}{4}$W	24773-237
R56	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
TR1	40673 ⚠	28459-032
TR2	BCY71	28435-235
TR3	BFY90	28452-157
TR4	BFY90	28452-157
TR5	BFY90	28452-157
TR6	BFY90	28452-157
TR7	40673 } Matched pair ⚠	44529-008
TR10	40673	
TR8	BCY71	28435-235
TR9	BFY90	28452-157
TR11	BFY90	28452-157
TR12	2N5109	28452-827
TR13	2N5109	28452-827

Unit A26 —A.L.C. and Envelope Feedback

When ordering, prefix circuit reference with A26.

C1	Plas 0.022μF 10% 400V	26582-234
C2	Cer 0.047μF -20 +50% 30V	26383-018
C3	Cer 100pF 20% 500V	26343-167
C4	Cer 33pF 20% 500V	26343-146
C5	Cer 0.1μF -20 +50% 30V	26383-031
C6	Cer 0.1μF -20 +50% 30V	26383-031
C7	Cer 0.022μF -20+50% 18V	26383-007
C8	Cer 0.01μF -20 +80% 100V	26383-055
C9	Cer 0.001μF -20 +80% 500V	26383-242
C10	Elec 47μF -20 +100% 10V	26415-809
C11	Elec 4.7μF 20% 35V	26486-219
C12	Elec 47μF -20 +100% 10V	26415-809
C13	Cer 10pF 20% 500V	26343-120

Circuit reference	Description	M.I. code
C14	Elec 4.7μF 20% 35V	26484-219
C15	Elec 250μF -20 +100% 25V	26415-818
C16	Cer 1.5pF ±0.1pF 500V	26343-027
C17	Cer 0.01μF -20 +80% 100V	26383-055
C18	Cer 1.5pF ±0.1pF 500V	26343-027
C19	Cer 0.001μF -20 +80% 500V	26383-242
C20	Cer 330pF 20% 500V	26383-136
C21	Cer 330pF 20% 500V	26383-136
C22	Cer 0.1μF -20 +50% 30V	26383-031
C23	Elec 47μF -20 +100% 10V	26415-809
C24	Cer 0.001μF -20+80% 500V	26383-242
C25	Plas 470pF 2% 160V	26516-406
D1	Z5B5.6	28371-434
D2	1N4148	28336-676
D4	1N4004	28357-028
D5	HP5082	28349-007
D6	HP5082	28349-007
D7	OA95	28323-287
D8	OA95	28327-287
D9	OA95	28327-287
D10	OA95	28327-287
IC1	CA3046	28461-901
IC2	μA739	28461-312
L1	Inductor	23642-553
R1	Met foil 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R2	Met foil 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R3	Var carb 47kΩ 20% $\frac{1}{2}$W	25711-549
R4	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R5	Met foil 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R6	Met ox 3.3kΩ 2% $\frac{1}{4}$W	24511-594
R7	Met ox 15kΩ 2% $\frac{1}{4}$W*	24511-614
R8	Met ox 12kΩ 2% $\frac{1}{4}$W	24511-612
R9	Met ox 22kΩ 2% $\frac{1}{4}$W	24511-528
R10	Met ox 4.7kΩ 2% $\frac{1}{4}$W	24511-600
R11	Met ox 10kΩ 2% $\frac{1}{4}$W*	24511-520
R12	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R13 †	Met ox 470Ω 2% $\frac{1}{4}$W	24511-569
R14	**Var carb** 4.7kΩ 2% $\frac{1}{4}$W	25541-327
R15	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R16	Met film 5kΩ 0.5% $\frac{1}{2}$W	24753-878
R17	Met ox 22kΩ 2% $\frac{1}{4}$W	24511-618
R18	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R19	Var carb 50kΩ 20% $\frac{1}{2}$W	35541-344
R20	Met ox 150kΩ 2% $\frac{1}{4}$W	24511-639
R21	Met film 68kΩ 2% $\frac{1}{4}$W	24773-317
R22	Met ox 470Ω 2% $\frac{1}{4}$W	24511-569
R23	Met ox 11Ω 2% $\frac{1}{4}$W	24511-611
R24	Met ox 11Ω 2% $\frac{1}{4}$W	24511-611
R25	Met ox 33kΩ 2% $\frac{1}{4}$W	24511-622
R26	Met ox 33kΩ 2% $\frac{1}{4}$W	24511-622
R27	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R28	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R29	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R30	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R31	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R32	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R33	Met ox 100kΩ 2% $\frac{1}{4}$W	24511-635
R34	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R35	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R36	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R37	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R38	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R39	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R40	Met ox 33kΩ 2% $\frac{1}{4}$W	24511-622
R41	Met ox 33kΩ 2% $\frac{1}{4}$W	24511-622
R42	Met film 50Ω 1% 1/8W	24616-321
R43	Met ox 2.2kΩ 2% $\frac{1}{4}$W	24511-588
R44 †	Met ox 470Ω 2% $\frac{1}{4}$W	24511-569
R45	Met ox 220Ω 2% $\frac{1}{4}$W	24511-558
R46 †	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R47 †	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R48 †	Met ox 1kΩ 2% $\frac{1}{4}$W	24511-580
R49 †	Met ox 2.2kΩ 2% $\frac{1}{4}$W	24511-588
R50 †	Met ox 10kΩ 2% $\frac{1}{4}$W	24511-610
R51	Met ox 33kΩ 2% $\frac{1}{4}$W	24511-622
R52	Met ox 68kΩ 2% $\frac{1}{4}$W	24511-631
R53	Met ox 100 Ω 2% $\frac{1}{4}$W	24511-550
R54	Met ox 6.8kΩ 2% $\frac{1}{4}$W	24511-606
R55	Met ox 470Ω 2% $\frac{1}{4}$W	24511-569
R56	Met ox 470Ω 2% $\frac{1}{4}$W	24511-569
R57	Met ox 47kΩ 2% $\frac{1}{4}$W	24511-626
RL1	RS12V	23486-427
TR1	BCY71	28435-235
TR2	BCY71	28435-235
TR3	BSX20	28452-197
TR4	BC108	28452-787
TR5	BCY71	28435-235

Unit A27 —Coarse Attenuator

When ordering, prefix circuit reference with A27.

Circuit reference	Description	M.I. code
R1	Met film 53.3Ω 0.5% ¼W	24634-365
R2	Met film 790Ω 0.5% ¼W	24634-806
R3	Met film 53.3Ω 0.5% ¼W	24634-356
R4	Met film 53.3Ω 0.5% ¼W	24634-356
R5	Met film 790Ω 0.5% ¼W	24634-806
R6	Met film 53.3Ω 0.5% ¼W	24634-356
R7	Met film 61Ω 0.5% ¼W	24634-357
R8	Met film 247Ω 0.5% ¼W	24634-609
R9	Met film 61Ω 0.5% ¼W	24634-357
R10	Met film 61Ω 0.5% ¼W	24634-357
R11	Met film 247Ω 0.5% ¼W	24634-609
R12	Met film 61Ω 0.5% ¼W	24634-357
R13	Met film 61Ω 0.5% ¼W	24634-357
R14	Met film 247Ω 0.5% ¼W	24634-609
R15	Met film 61Ω 0.5% ¼W	24634-357

Unit A28 —Fine Attenuator

When ordering, prefix circuit reference with A28.

Circuit reference	Description	M.I. code
R1	Met film 150Ω 1% ¼W	24636-613
R2	Met film 37.3Ω 1% ¼W	24636-224
R3	Met film 150Ω 1% ¼W	24636-613
R4	Met film 292Ω 1% ¼W	24636-710
R5	Met film 17.6Ω 1% ¼W	24636-116
R6	Met film 292Ω 1% ¼W	24636-710
R7	Met film 870Ω 1% ¼W	24636-905
R8	Met film 5.77Ω 0.5% ¼W	24634-032
R9	Met film 870Ω 1% ¼W	24636-905
R10	Met film 436Ω 1% ¼W	24636-711
R11	Met film 11.6Ω 1% ¼W	24636-113
R12	Met film 436Ω 1% ¼W	24636-711
R13	Met film 96.3Ω 0.5% ¼W	24634-494
R14	Met film 71.2Ω 0.5% ¼W	24634-368
R15	Met film 96.3Ω 0.5% ¼W	24634-494

Unit A29 —Capacitor Board

When ordering, prefix circuit reference with A29.

Circuit reference	Description	M.I. code
C1	Plas 0.372μF 0.5% 125V	26516-879
C2	Plas 0.118μF 0.5% 125V	26516-856
C3	Plas 0.0372 0.5% 125V	26516-815
C4	Plas 0.0118μF 0.5% 125V	26516-721
C5	Plas 0.00372 1% 125V	26516-623
C6	Plas 0.0011μF 2% 125V	26516-494
C7	Plas 0.372μF 0.5% 125V	26516-879
C8	Plas 0.118μF 0.5% 125V	26516-856
C9	Plas 0.0372 0.5% 125V	26516-815
C10	Plas 0.0118μF 0.5% 125V	26516-721
C11	Plas 0.00372 1% 125V	26516-623
C12	Plas 0.0011μF 2% 125V	26516-494

Unit A30 —Coarse Tracking Potentiometer

When ordering, prefix circuit reference with A30.

Circuit reference	Description	M.I. code
R1	Met ox 220Ω 20% ½W	24573-057
R2	Met ox 220Ω 20% ½W	24573-056
R3	Met ox 180Ω 20% ½W	24573-058
R4	Met ox 160Ω 20% ½W	24573-054
R5	Met ox 150Ω 20% ½W	24573-053
R6	Met ox 130Ω 20% ½W	24573-052
R7	Met ox 120Ω 20% ½W	28573-051
R8	Met ox 110Ω 20% ½W	28573-050
R9	Met ox 100Ω 20% ½W	28573-049
R10	Met ox 91Ω 20% ½W	28573-048
R11	Met ox 82Ω 20% ½W	28573-047
R12	Met ox 75Ω 20% ½W	28573-046
R13	Met ox 68Ω 20% ½W	28573-045
R14	Met ox 62Ω 2% ½W	24573-044
R15	Met ox 56Ω 2% ½W	24573-043
R16	Met ox 51Ω 2% ½W	24573-042
R17	Met ox 47Ω 2% ½W	24573-061
R18	Met ox 43Ω 2% ½W	24573-040
R19	Met ox 39Ω 2% ½W	24573-039
R20	Met ox 36Ω 2% ½W	24573-038
R21	Met ox 33Ω 2% ½W	24573-037
R22	Met ox 30Ω 2% ½W	24573-036
R23	Met ox 27Ω 2% ½W	24573-035
R24	Met ox 24Ω 2% ½W	24573-034
R25	Met ox 240Ω 2% ½W	24573-058

Unit A31 Pre-distortion Resistors

When ordering, prefix circuit reference with A31.

Circuit reference	Description	M.I. code
R1	† Met ox 47kΩ 2% ½W	24573-113
R2	† Met ox 47kΩ 2% ½W	24573-113
R3	† Met ox 150kΩ 2% ½W	24573-125
R4	† Met ox 220kΩ 2% ½W	24573-129
R5	† Met ox 150kΩ 2% ½W	24573-125
R6	† Met ox 270kΩ 2% ½W	24573-131

Description	M.I. code	Description	M.I. code
Miscellaneous Items			
Control Knobs		Set scale	31141-111
Supply switch	41142-209	Frequency	41146-015
Function switch	41145-220	Range	41145-206
Carrier level	41141-503	RF Unit	
Modulation selector switch	41142-212	Dial drive assembly	41319-004
Modulation level	41141-503	Coupling bellows	41315-021
Modulation frequency	41141-308	Gear box	41334-019
Modulation frequency(dial assembly)	41174-017	Drive tape	34112-713
Cursor for frequency scale	31185-722	Mains input plug	23423-159

For symbols and abbreviations see introduction to this chapter

Index to Units

Unit No.	M.I. code	Description	Parts list page	Circuit diagram Fig.
A1	44823-325	Power supply -15 V	68	7.18
A2	44821-277	Modulation oscillator	69	7.11
A3	44825-229	AM/FM drive and monitor	69	7.13
A4	44825-227	Δ f control supply and monitor amplifier	70	7.13 & 7.18
A5	44825-228	Crystal cal. amplifier	70	7.15
A6	44823-326	Crystal calibrator	71	7.15
A7	44811-330	RF unit filters	72	7.17
A8	44811-331	RF unit filters	72	7.17
A9	44821-281	Range A oscillator	72	7.2
A10	44821-282	Range B oscillator	73	7.2
A11	44821-283	Range C oscillator	73	7.2
A12	44821-284	Range D oscillator	73	7.2
A13	44821-278	Range E oscillator	73	7.4
A14	44821-279	Range F oscillator	74	7.4
A15	44823-315	Range G oscillator	74	7.4
A16	44823-314	Range H oscillator	74	7.4
A17	44811-332	Range A output filter	75	7.7
A18	44811-333	Range B output filter	75	7.7
A19	44811-334	Range C output filter	75	7.7
A20	44811-335	Range D output filter	75	7.7
A21	44811-336	Range E output filter	75	7.7
A22	44811-337	Range F output filter	76	7.7
A23	44811-338	Range G output filter	76	7.7
A24	44811-339	Range H output filter	76	7.7
A25	44823-744	Wideband amplifier	76	7.5
A26	44823-313	ALC and envelope feedback circuits	77	7.9
A27	44426-009	Attenuator (coarse)	78	7.16
A28	44425-507	Attenuator (fine)	79	7.16
A29	44831-207	Capacitor board for mod. oscillator	79	7.11
A30	44811-340	Tracking resistors	79	7.13
A31	44811-341	Pre-distortion resistors	79	7.13

Chapter 7

Circuit diagrams

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

Shown in italics adjacent to the point to which the measurement refers. See section 5.2.1 for conditions.

3. SYMBOLS

→ arrow indicates clockwise rotation of knob.

FUNCTION etc., external front or rear panel marking.

—□— tag on printed board.

—○— other tag.

⊘ preset control.

(A3) unit identification number.

point marked with this symbol is connected to and receives power from point marked with this symbol — These symbols are used to identify branches of the power supply circuitry but have no particular physical reality on the printed boards.

⚠ static sensitive device

4. CIRCUIT REFERENCES

These are, in general, given in abbreviated form. See Chapter 6.

5. SWITCHES

Rotary switches are drawn schematically.
Letters indicate control knob settings.
1F = 1st section (front panel), front
1B = 1st section, back
2F = 2nd section, front
etc.

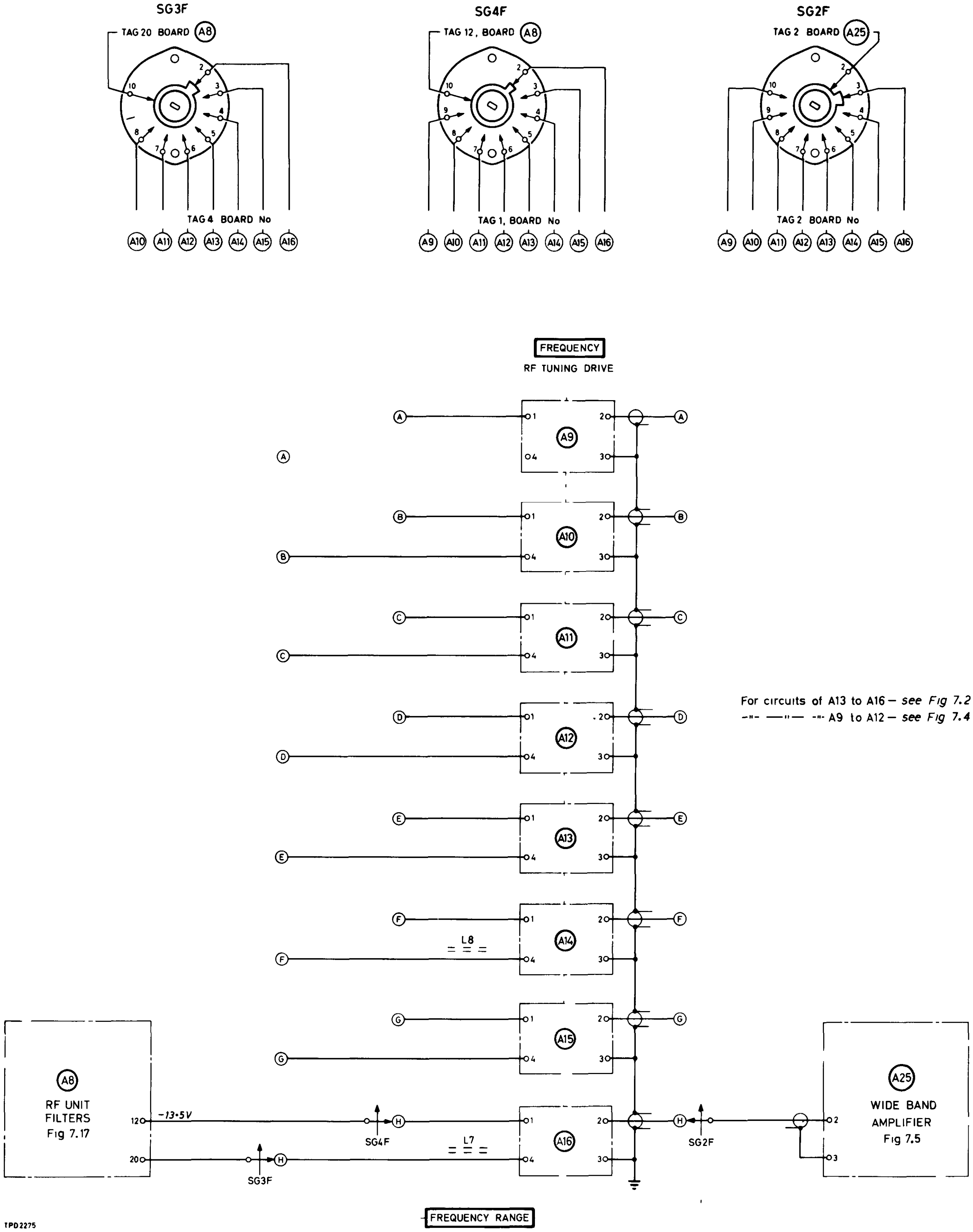
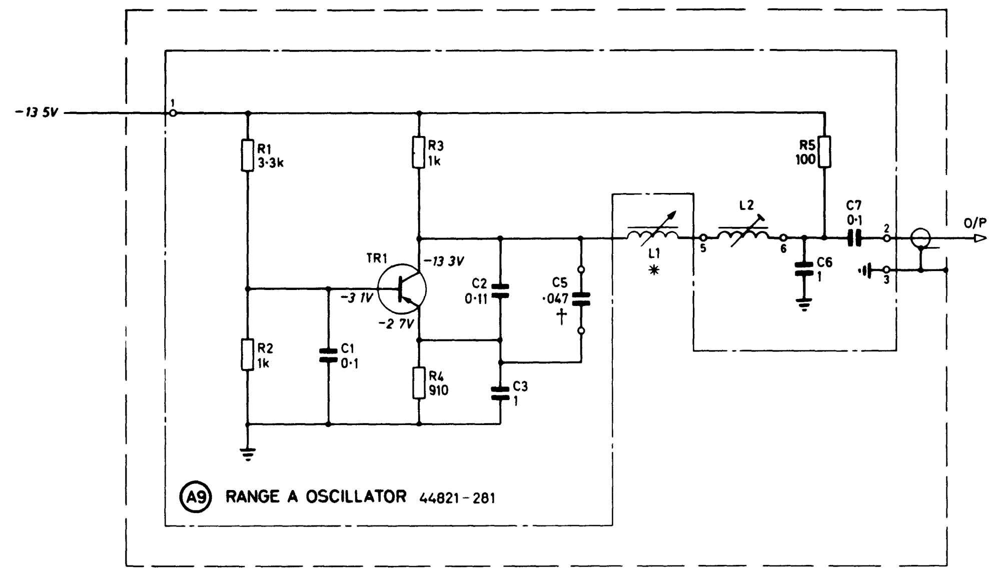
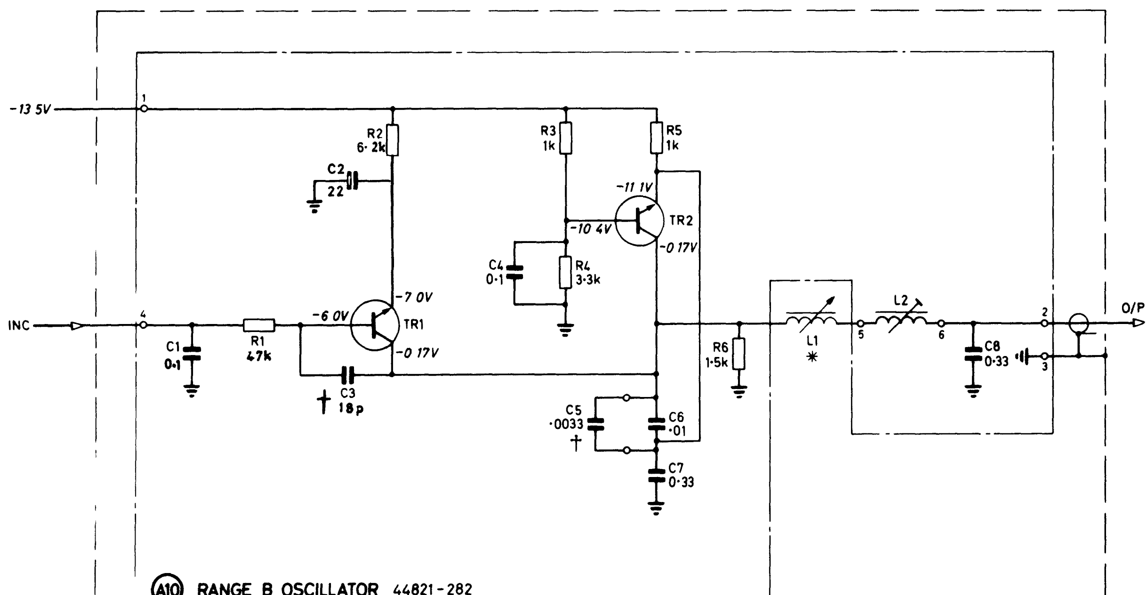


