WAYNE KERR

COMPONENT METER B424

COMPONENT ADAPTOR CA4

LIMITS UNIT LU4

OPERATION AND MAINTENANCE

The reference number of this publication is TP90

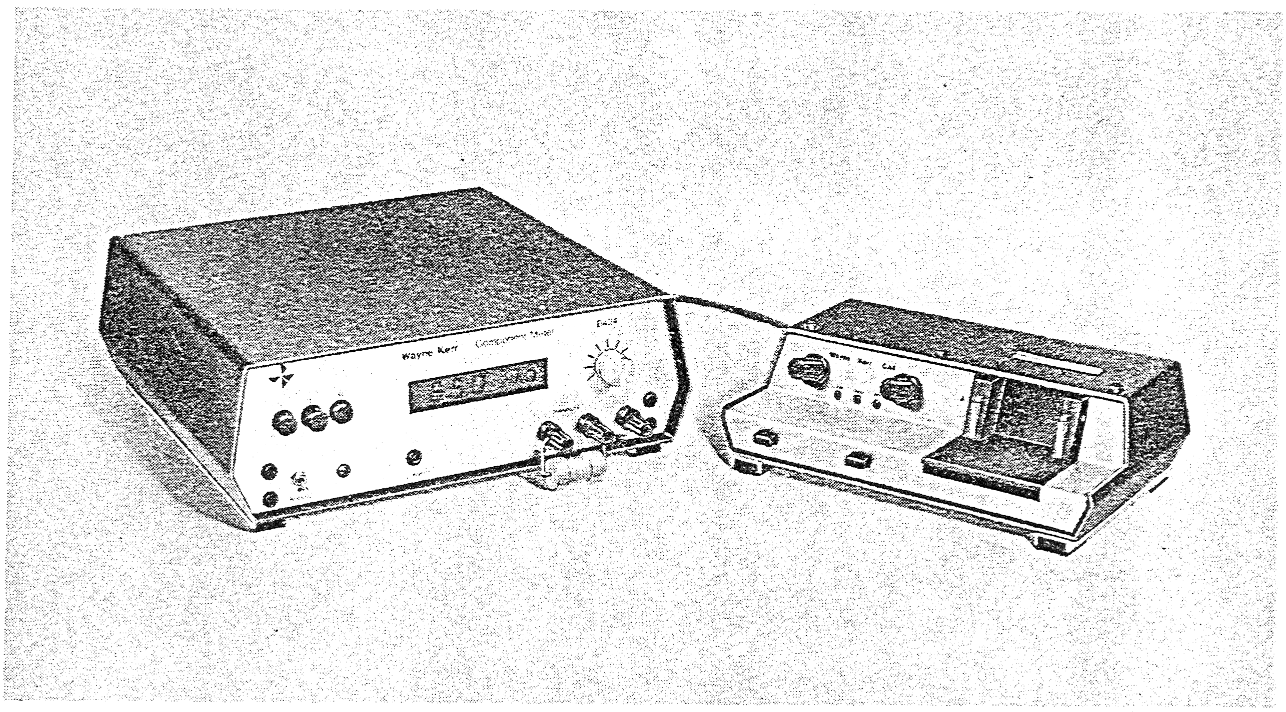
Wilmot Breeden Electronics Limited,
442 Bath Road, Slough, SL1 6BB, England.

CONTENTS

ILLUSTRATIONS

WAYNE KERR
COMPONENT METER B424 257
COMPONENT ADAPTOR CA4 258.
LIMITS UNIT LU4

Wilmot Breeden Electronics


Wayne Kerr

1.0 INTRODUCTION

This Manual describes the operation, circuit features and setting-up procedures for Component Meter B424, Component Adaptor CA4 and Limits Unit LU4. It includes complete circuit diagrams and lists of all electrical components.

B424 is a compact and portable unit, suitable for mains or battery operation, giving direct digital readout of resistance, inductance and capacitance values over an extremely wide measurement range. The liquid crystal display shows the units of measurement as well as the full numerical value up to 1999 on all its 24 ranges.

Operation is simple: three push-buttons select R, L or C, a single range-switch serves for all three component types, and the LCD display includes arrows to show when a change of range is needed. The B424 automatically selects the frequency of measurement (1kHz or 100/120Hz) and a series or parallel test arrangement to suit the type and value of component being measured.

Component Adaptor CA4 is used with B424 to give fast and positive connection facilities for all types of component, together with limits circuits controlling Low, Pass and High lamps. The pass limits are immediately adjustable, by the user, to give any desired max/min values.

Limits Unit LU4 is similar to CA4 but does not have component connection facilities.