Fig. 7.1 RF oscillator switching

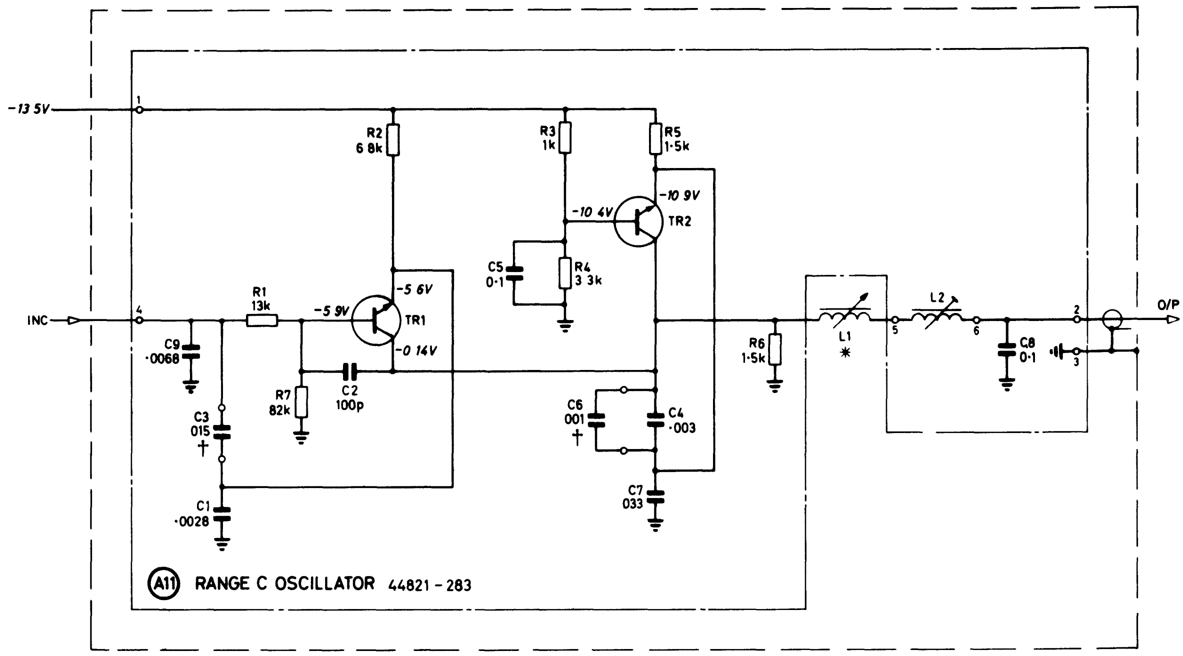


key:–

✳	Coupled to RF TUNING DRIVE	Fig 7 3
O/P	OUTPUT to SG2F	
INC	INCREMENTAL FREQUENCY DRIVE from SG3F	
−13 5V	−13 5V from SG4F	



TPE 2266B



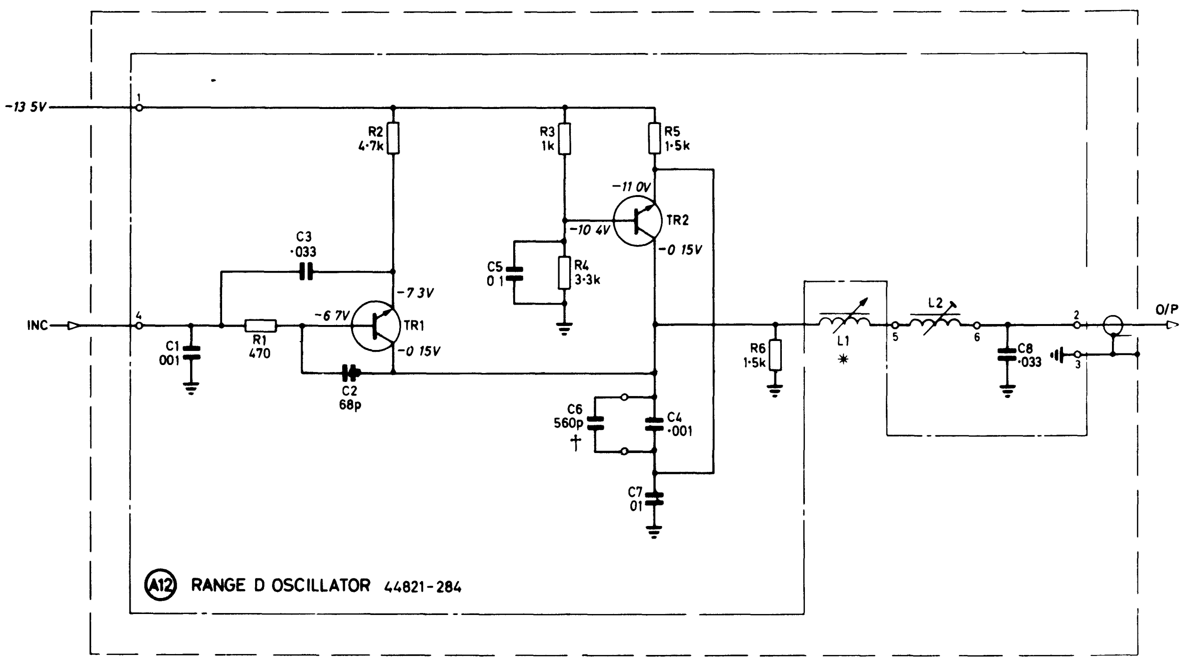


Fig. 7.2 RF oscillators A to D

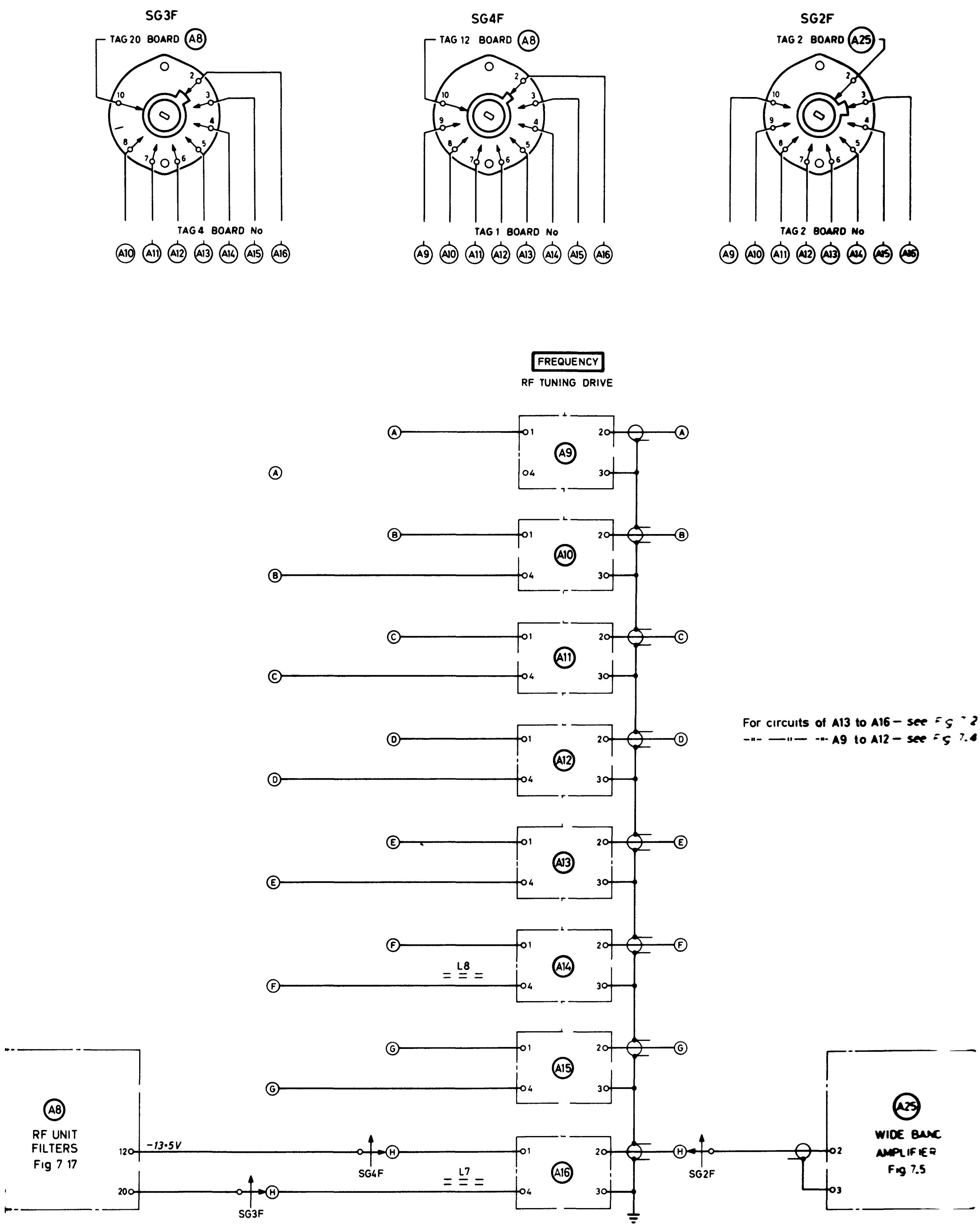
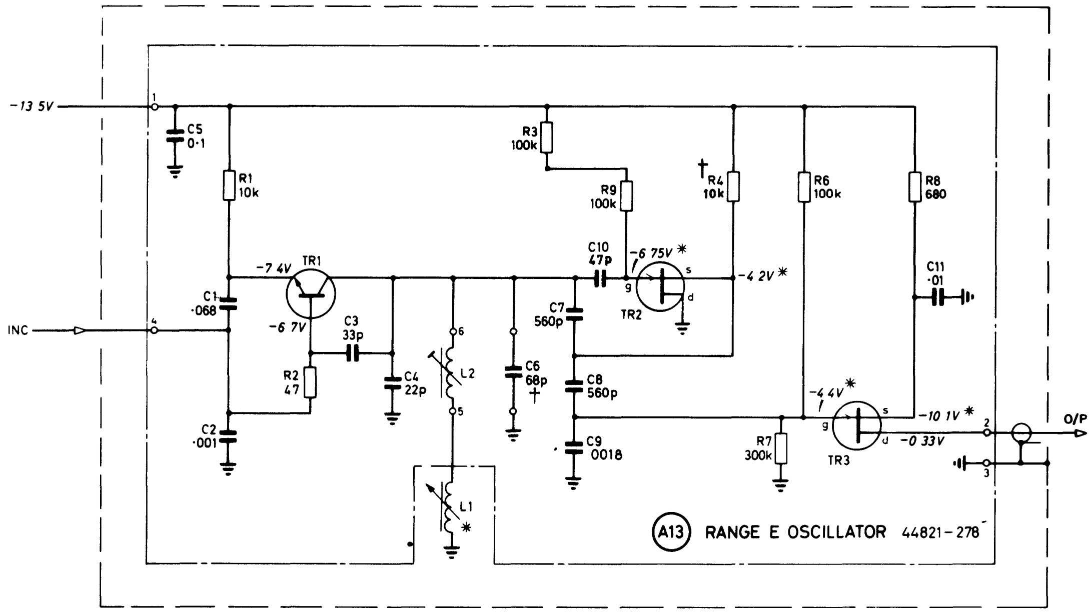
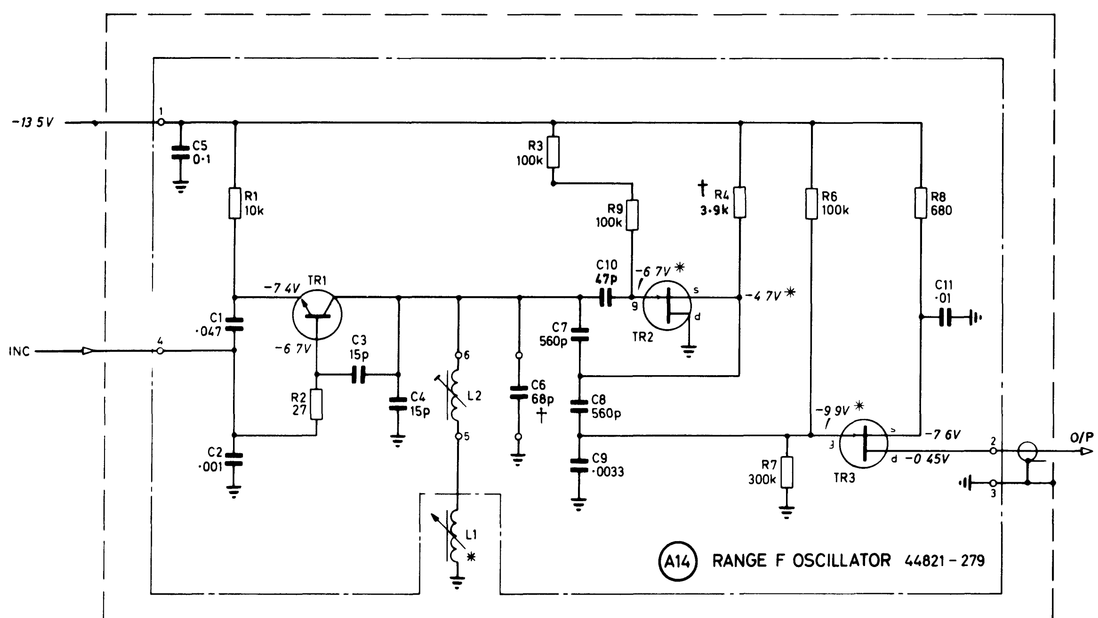


Fig 7 3 RF oscillator switching

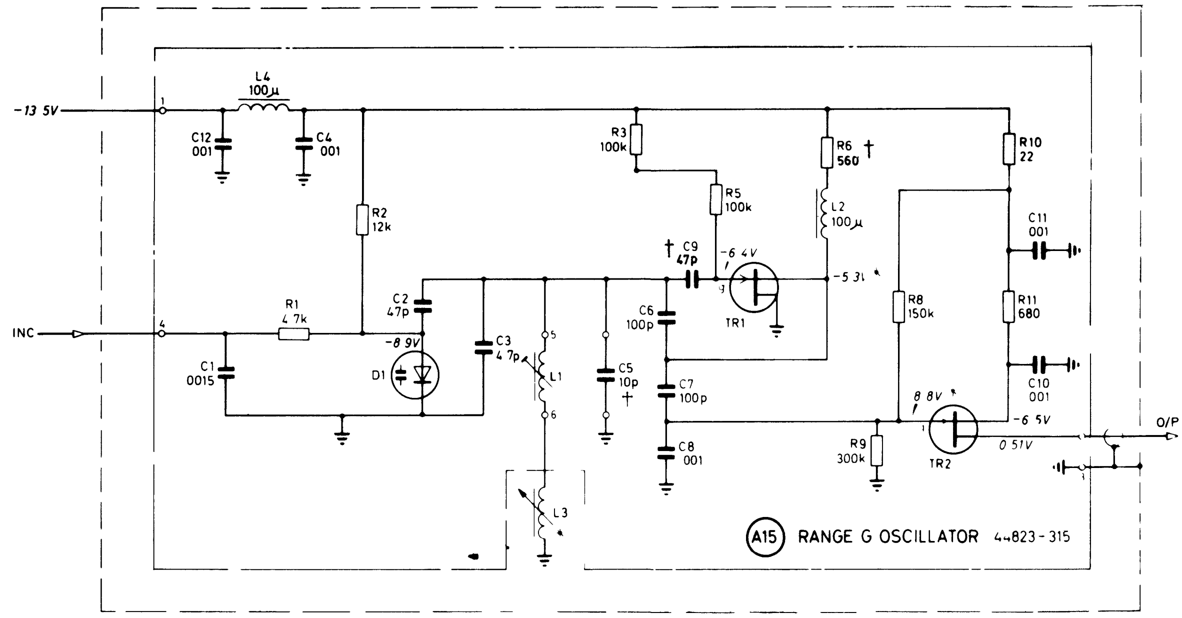


key:–

*	Coupled to RF TUNING DRIVE	Fig 7.1
O/P	OUTPUT to SG2F	
INC	INCREMENTAL FREQUENCY DRIVE from SG3F	
−13 5V	−13 5V from SG4F	



TPE 2265 D



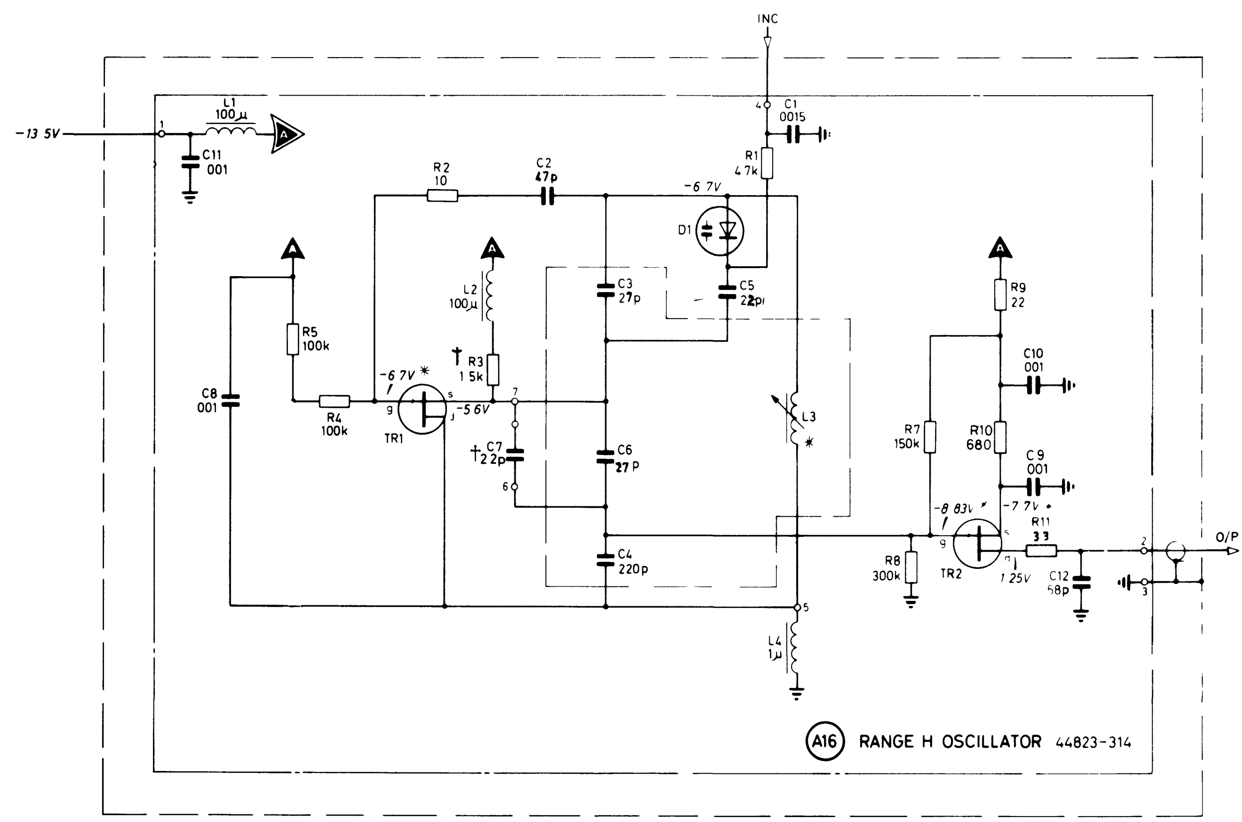


Fig. 7.4 RF oscillators E to H

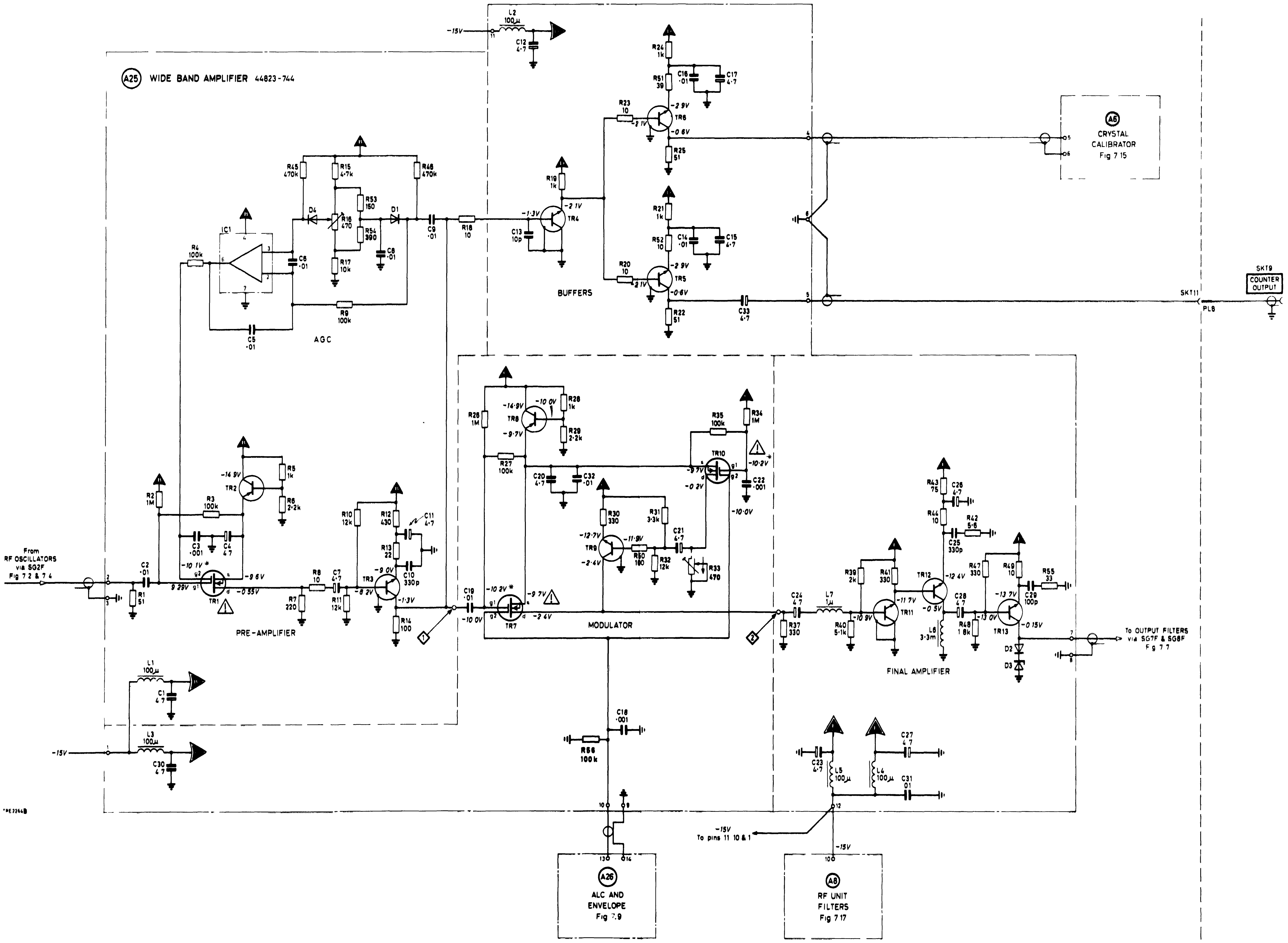


Fig. 7.5 Wide band amplifier

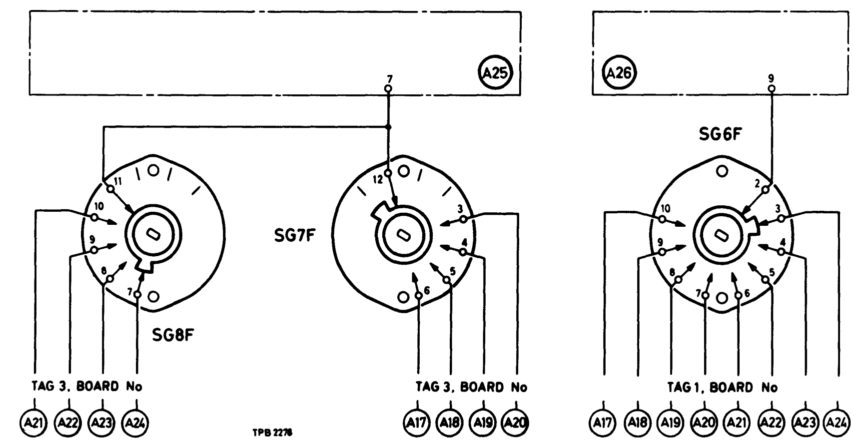


Fig. 7.6 Carrier filter switching

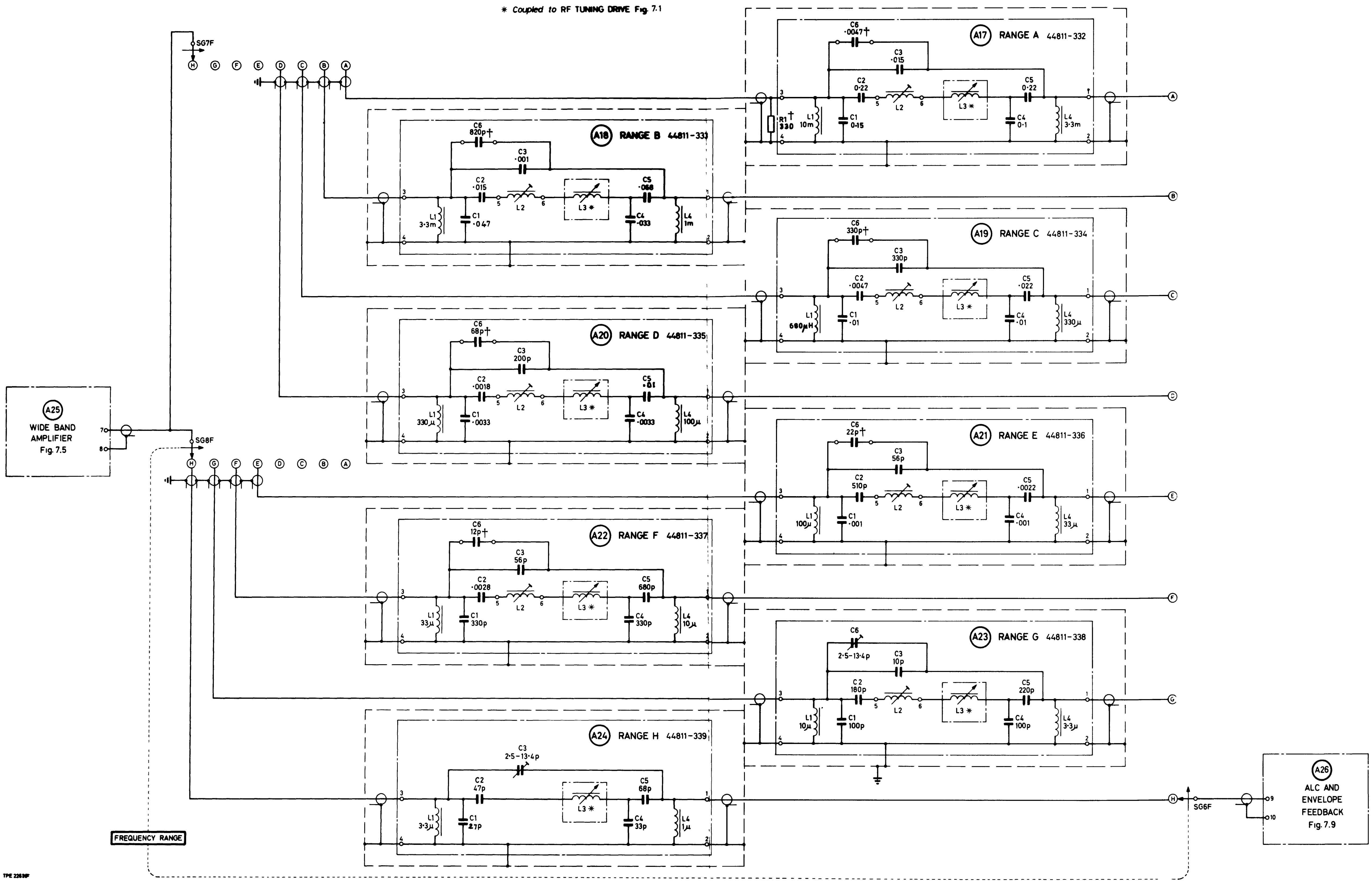
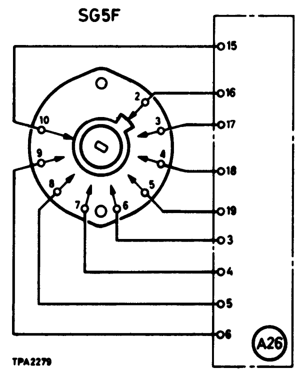


Fig. 7.7 Tuned output filters



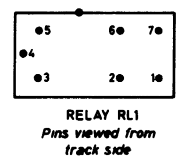


Fig. 7.8 Frequency range switching a.l.c. circuits

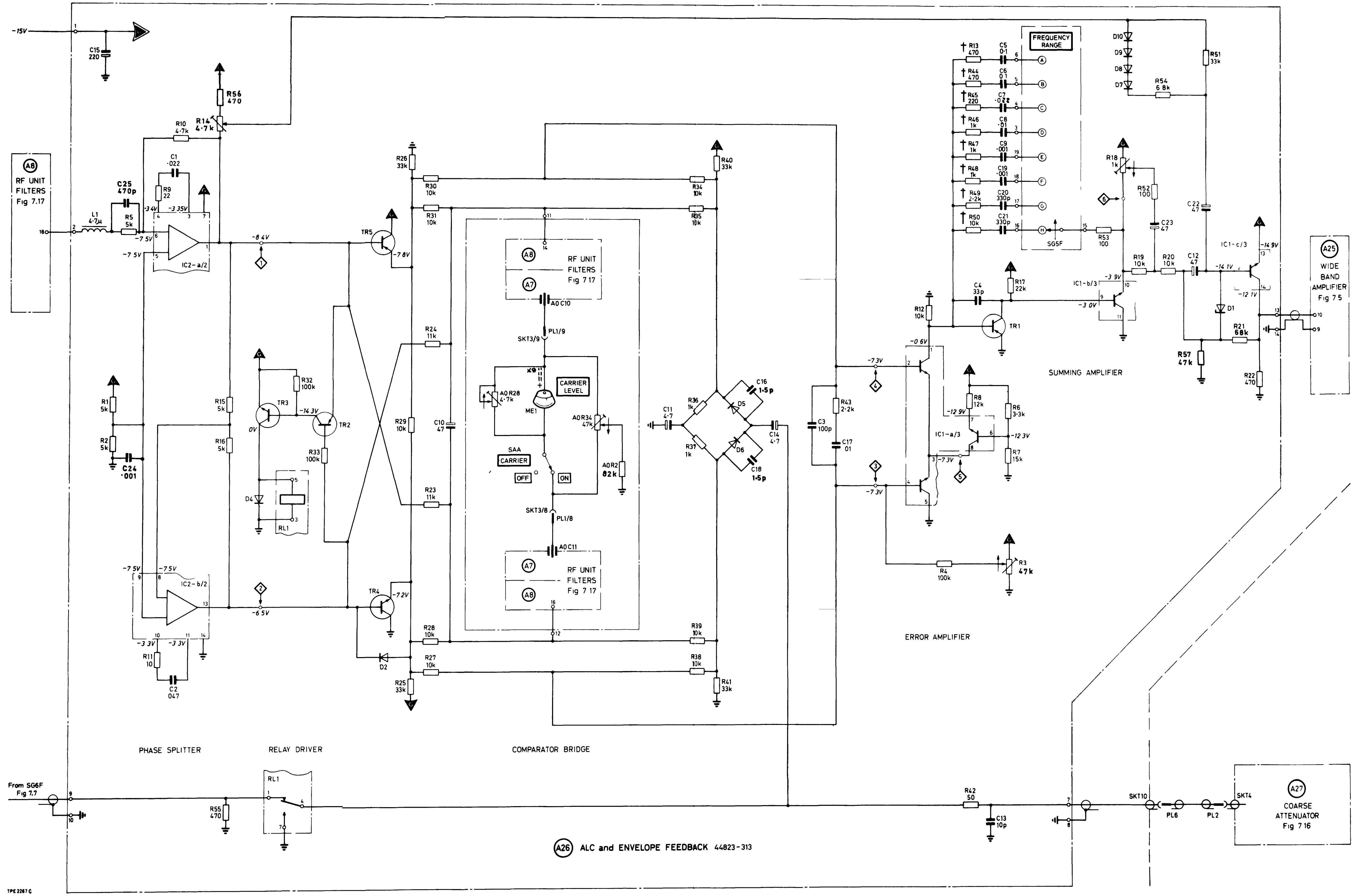


Fig. 7.9 ALC and envelope feedback circuits

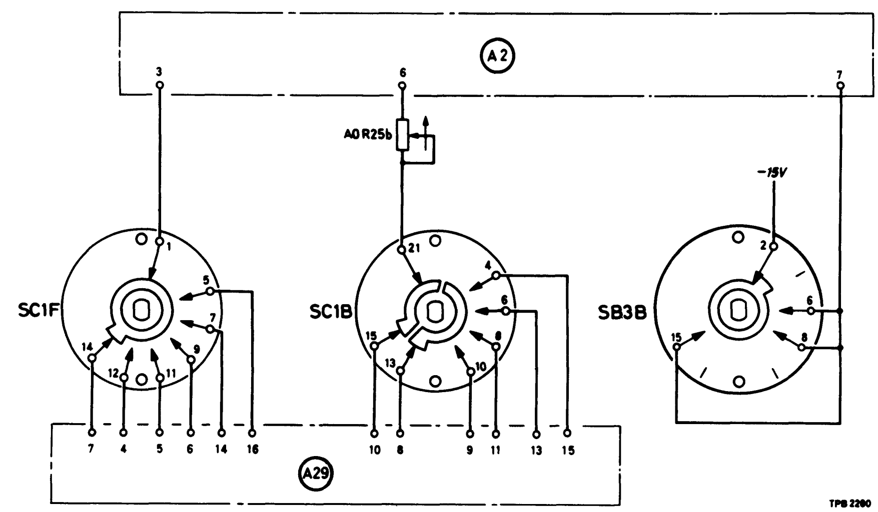


Fig. 7.10 Modulation oscillator switch

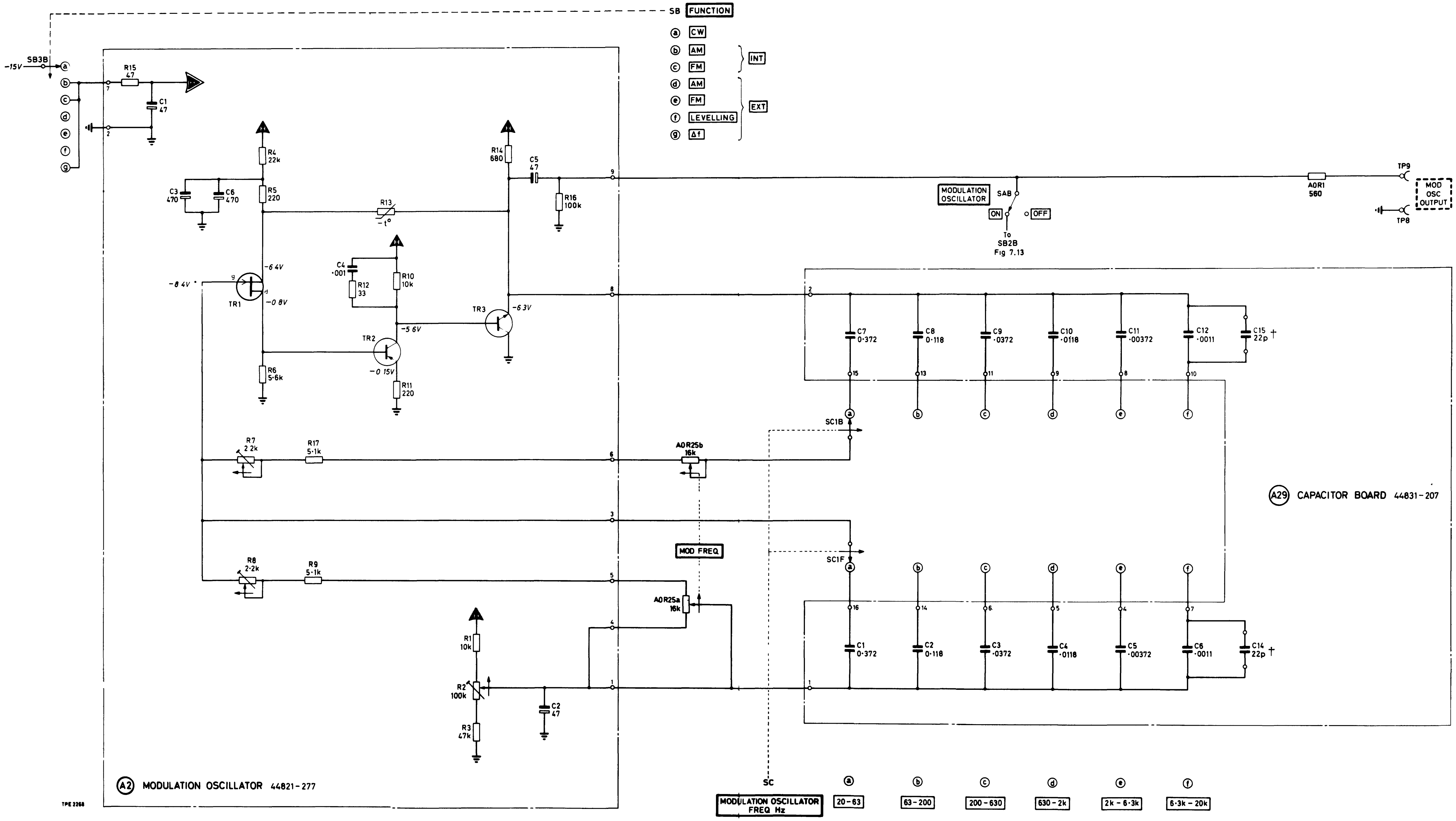


Fig. 7.11 Modulation oscillator

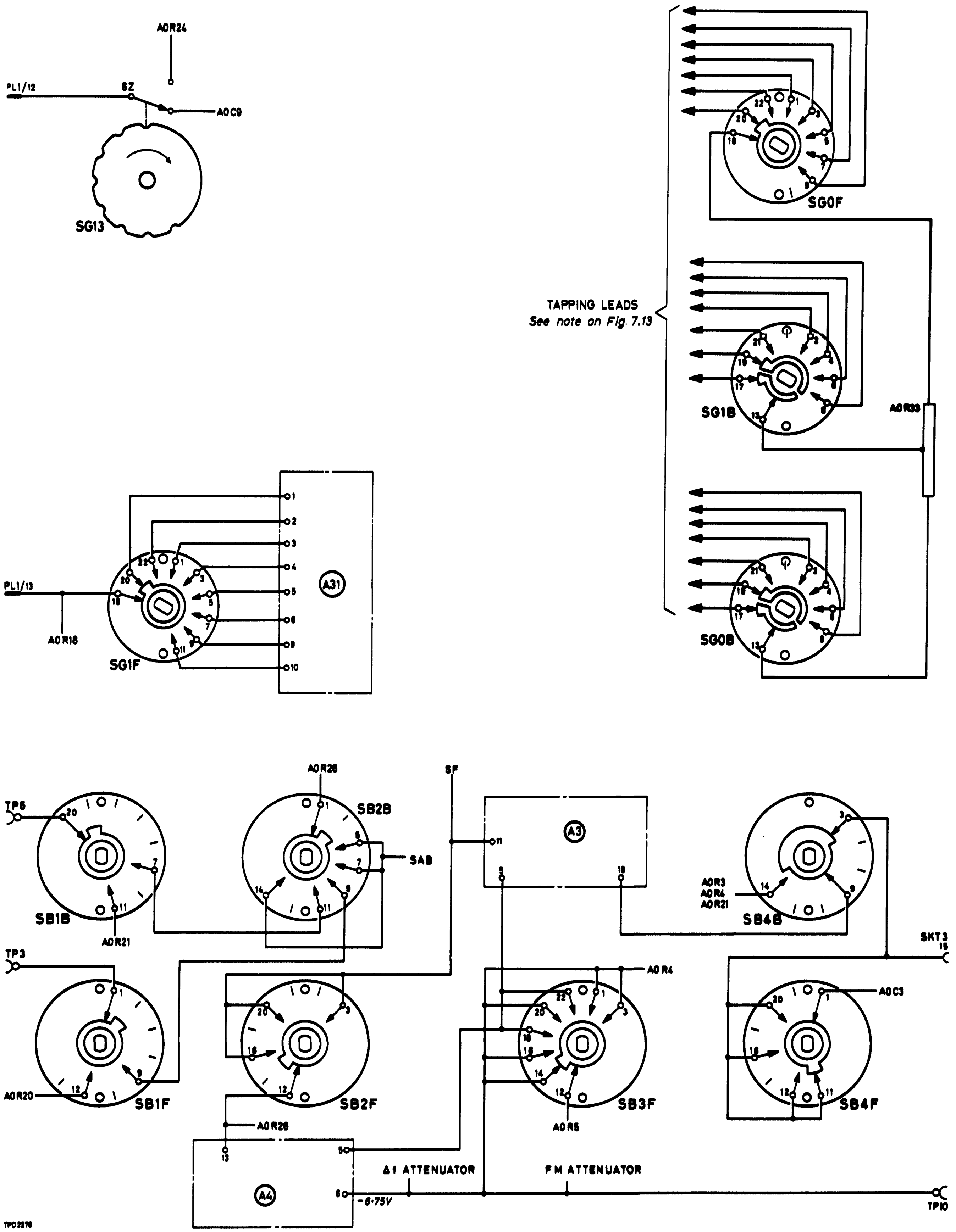


Fig. 7.12 Switching: modulation drive and monitor circuits

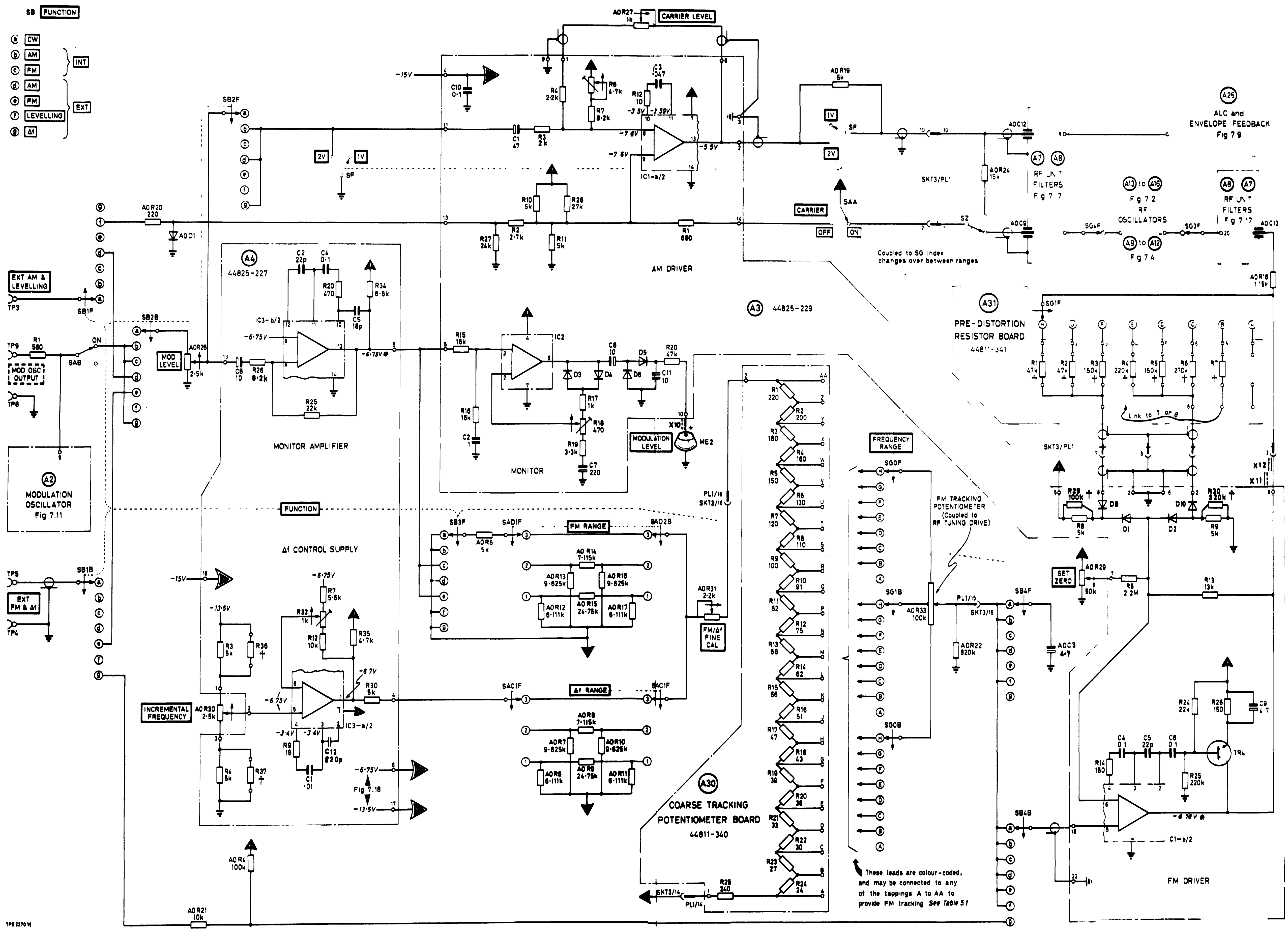


Fig. 7.13 Modulation drive and monitor circuits

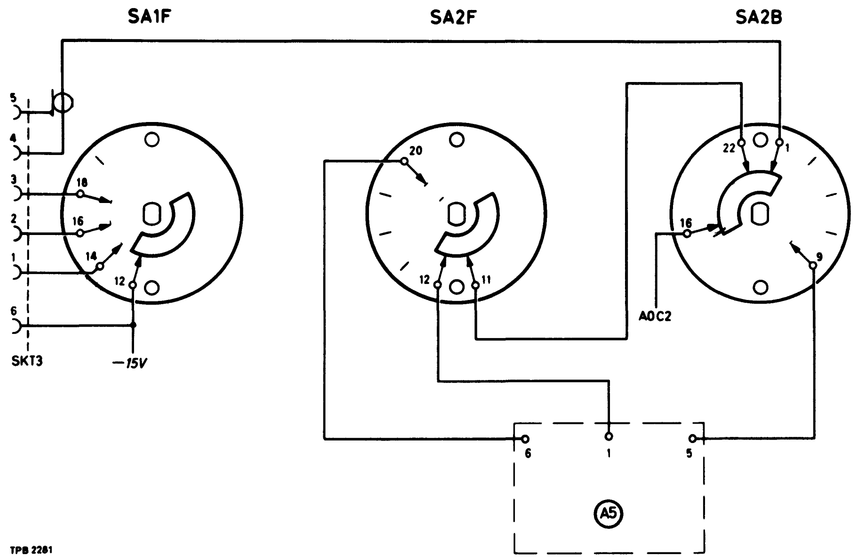


Fig. 7.14 Crystal calibrator amplifier switching

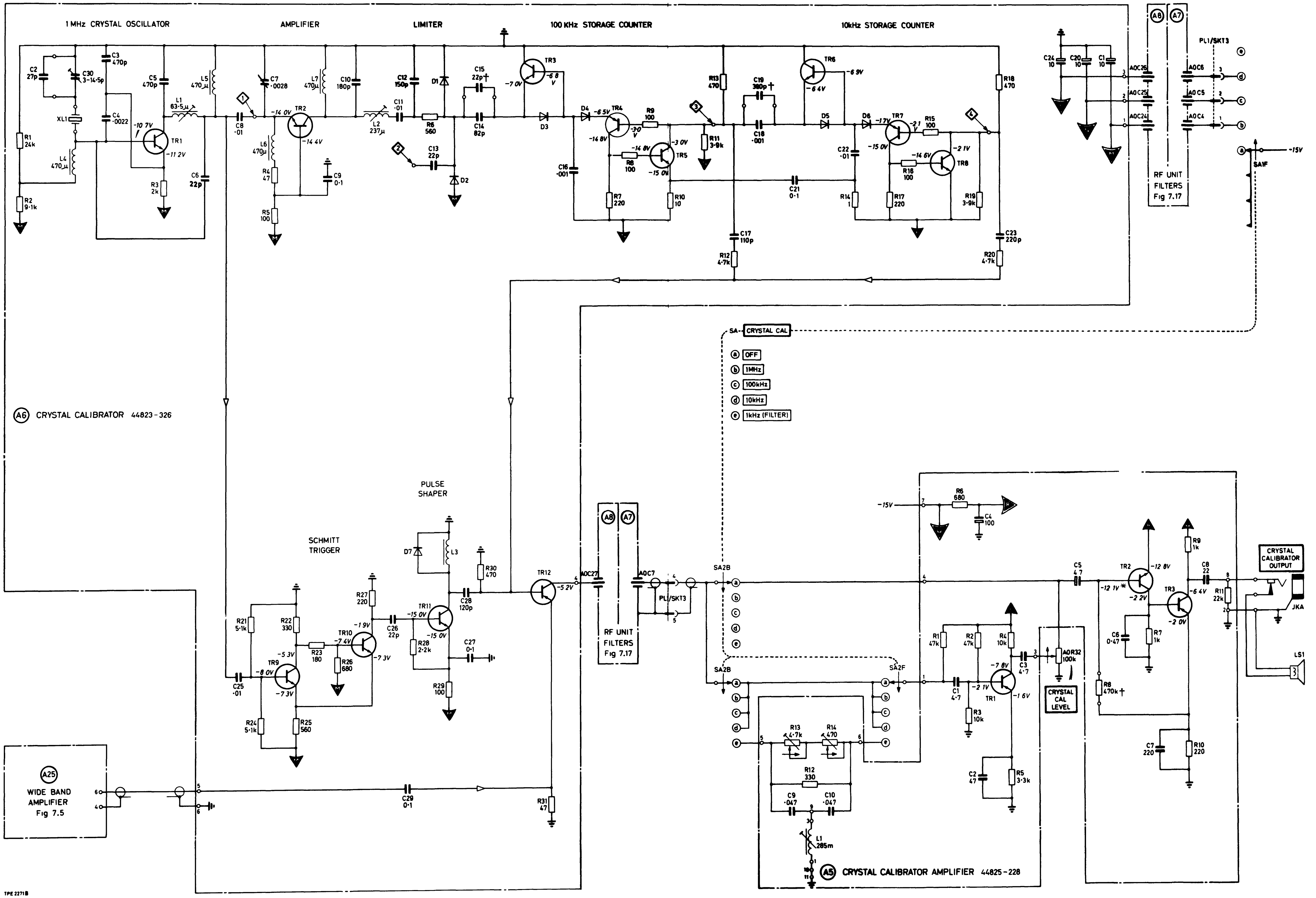
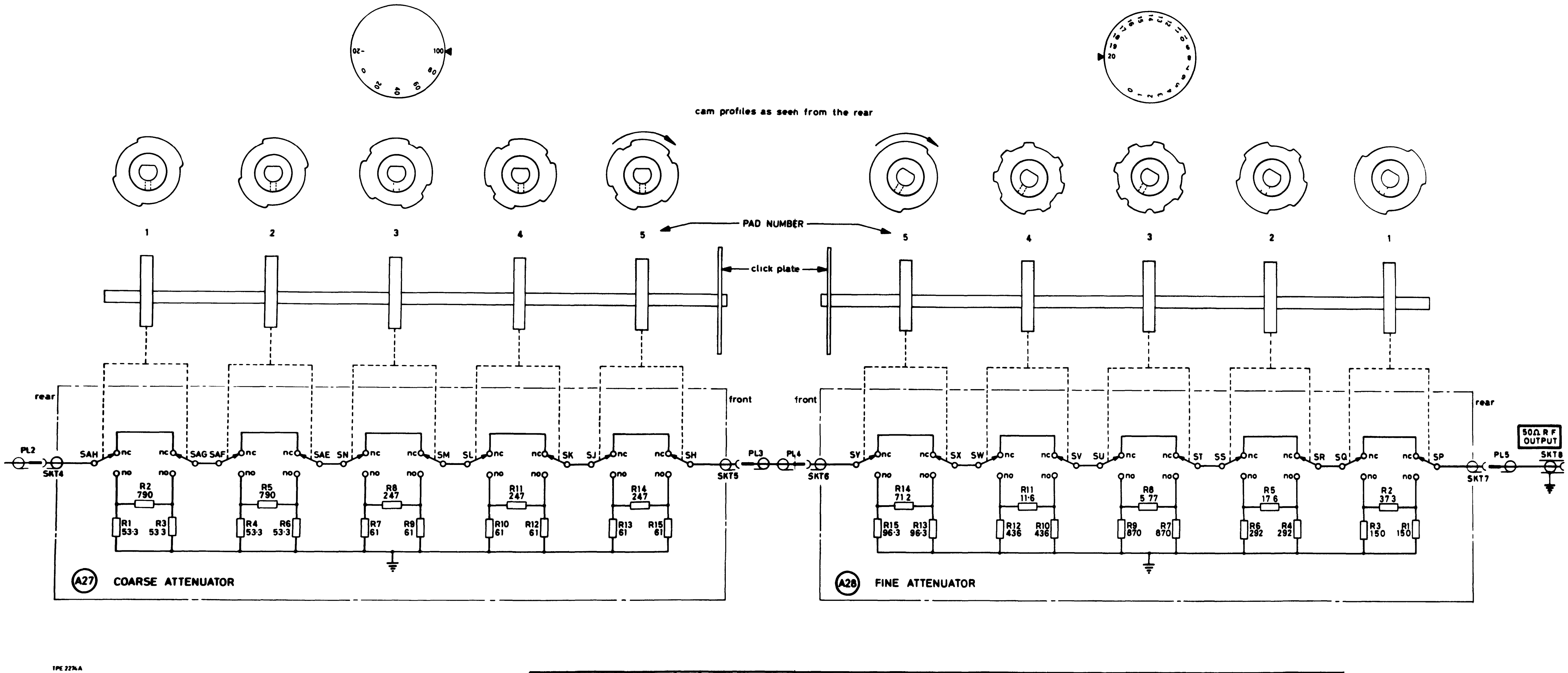


Fig. 7.15 Crystal calibrator and amplifier



100	80	60	40	20	0	-20	dB ABOVE 1µV —ADD—			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	20	40	60	80	100	120	ATTENUATION dB			20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
							dB	PAD SECTIONS IN CIRCUIT	dB																					
—	—	—	—	Π	Π	Π	30	1	6	Π	Π	Π	Π	Π	—	—	—	—	—	—	Π	Π	Π	Π	—	—	—	—	—	—
—	—	—	—	Π	Π	Π	30	2	3	Π	Π	Π	—	—	Π	Π	Π	—	—	—	Π	—	—	—	Π	Π	Π	—	—	—
—	Π	—	Π	Π	—	Π	20	3	1	Π	—	—	Π	—	—	Π	—	—	Π	—	—	—	Π	—	—	Π	—	—	Π	—
—	—	Π	Π	—	Π	Π	20	4	2	—	—	—	—	—	Π	—	—	Π	—	—	—	Π	—	—	Π	—	—	Π	—	—
—	—	Π	Π	—	Π	Π	20	5	10	Π	Π	Π	Π	Π	Π	Π	Π	Π	Π	Π	—	—	—	—	—	—	—	—	—	—

Fi 7.16 Attenuators

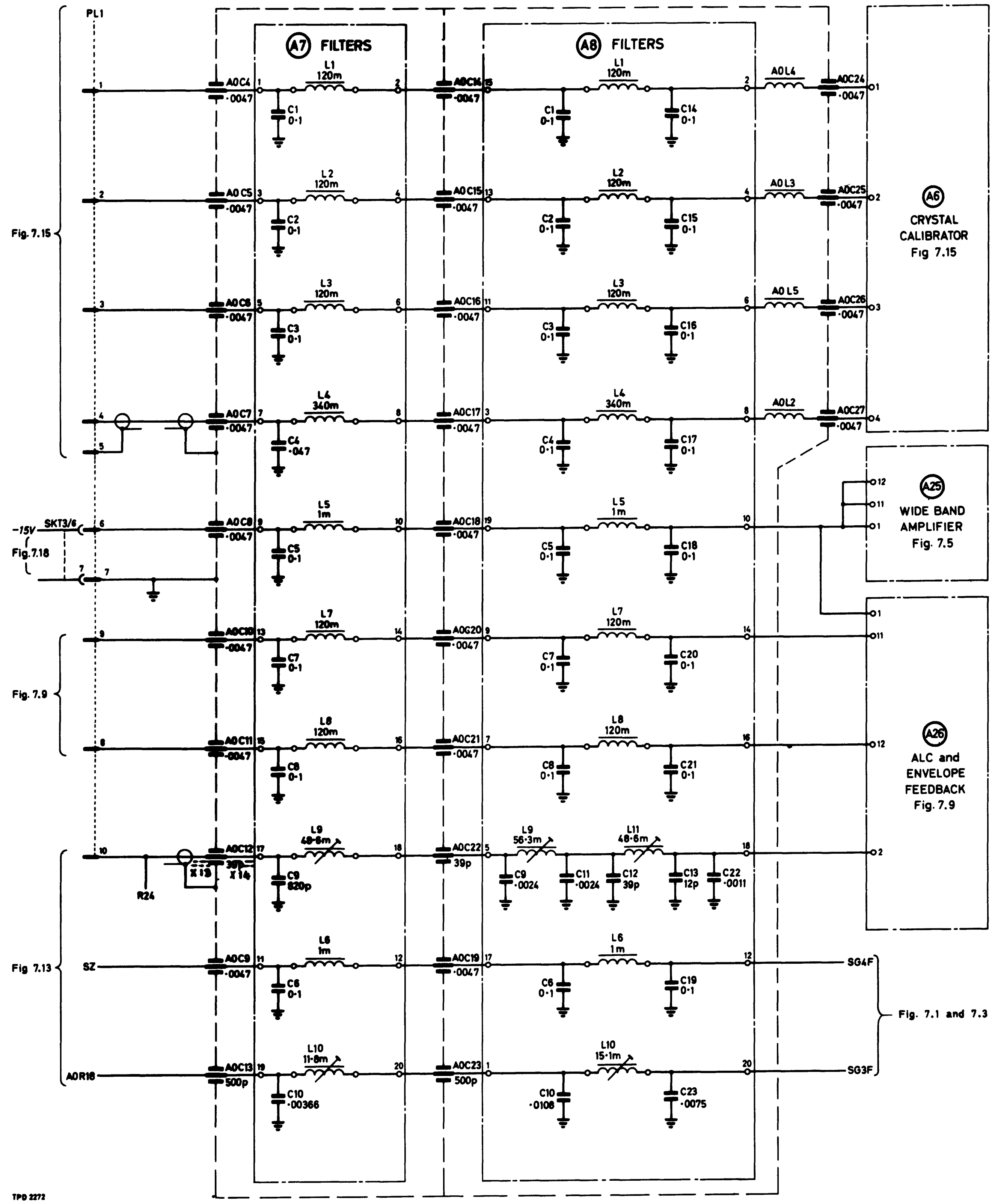


Fig. 7.17 RF unit filters

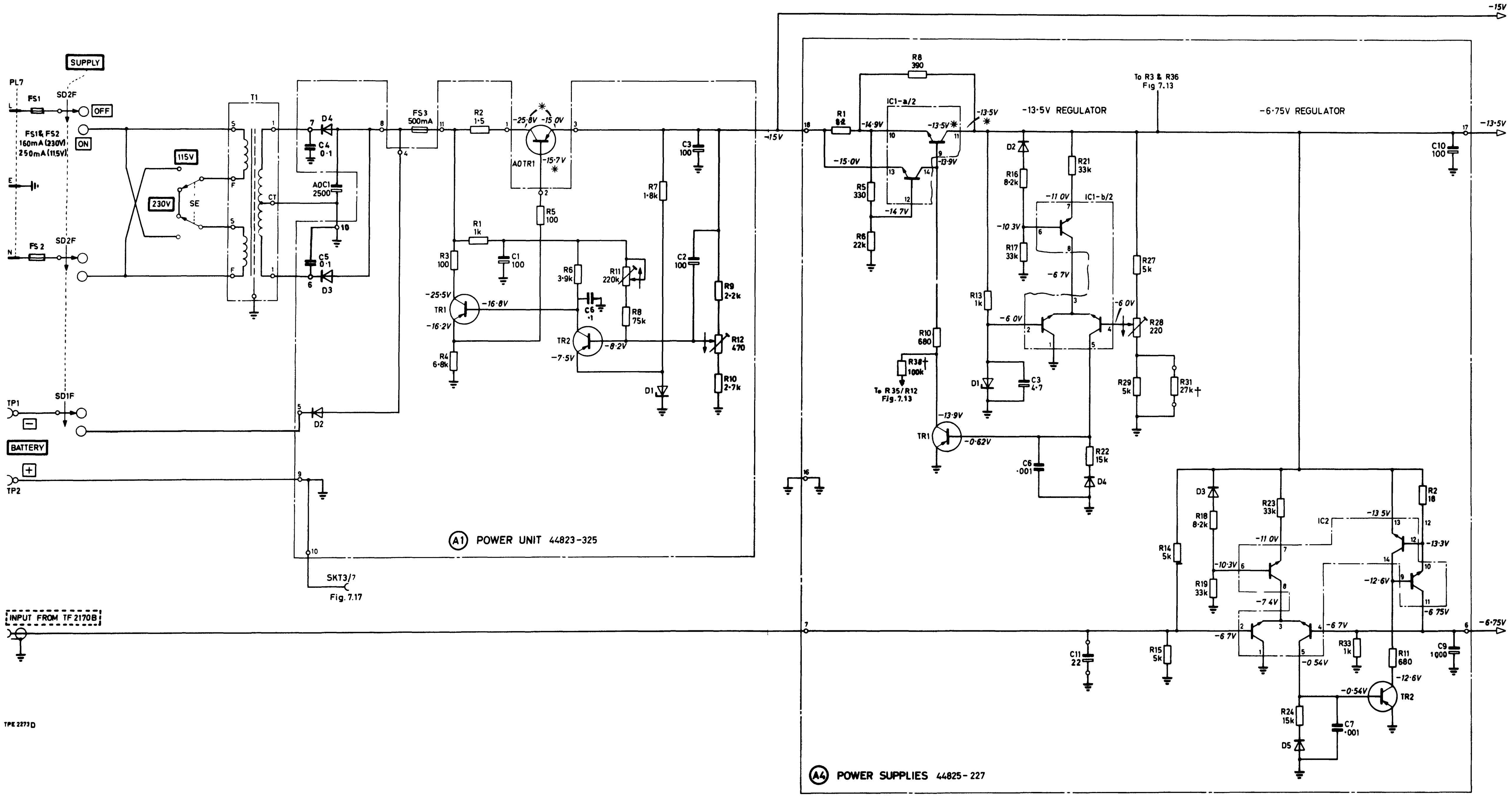


Fig. 7.18 Power unit and regulators

Instruction Manual No. EB 2002B
for MF/HF AM/FM SIGNAL GENERATOR TF 2002B

Supplement for
SPECIAL VERSION WITH WIDE BAND FM

Model Nos. 52002-301L
52002-302J

Chapter 1 GENERAL INFORMATION

1.1 INTRODUCTION

Both the '301' and the '302' versions of the generator retain all the features of the standard TF 2002B with the added facility of wide band f.m. on r.f. ranges G and H. The accompanying manual for the standard model applies also to the '-301' and '-302' versions except for the differences listed below for each chapter. The '302' version consists of a '301' version with additional accessories - see below.

1.2 DATA SUMMARY

Characteristics and performance of the instrument are as detailed in Manual EB 2002B Sect. 1.2 with the following addition which is related only to the wide band f.m. facility.

Characteristic	*Performance*	*Supplementary information*
External wide band f.m relative to r.f. ranges G and H.	Enables square wave modulation up to a p.r.f. of 20 kHz or sine wave modulation up to approximately 200 kHz.	Approximate input for maximum deviation is 3.4 V p-p.

1.3 ACCESSORIES

Except for the 2 : 1 voltage ratio pad TM 5573/3, MI code 44411-019, which is not supplied with the '-301' version, the supplied and available accessories are as listed in manual EB 2002B.

The '-302' version is supplied with additional accessories and these are listed below.

1.	Stowage lid	MI code 41690-018
2.	RF Fuse Unit TM 9881	MI code 43281-007
3.	20 dB Pad TM 5573	MI code 44125-501
4.	Voltage ratio pad 2 : 1	MI code 44459-015
5.	Spanner 7/16 in AF 1/2 in AF	MI code 22952-001

Chapter 2 OPERATION

2.1 INTRODUCTION

Except for the addition of a FM WIDE BAND/NORMAL switch located at the rear of the instrument as shown in Fig. 2.1, the controls and connectors are the same as those detailed in Manual EB2002B and since the features of the standard model are retained the following operating instructions are concerned with the wide band f.m. facility for use on ranges G and H only.

2.2 WIDE BAND FM (a.c. coupled)

(1) Release the coin slotted screw (1) and raise the hatch (2). Then remove the now exposed button seal on the r.f. box to obtain access to the FM WIDE BAND/NORMAL switch.

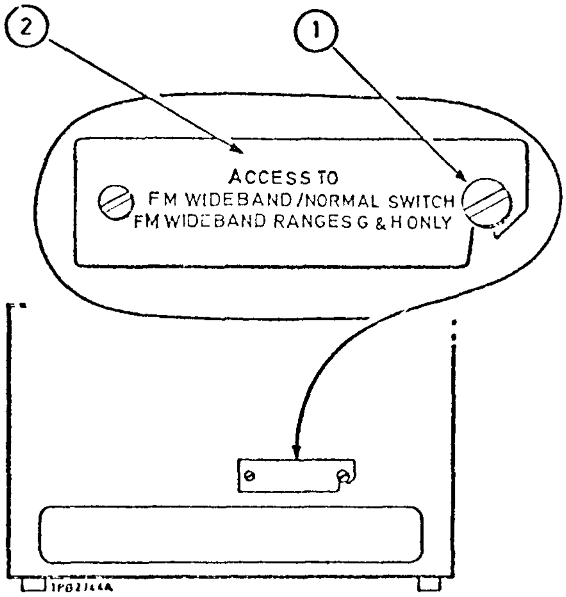


Fig. 2.1 Rear panel of '-301' version of TF 2002B

(2) Using a screwdriver, position the toggle of the switch UP, i.e. at FM WIDE BAND. Replace the button seal and secure the hatch.

(3) For wide band (square wave) frequency modulation up to 20 kHz using r.f. ranges G and H, connect an external generator between EXT FM/Af terminal and EARTH terminal.

(4) Set the external generator to provide an output of approximately 3.5 V p-p at the required frequency. Set the MODULATION LEVEL control and FM RANGE switch on the signal generator to give the desired deviation. The deviation is indicated by the MODULATION meter on the signal generator.

NOTE. The wide band f.m. feature extends the sine wave response to approximately 200 kHz.

Chapter 3 TECHNICAL DESCRIPTION

3.1 INTRODUCTION

This chapter describes only the differences between the '-301' version and standard model of TF 2002B.

3.2 MECHANICAL DIFFERENCE

The '-301' version incorporates a s.p.d.t. toggle type switch SAJ (MI code 23162-252) which is fitted within the r.f. box. The switch enables the generator to be used for wide band frequency modulation and access is obtained by following the instructions given in Sect. 2.2 of this supplement.

3.3 CIRCUIT MODIFICATIONS

(1) Block diagram (Manual EB 2002B, Fig. 3.2) :

The only change is shown in Fig. 3.1.

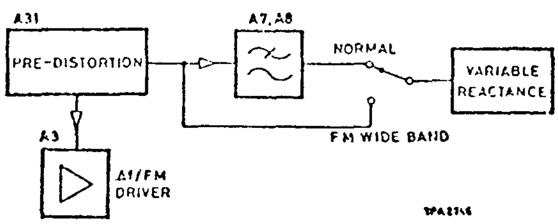


Fig. 3.1 Modification to block diagram

(2) Range B oscillator Unit A10 (Manual EB2002B Fig. 7.2 and Sect. 6, A10) :

mi

:0

(3) Range E oscillator Unit A13 (Manual EB 2002B Fig. 7.4 and Sect. 6, A13) :

A metal film 100 Ω ±2% ¼ W resistor R50 (MI code 24773-249) is incorporated in the circuit of the range E oscillator as shown in Fig. 3.2.

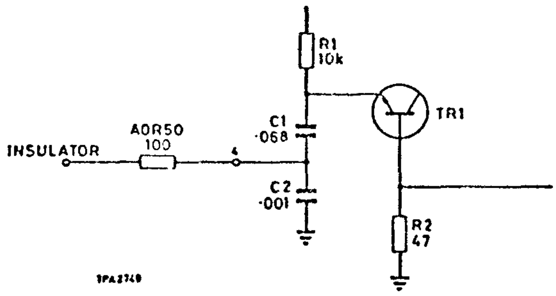


Fig. 3.2 100 Ω resistor added to range E oscillator circuit

(4) Filter Units A7 and A8 (Manual EB 2002B Figs 7.13 and 7.17) :

To enable wide band frequency modulation the circuits of units A7 and A8 are modified as shown in Fig. 3.3.

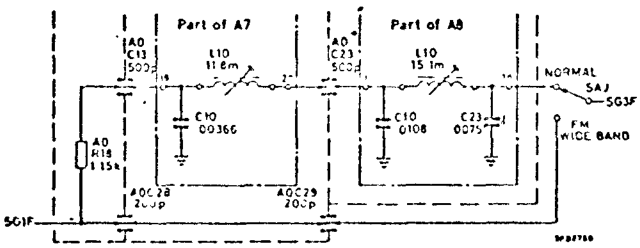


Fig. 3.3 Modified circuits for units A7 and A8

A0C28	:	Ceramic Ø 200pF ±20% 500V	26333-568
A0C29	:	Ceramic Ø 200pF ±20% 500V	26333-568
SAJ	:	Switch SPDT 250V 3A	23162-252

A0R18 is now positioned within the filter box.

Modified inter-circuit connections are shown in Fig. 3.4.

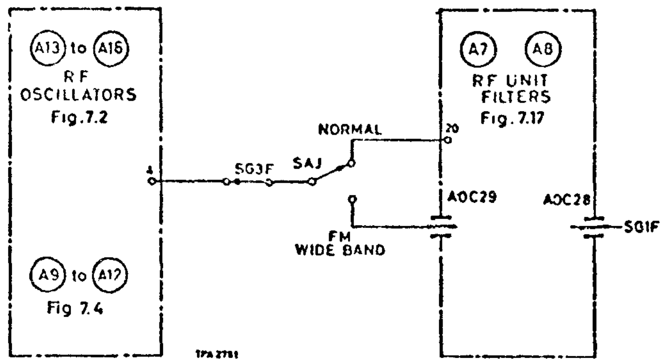


Fig. 3.4 Modified inter-circuit connections

Chapter 4 MAINTENANCE

4.1 INTRODUCTION

Except for checks related to the wide band f.m. facility, the information given in EB 2002B Sect. 4 can, in general, be accepted as applicable to the '-301' version.

4.2

To check the operation of the wide band f.m. facility proceed as follows :

(1) Connect a modulation meter (MI TF 2300 or equivalent) to the 50 Ω r.f. output on the signal generator. Connect the output of a sine wave a.f. generator between the EXT FM/Δf terminal and EARTH terminal.

(2) Set the signal generator RANGE switch at G, the FUNCTION selector at EXT FM, the FM WIDE BAND/NORMAL switch at FM WIDE BAND and the frequency of the signal generator at 20 MHz.

(3) Connect the instruments to the mains supply and switch on.

(4) Set the a.f. generator for an approximate output of 3.5 V p-p at 30 kHz. Then adjust the signal generator output and the FM controls for an indication of 50 kHz deviation on the Modulation Meter TF 2300.

(5) Set the FM WIDE BAND/NORMAL switch at NORMAL. The indicated deviation should then approximate 5 kHz.

(6) If desired, repeat the check at other carrier frequencies on ranges G and H. It should then be noted that the f.m. tracking network incorporated in the generator causes some variation in response.

Chapter 5 REPAIR

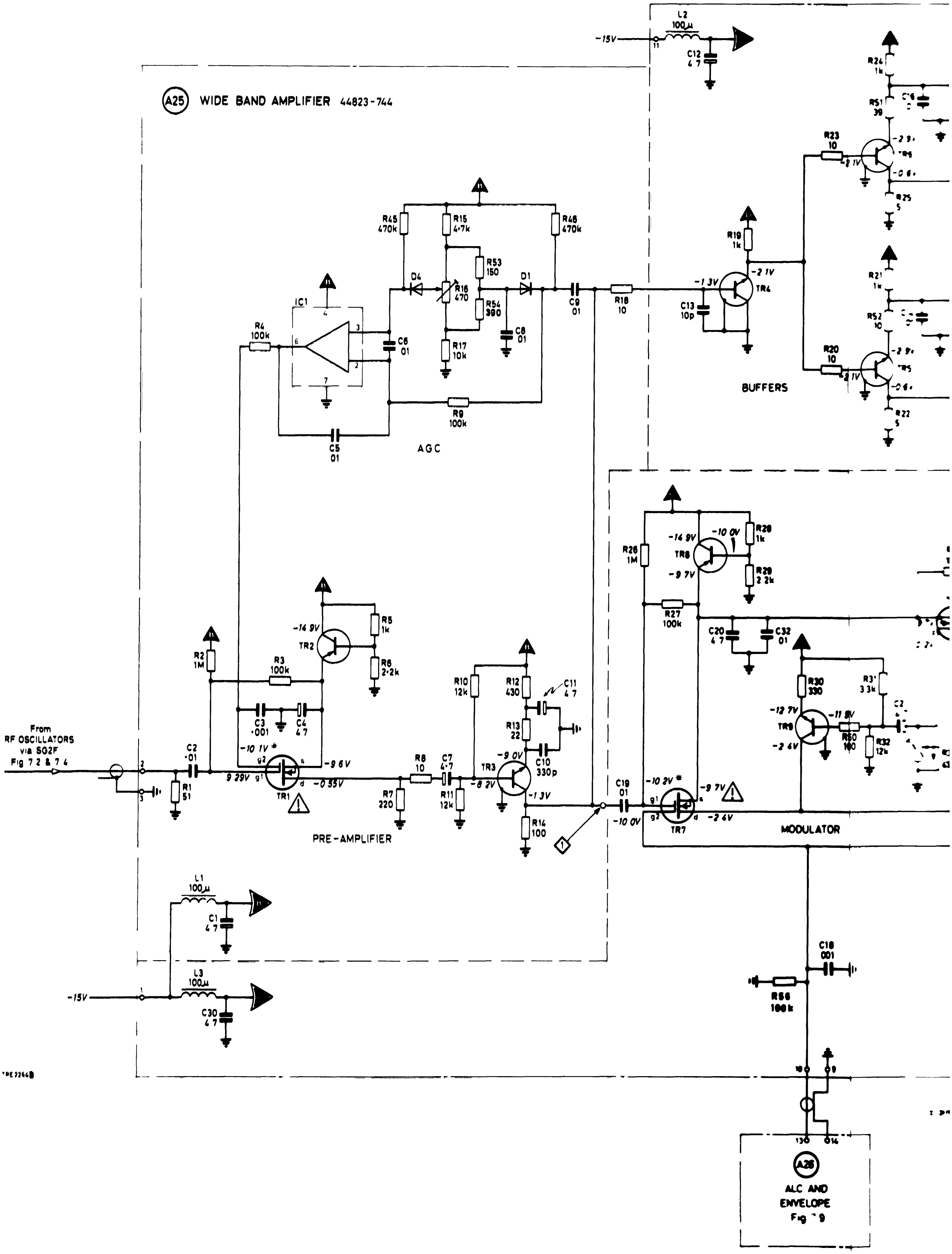
The information given in EB 2002B is in general applicable to the '-301' version, taking into consideration the wide band f.m. feature.

Chapter 6 REPLACEABLE PARTS

Refer to manual EB 2002B noting additions contained within this supplement.

Chapter 7 CIRCUIT DIAGRAMS

Refer to manual EB 2002B noting modifications given in this supplement.


A25 WIDE BAND AMPLIFIER 44823-744
AGC
BUFFERS
PRE-AMPLIFIER
MODULATOR
From
RF OSCILLATORS
via SG2F
Fig 7 2 & 7 4
-15V
L1 100μ
L2 100μ
L3 100μ
IC1
R4 100k
R45 470k
R15 4·7k
R46 470k
R53 150
R16 470
R54 390
R17 10k
D4
D1
C6 01
C8 01
C9 01
R18 10
R9 100k
C5 01
TR4
R19 1k
C13 10p
R23 10
R20 10
R2 1M
R3 100k
R5 1k
R6 2·2k
TR2
C2 ·01
R1 51
C3 ·001
C4 4 7
TR1
R7 220
R8 10
C7 4·7
R11 12k
R10 12k
R12 430
R13 22
C11 4 7
C10 330p
R14 100
TR3
C19 01
TR7
R26 1M
TR8
R28 1k
R29 2 2k
R27 100k
C20 4 7
C32 01
R30 330
TR9
R32 12k
C1 4 7
C12 4 7
C30 4 7
C18 001
R56 100k
A25
ALC AND
ENVELOPE

2002B (1b)

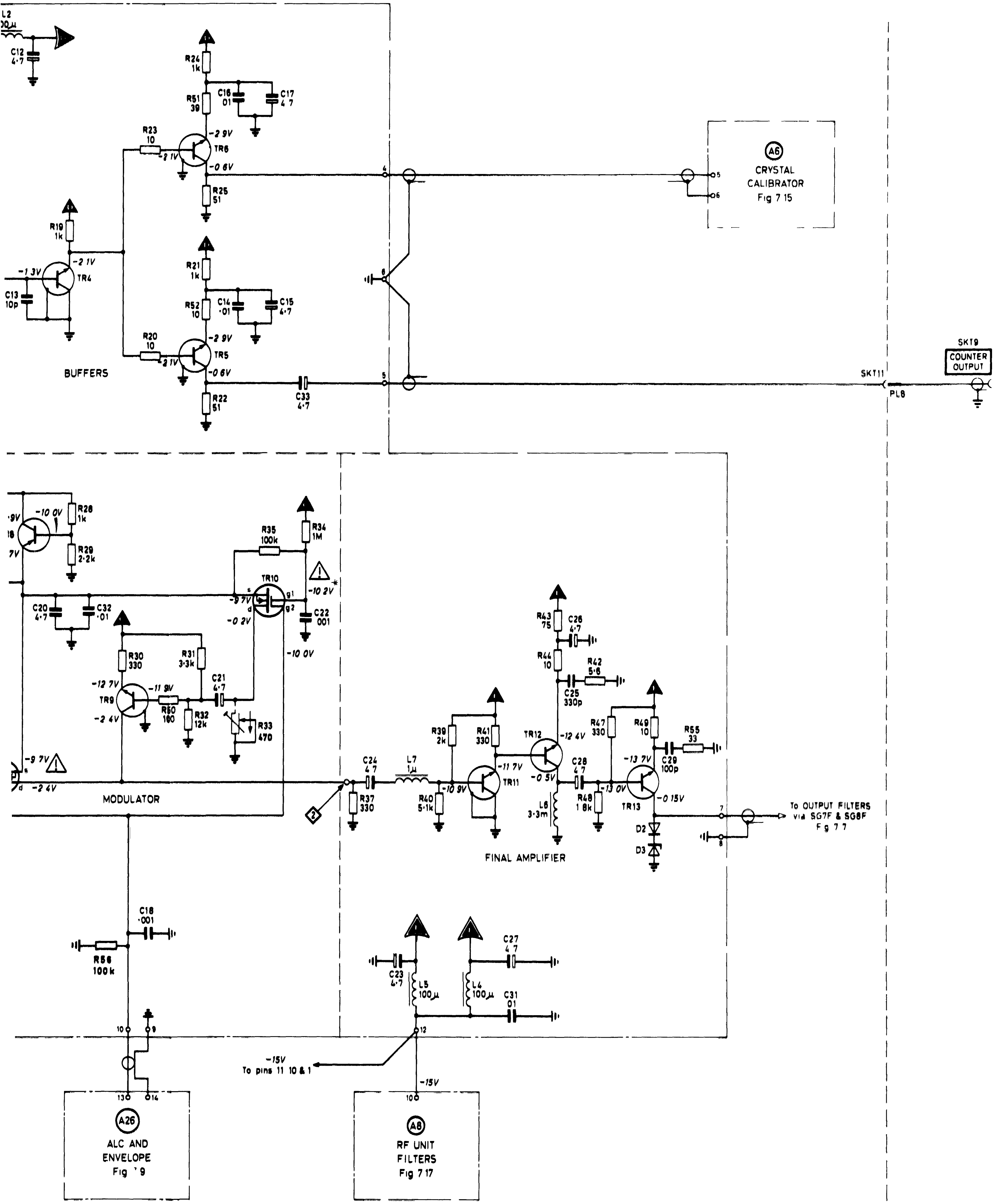
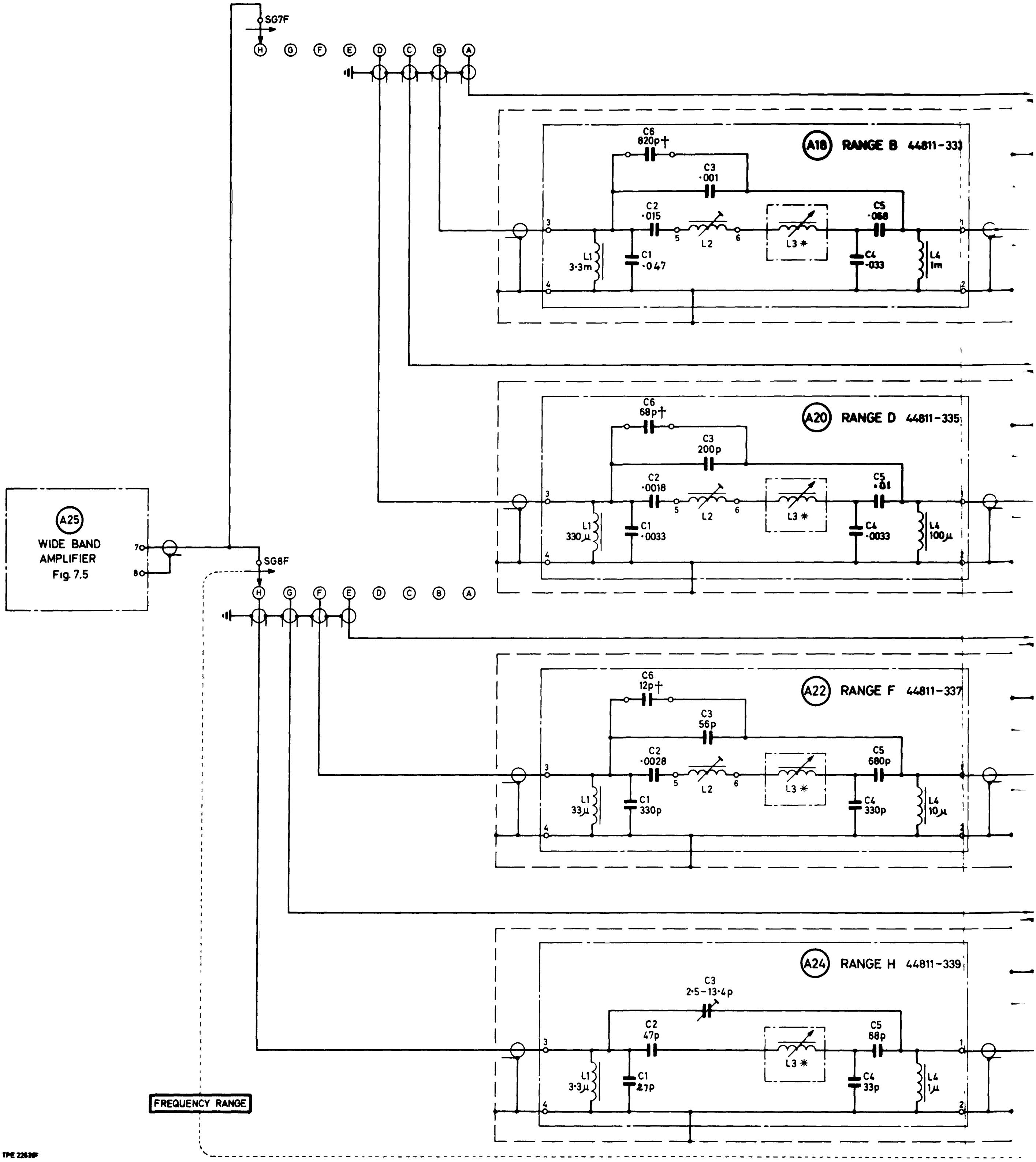


Fig. 7.5 Wide band amplifier

* Coupled to RF TUNING DRIVE Fig. 7.1



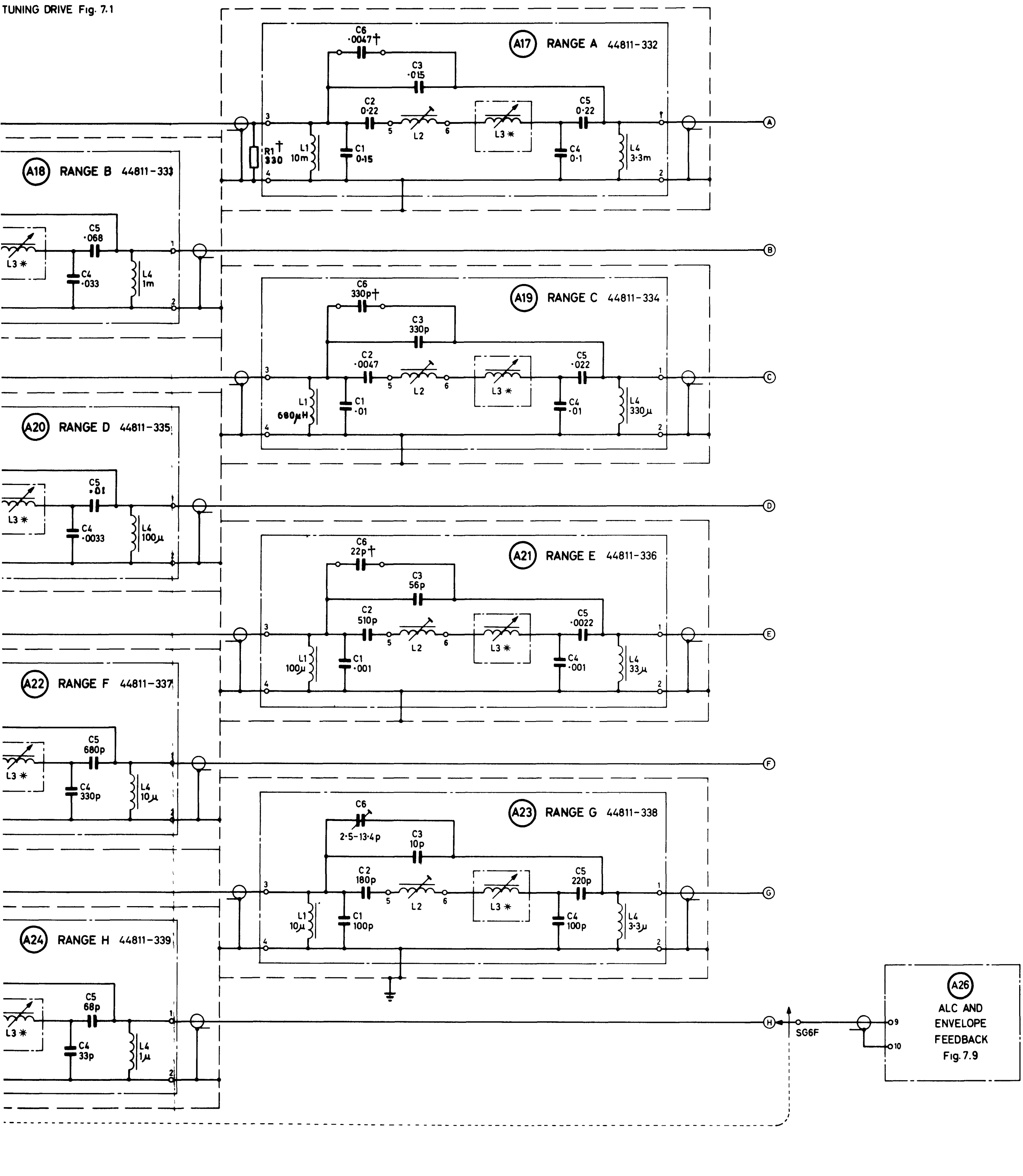
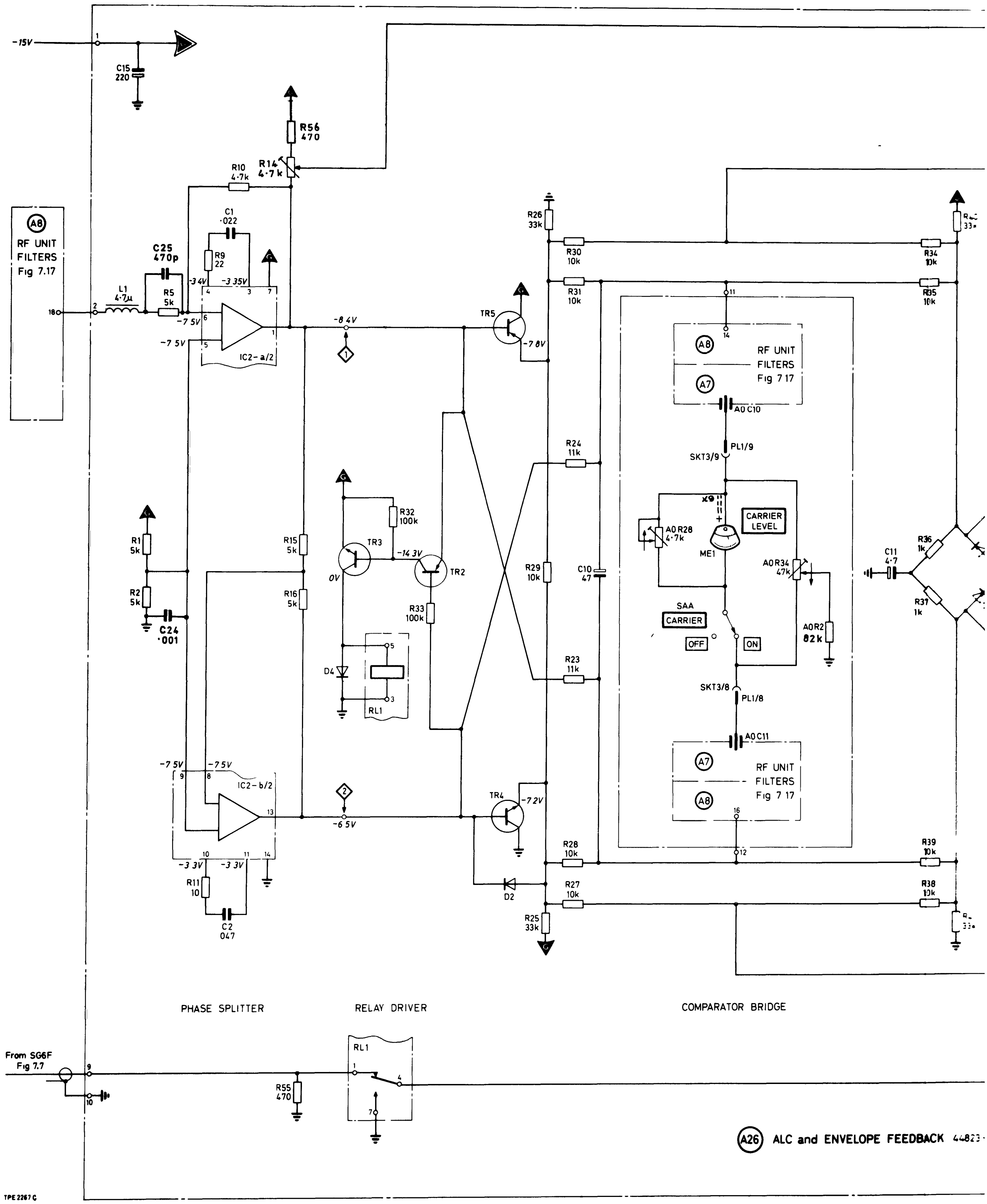


Fig. 7.7 Tuned output filters


-15V
C15 220
R56 470
R10 4·7k
R14 4·7k
RF UNIT FILTERS Fig 7.17
C1 ·022
C25 470p
R9 22
L1 4·7µ
R5 5k
IC2-a/2
-8·4V
TR5
-7·8V
R26 33k
R30 10k
R31 10k
R34 10k
R35 10k
RF UNIT FILTERS Fig 7 17
A0 C10
PL1/9
SKT3/9
R24 11k
CARRIER LEVEL
A0 R28 4·7k
ME1
A0 R34 47k
A0 R2 82k
SAA
CARRIER
OFF
ON
R1 5k
R2 5k
C24 ·001
R15 5k
R16 5k
R32 100k
TR3
TR2
-14·3V
0V
R33 100k
D4
RL1
R29 10k
C10 47
R23 11k
SKT3/8
PL1/8
A0 C11
C11 4·7
R36 1k
R37 1k
IC2-b/2
-7·5V
TR4
-7·2V
-6·5V
-3·3V
R11 10
C2 ·047
D2
R28 10k
R27 10k
R25 33k
R39 10k
R38 10k
PHASE SPLITTER
RELAY DRIVER
COMPARATOR BRIDGE
From SG6F Fig 7.7
R55 470
RL1
ALC and ENVELOPE FEEDBACK
TPE 2267 C

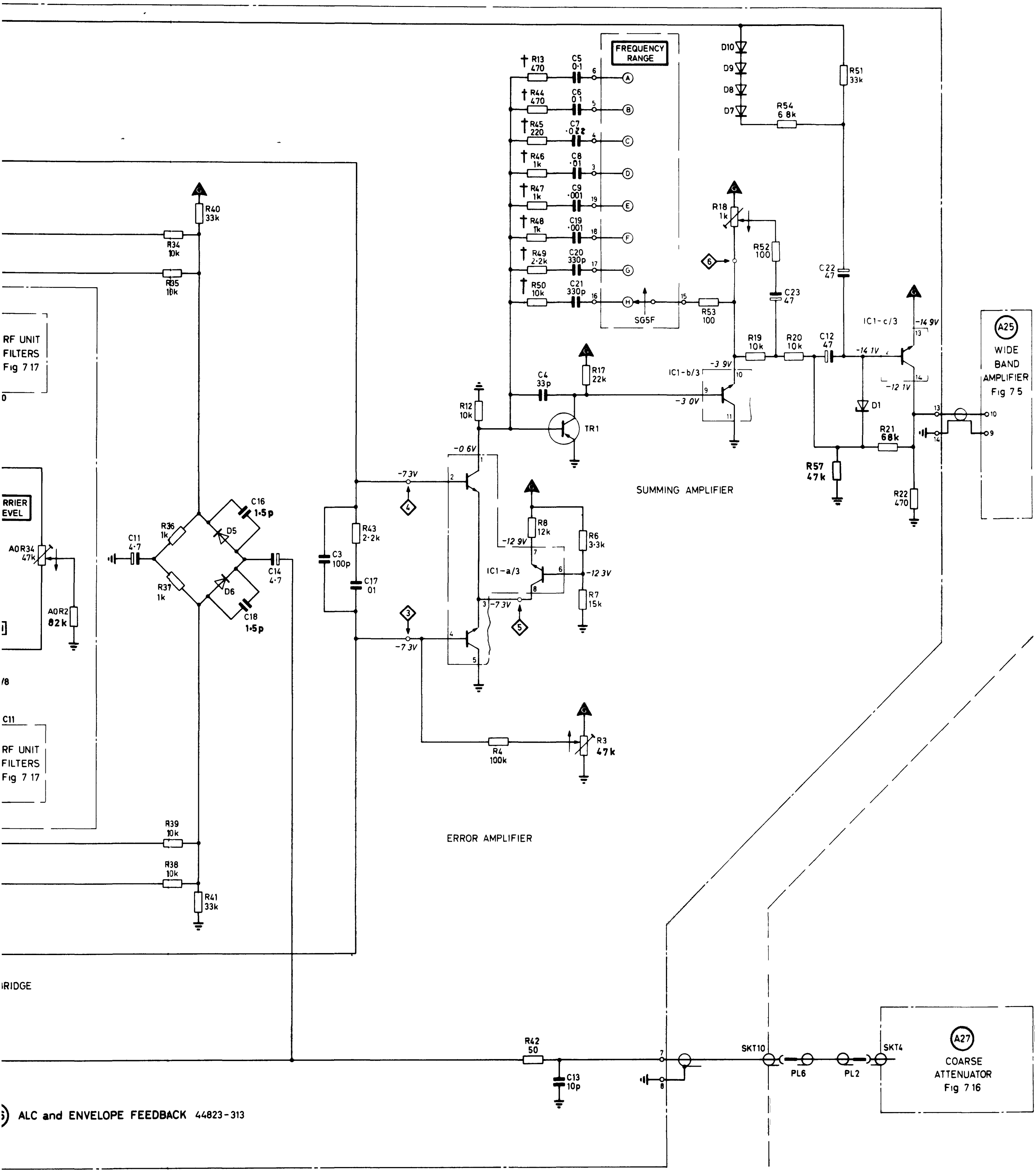
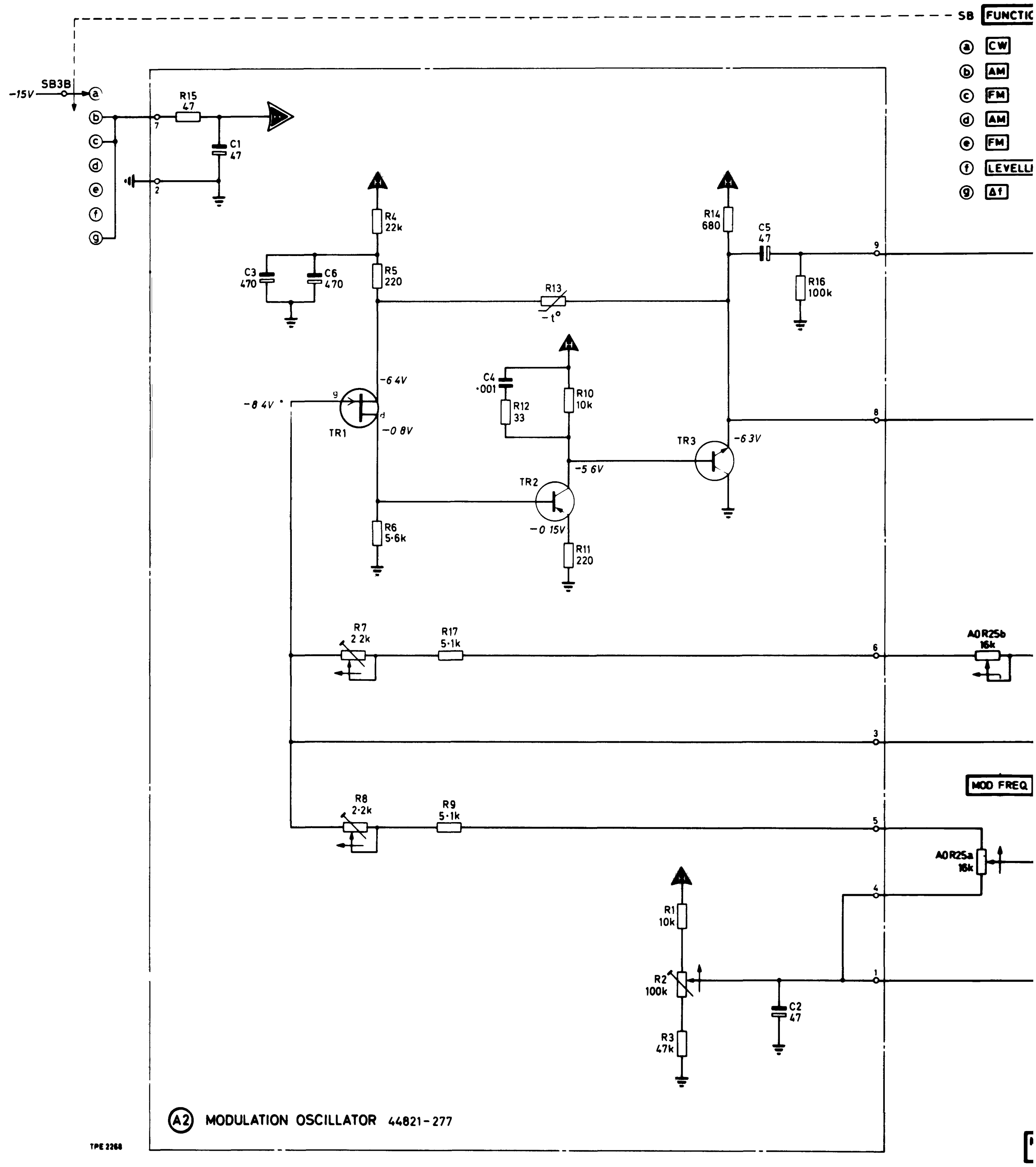


Fig. 7.9 ALC and envelope feedback circuits


SB FUNCTIC
CW
AM
FM
AM
FM
LEVELLI
Δf
-15V
SB3B
R15
47
C1
47
R4
22k
C3
470
C6
470
R5
220
R13
-t°
R14
680
C5
47
R16
100k
C4
·001
R10
10k
R12
33
-6·4V
-8·4V
TR1
-0·8V
TR2
-5·6V
TR3
-6·3V
R6
5·6k
-0·15V
R11
220
R7
2·2k
R17
5·1k
A0R25b
16k
MOD FREQ
R8
2·2k
R9
5·1k
A0R25a
16k
R1
10k
R2
100k
C2
47
R3
47k
A2 MODULATION OSCILLATOR 44821-277
TPE 2268

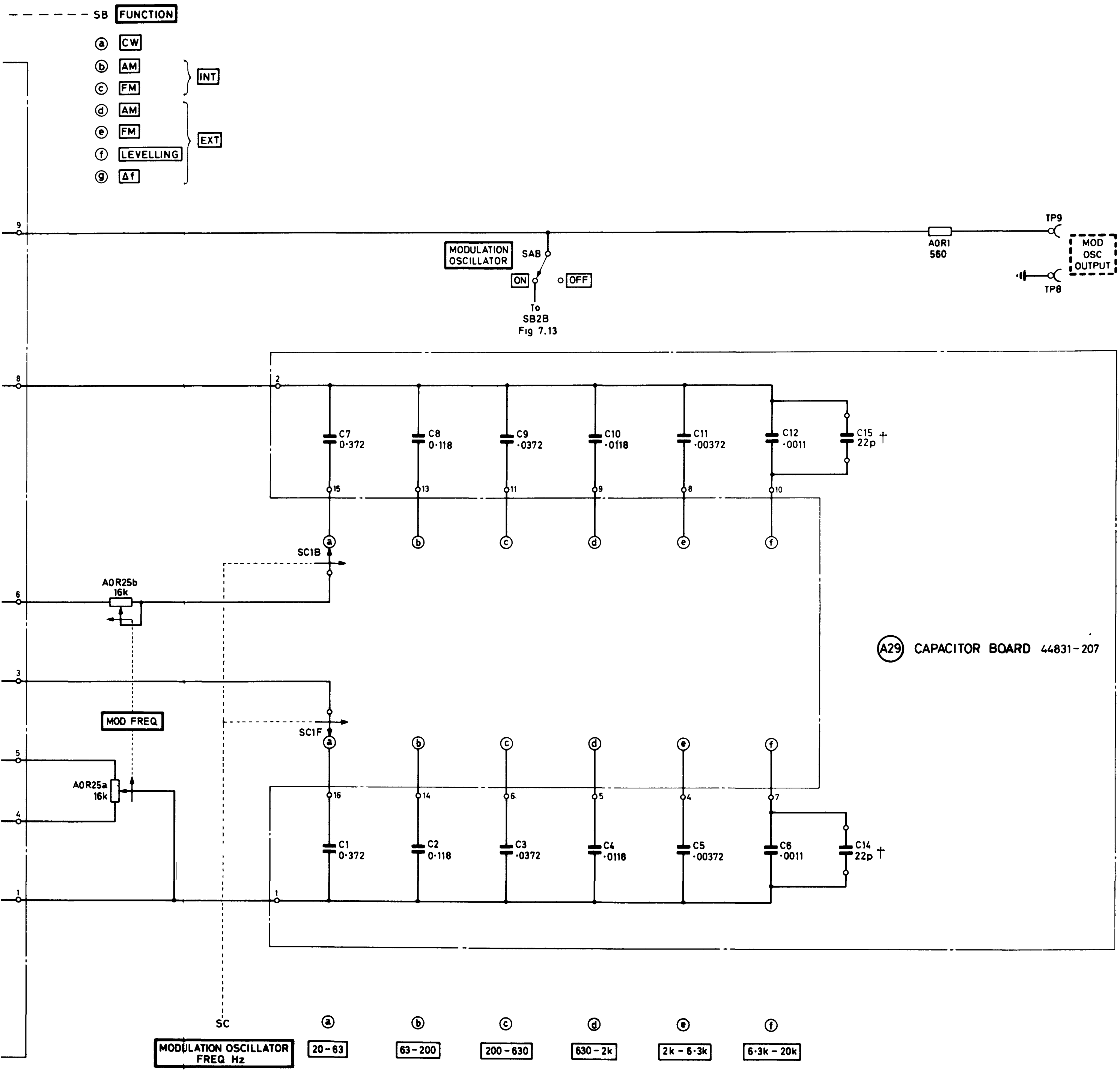
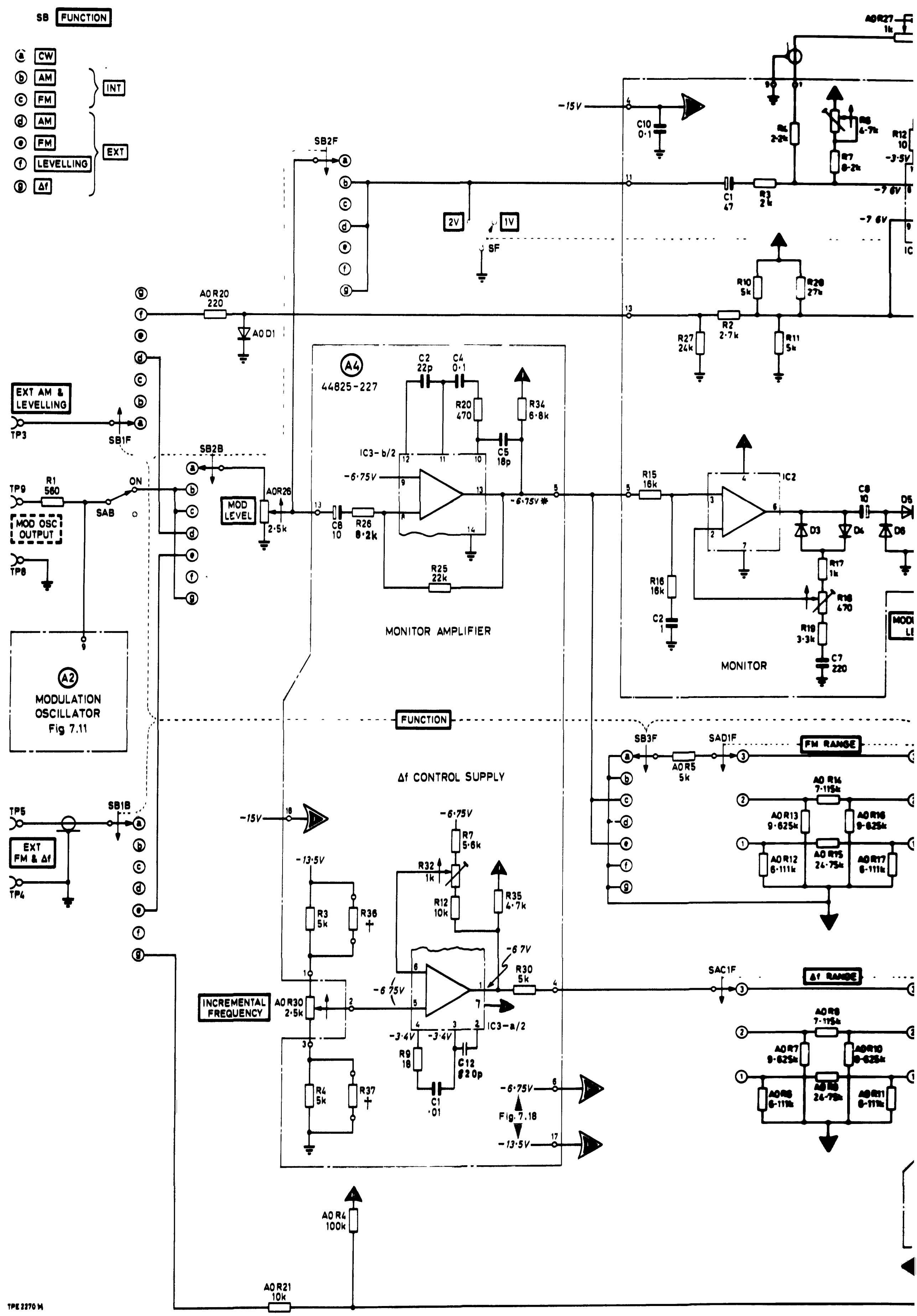


Fig. 7.11 Modulation oscillator


SB FUNCTION
CW
AM
FM
INT
AM
FM
LEVELLING
EXT
Δf
SB2F
2V
1V
SF
-15V
C10 0·1
R3 2k
C1 47
R10 5k
R28 27k
R2 2·7k
R27 24k
R11 5k
A0R20 220
A0D1
A4
44825-227
C2 22p
C4 0·1
R20 470
R34 6·8k
C5 18p
IC3-b/2
-6·75V
-6·75V
EXT AM & LEVELLING
TP3
SB1F
SB2B
TP9
R1 560
ON
SAB
MOD OSC OUTPUT
TP8
MOD LEVEL
A0R26 2·5k
C8 10
R26 8·2k
R25 22k
MONITOR AMPLIFIER
R15 16k
IC2
R16 16k
C2 1
R17 1k
R18 470
R19 3·3k
C7 220
MONITOR
A2
MODULATION OSCILLATOR Fig 7.11
FUNCTION
Δf CONTROL SUPPLY
SB3F
SAD1F
FM RANGE
A0R5 5k
A0 R14 7·115k
A0R13 9·625k
A0R16 9·625k
A0R12 6·111k
A0 R15 24·75k
A0R17 6·111k
TP5
SB1B
EXT FM & Δf
TP4
-15V
-6·75V
R7 5·6k
R32 1k
R12 10k
R35 4·7k
-13·5V
R3 5k
R36
INCREMENTAL FREQUENCY
A0R30 2·5k
-6·7V
R30 5k
SAC1F
Δf RANGE
IC3-a/2
-3·4V
-3·4V
R9 18
C12 820p
C1 ·01
R4 5k
R37
-6·75V
Fig. 7.18
-13·5V
A0R9 7·115k
A0R7 9·625k
A0R10 9·625k
A0R8 6·111k
A0R6 24·75k
A0R11 6·111k
A0 R4 100k
A0R21 10k
A0R27 1k
R6 4·7k
R7 8·2k
R12 10
C8 10
D3
D4
D5
D6

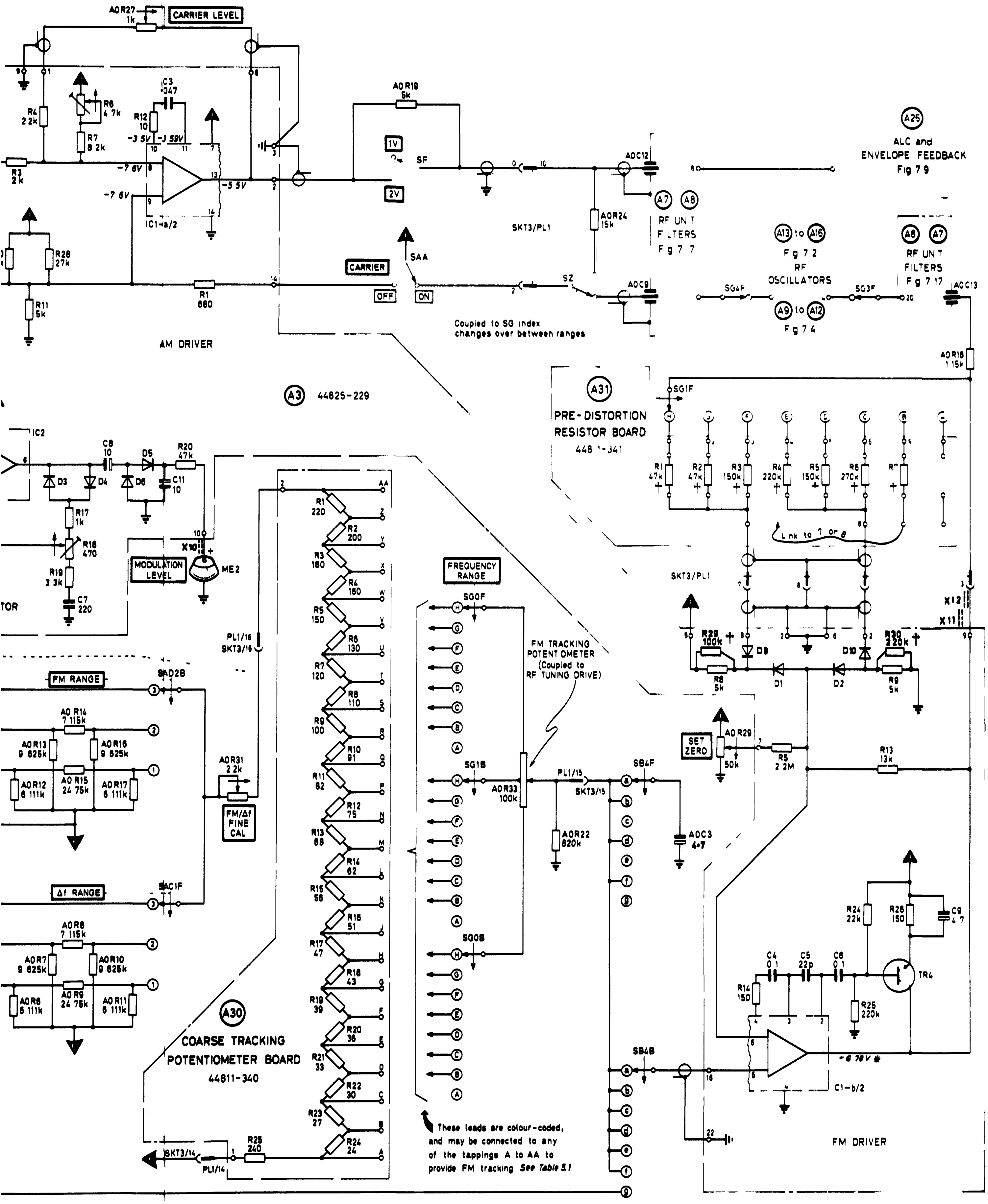
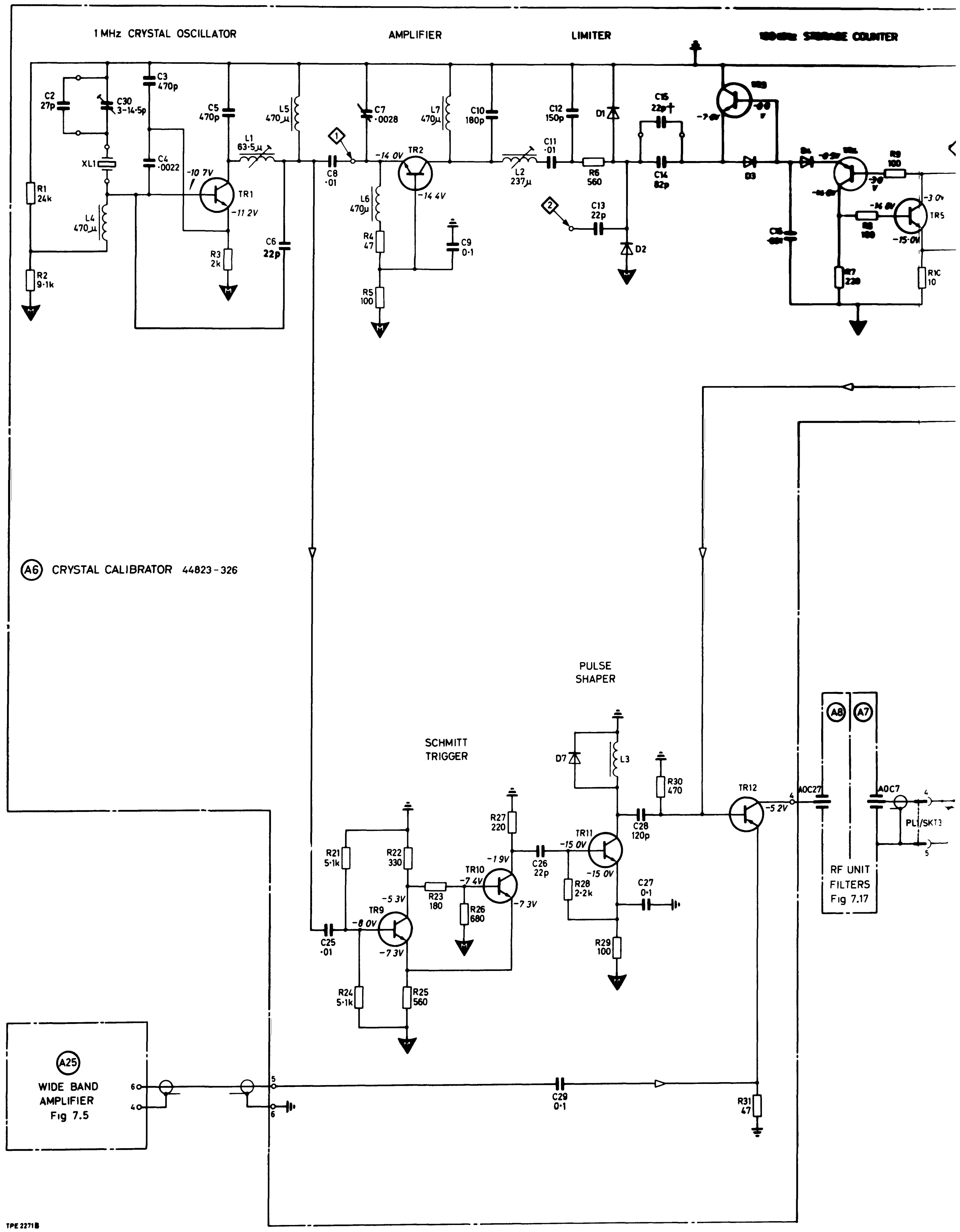


Fig. 7.13 Modulation drive and monitor circuits


1 MHz CRYSTAL OSCILLATOR
AMPLIFIER
LIMITER
(A6) CRYSTAL CALIBRATOR 44823-326
PULSE SHAPER
SCHMITT TRIGGER
RF UNIT FILTERS Fig 7.17
(A25) WIDE BAND AMPLIFIER Fig 7.5
TPE 2271B

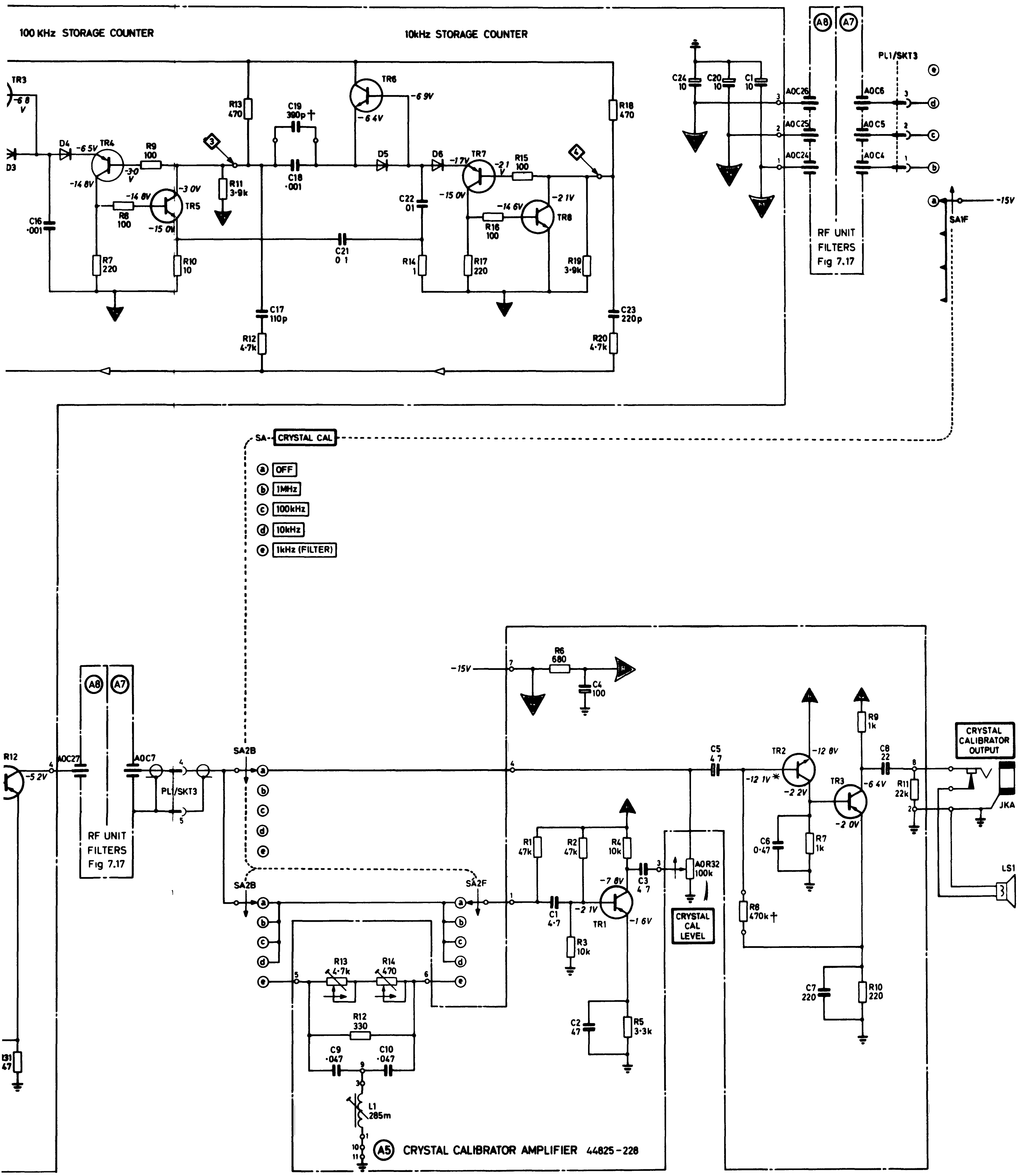
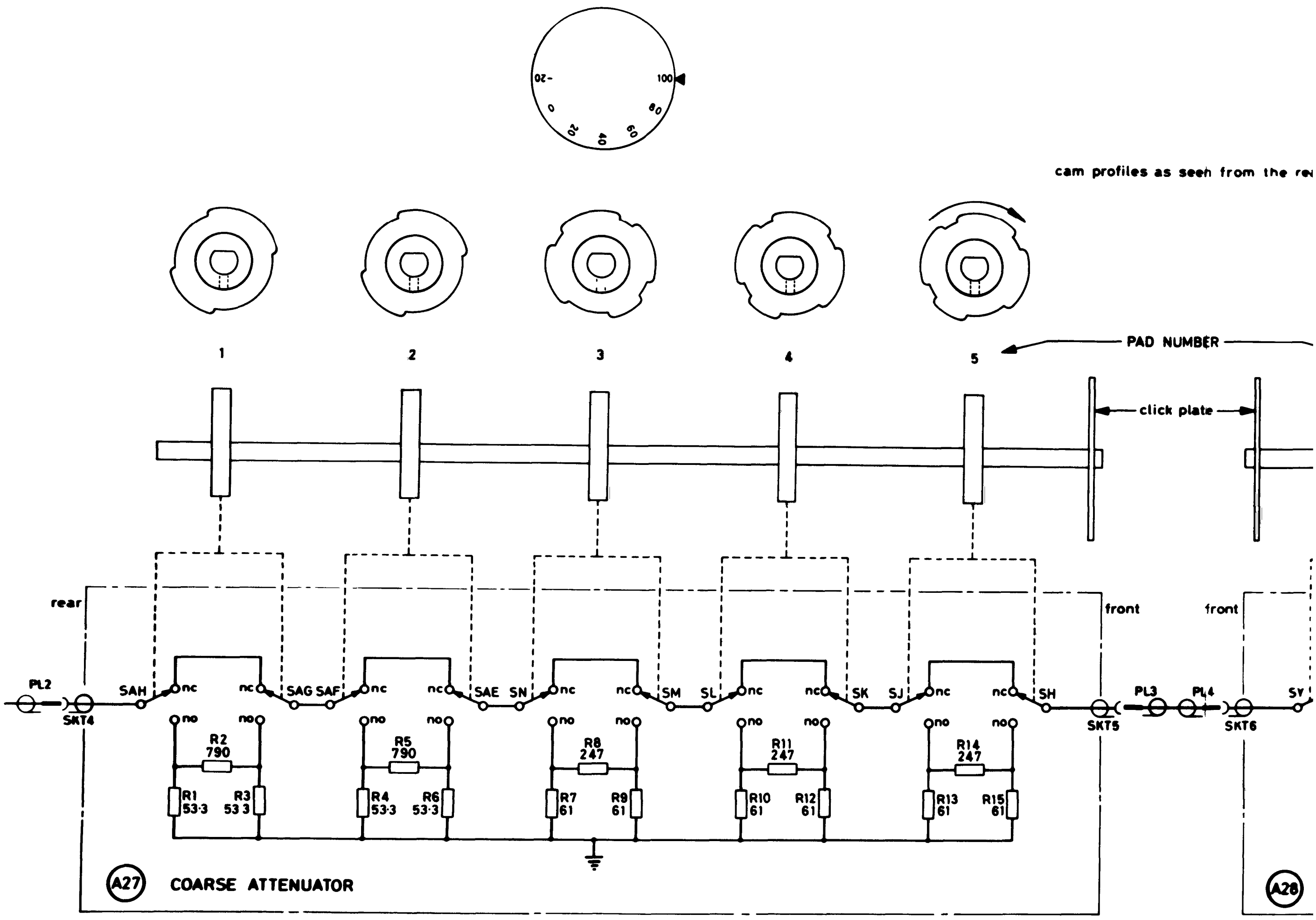
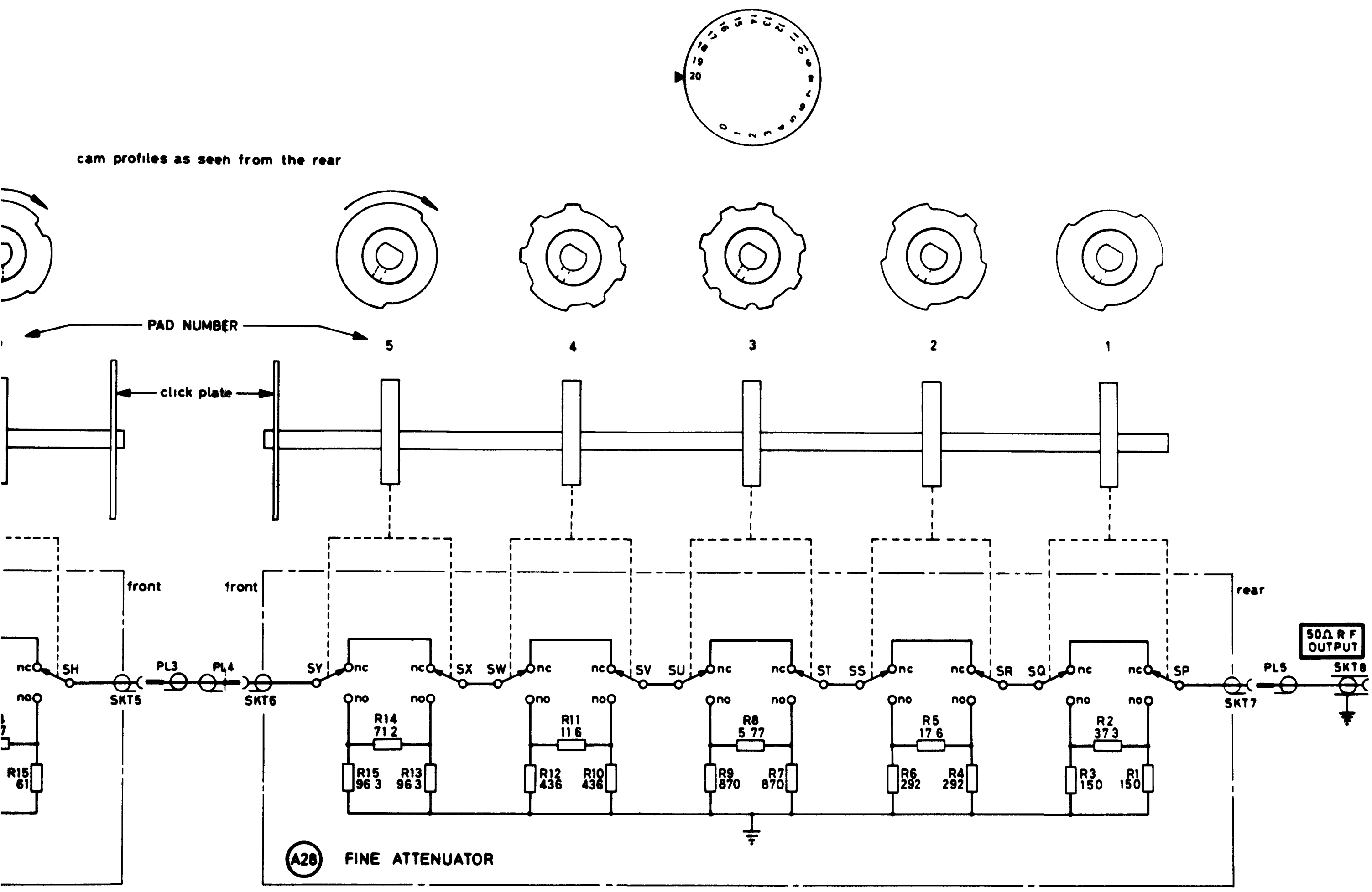


Fig. 7.15 Crystal calibrator and amplifier



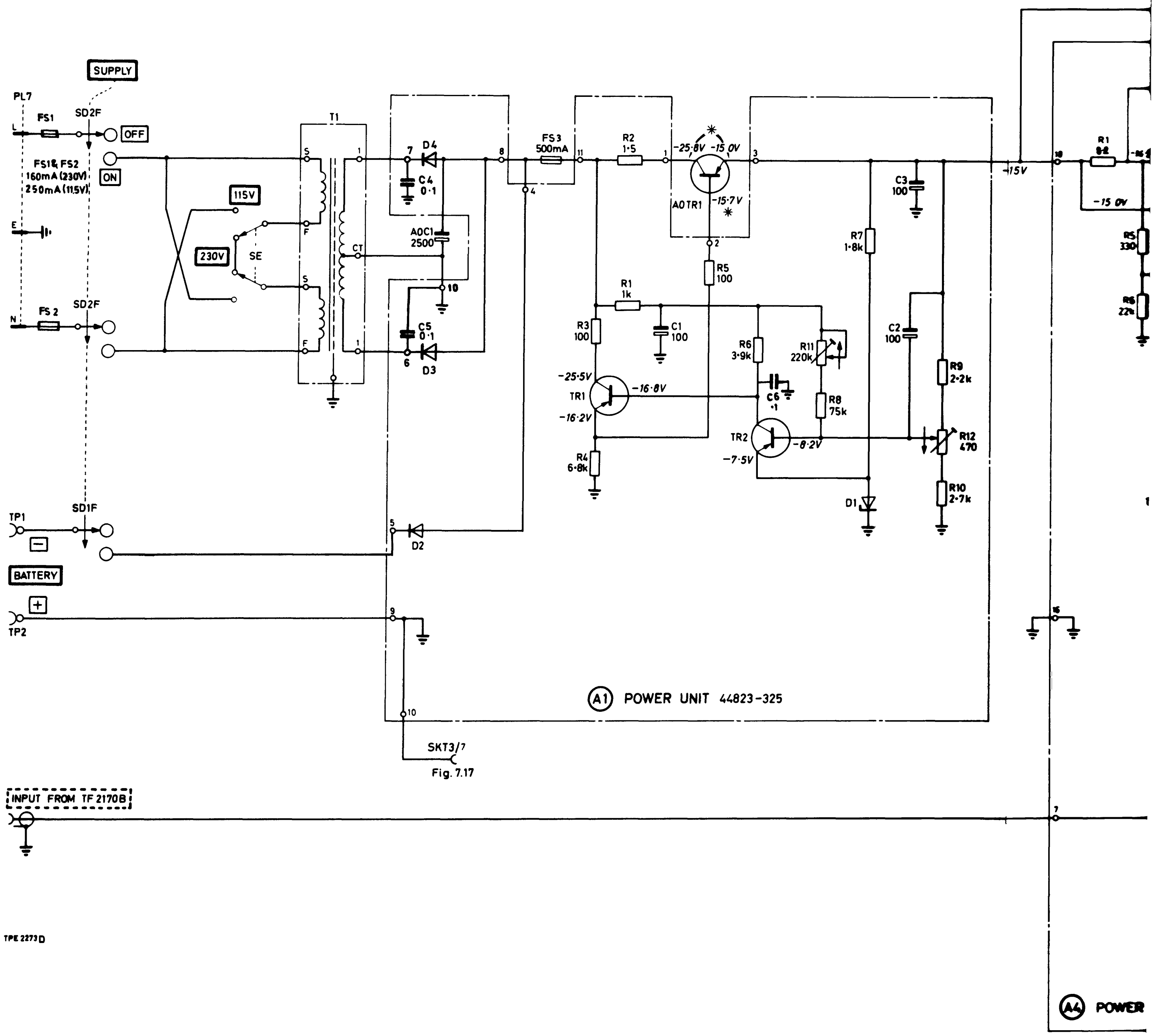
TPE 2274A

100	80	60	40	20	0	-20	dB ABOVE 1μV —ADD—			0
0	20	40	60	80	100	120	ATTENUATION dB			20
							dB	PAD SECTIONS IN CIRCUIT	dB	
—	—	—	—	Π	Π	Π	30	1	6	Π
—	—	—	—	Π	Π	Π	30	2	3	Π
—	Π	—	Π	Π	—	Π	20	3	1	Π
—	—	Π	Π	—	Π	Π	20	4	2	—
—	—	Π	Π	—	Π	Π	20	5	10	Π



	0	-20	dB ABOVE 1µV ADD			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	100	120	ATTENUATION dB			20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			dB	PAD SECTIONS IN CIRCUIT	dB																					
Π	Π	Π	30	1	6	Π	Π	Π	Π	Π	—	—	—	—	—	—	Π	Π	Π	Π	—	—	—	—	—	—
Π	Π	Π	30	2	3	Π	Π	Π	—	—	Π	Π	Π	—	—	—	Π	—	—	—	Π	Π	Π	—	—	—
—	—	Π	20	3	1	Π	—	—	Π	—	—	Π	—	—	Π	—	—	—	Π	—	—	Π	—	—	Π	—
Π	Π	Π	20	4	2	—	—	—	—	—	Π	—	—	Π	—	—	—	Π	—	—	Π	—	—	Π	—	—
Π	Π	Π	20	5	10	Π	Π	Π	Π	Π	Π	Π	Π	Π	Π	Π	—	—	—	—	—	—	—	—	—	—

Fig. 7.16 Attenuators



SUPPLY
PL7
FS1
SD2F
OFF
ON
FS1 & FS2
160mA (230V)
250mA (115V)
E
N
FS 2
SD2F
T1
115V
230V
SE
D4
C4 0·1
A0C1 2500
CT
10
C5 0·1
D3
FS3 500mA
R2 1·5
-25·8V
-15·0V
A0TR1
-15·7V
R5 100
R1 1k
R3 100
C1 100
R6 3·9k
R11 220k
C6 ·1
R8 75k
TR1
-25·5V
-16·8V
-16·2V
R4 6·8k
TR2
-8·2V
-7·5V
R7 1·8k
C3 100
C2 100
R9 2·2k
R12 470
R10 2·7k
D1
-15V
TP1
SD1F
D2
BATTERY
TP2
A1 POWER UNIT 44823-325
SKT3/7
Fig. 7.17
INPUT FROM TF 2170B
TPE 2273D
R1
-15 0V
A4 POWER

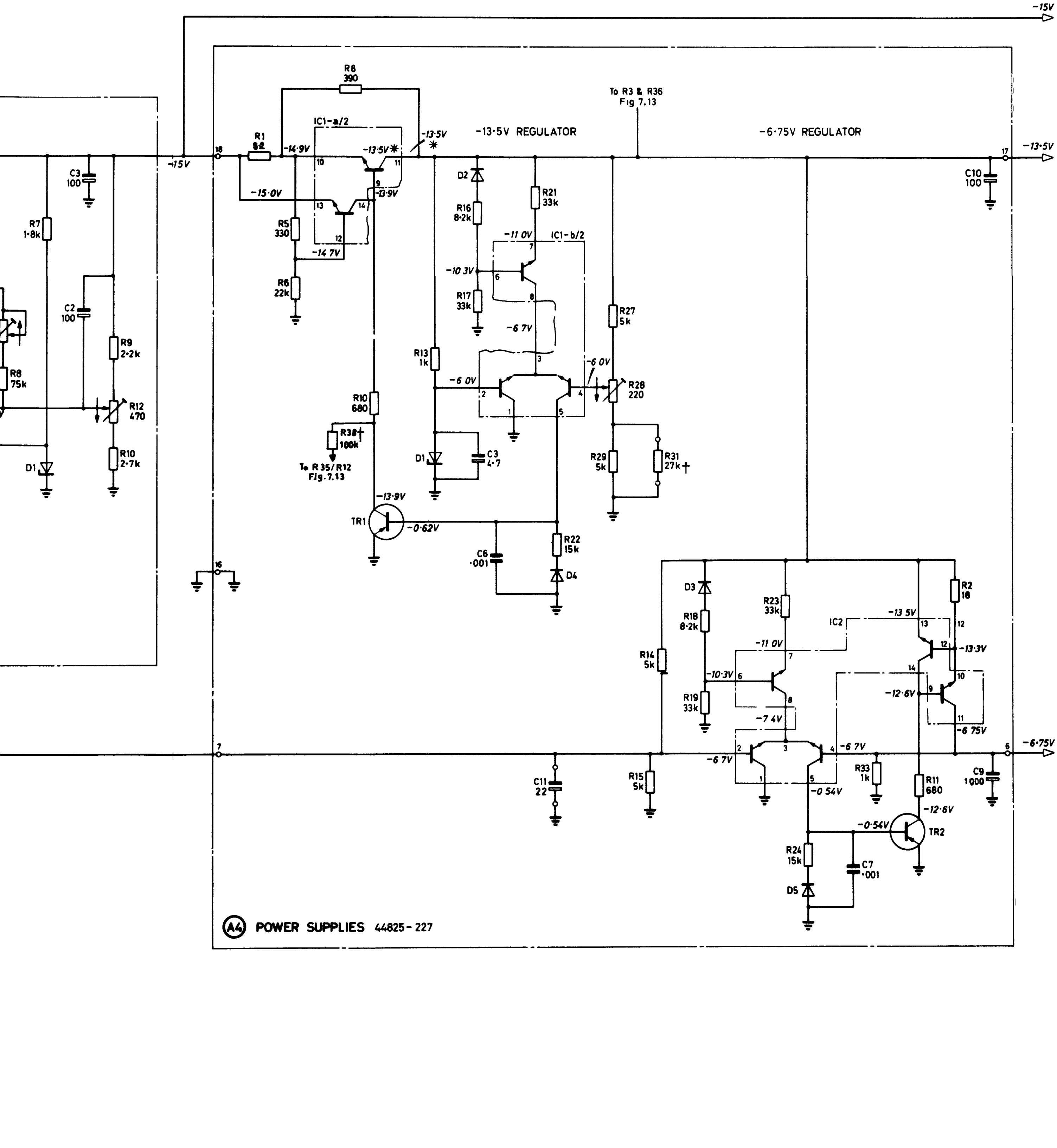


Fig. 7.18 Power unit and regulators

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