The value of B424 in Goods Inwards departments, and for the tolerance batching of components, is increased by the use of these two ancillary units, particularly since it is possible to use CA4 and one or more LU4 units simultaneously (or a number of LU4 units) when graded selection is required.

2.0 SPECIFICATIONS

COMPONENT METER B424

DISPLAY	1999 Liquid Crystal Display (LCD) including units of measurement and range-change pointers.
OVERALL COVERAGE	R 10mΩ - 20MΩ C 0.1pF - 20,000µF L 0.1µH - 2kH

MEASUREMENT RANGES AND TEST SIGNALS

<table>
<tr><td>RANGE</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>R (max)</td><td>-</td><td>20Ω</td><td>200Ω</td><td>2kΩ</td><td>20kΩ</td><td>200kΩ</td><td>2MΩ</td><td>20MΩ</td><td>-</td></tr>
<tr><td>FREQUENCY</td><td>-</td><td colspan="4">1kHz</td><td colspan="3">100Hz*</td><td>-</td></tr>
<tr><td>V (max)</td><td>-</td><td>32mV</td><td colspan="3">130mV</td><td colspan="3">1.3mV</td><td>-</td></tr>
<tr><td>C (max)</td><td>20mF</td><td>2mF</td><td>200µF</td><td>20µF</td><td>2µF</td><td>200nF</td><td>20nF</td><td>2nF</td><td>200pF</td></tr>
<tr><td>FREQUENCY</td><td colspan="5">100Hz*</td><td colspan="4">1kHz</td></tr>
<tr><td>V (approx)</td><td colspan="2">1.6mV</td><td colspan="3">6.5mV</td><td colspan="3">65mV</td><td>650mV</td></tr>
<tr><td>L (max)</td><td>200µH</td><td>2mH</td><td>20mH</td><td>200mH</td><td>2H</td><td>20H</td><td>200H</td><td>2kH</td><td>-</td></tr>
<tr><td>FREQUENCY</td><td colspan="5">1kHz</td><td colspan="3">100Hz*</td><td>-</td></tr>
<tr><td>V (max)</td><td colspan="2">20mV</td><td colspan="6">82mV</td><td>-</td></tr>
</table>

* 120Hz on 60Hz instruments.
Ranges 1-5 give equivalent series value of Unknown.
Ranges 6-9 give equivalent parallel value of Unknown.
All 1kHz ranges read down to zero.
All 100Hz ranges read down to 100.

ACCURACY	± 0.25% of reading ± 1 digit [Ratio (measured term/quadrature term) >10. Additional error for ratios 1-10: R } ± 0.5% C & L } ± 0.25%]

POLARISATION	2V internal } On all C ranges Up to 50V external }
PROTECTION	Measure circuits protected against damage from connection of charged capacitors, on all ranges: Capacitors up to 2μF : up to 500V Capacitors above 2μF : up to 50V
GUARD FACILITY	Third terminal for screen connections. Max. capacitance from either or both measure terminals to Guard : 200pF.
OUTPUTS	Multiway connector provides analog output of Reference and Measure signals for Limits Units, Recorders etc. Also +5V and -5V, regulated, 10mA max, and +15V (unregulated). See para 3.15.
AMBIENT	Operating temperature range 0°C to 50°C.
POWER SUPPLY	115V ± 10% and 230V ± 10% (both models) Sep. models for 50Hz and 60Hz. Batteries 12-20V, 30-45mA.
DIMENSIONS (Overall, including plugs)	Width 277mm (10.9 in) Height (flat) 102mm (4 in) Height (raised) 181mm (7.2 in) Depth 330mm (13 in)
WEIGHT	Approx. 3.2kg (7 lb)

<u>COMPONENT ADAPTOR CA4</u>

CONNECTORS	a) For radial leads and pre-formed wire ends: In-line troughs to accept all pitches in normal use. b) For axial leads: Spring-loaded jaws for single-handed operation.
LIMIT SETTING	Push-buttons and potentiometers for independent setting of Low and High limits (as seen on LCD display).
LIMIT INDICATION	Separate red lamps show LOW or HIGH. Green lamp shows PASS.
POWER REQUIREMENT	From B424 (on a.c. supplies only).
DIMENSIONS	Width 233mm (9.2 in) Height 75mm (3 in) Depth 150mm (6 in)
WEIGHT	Approx. 0.9kg (2 lb)

LIMITS UNIT LU4

LIMIT SETTING	As CA4.		
LIMIT INDICATION			
POWER REQUIREMENT			
DIMENSIONS	Width	165mm	(6.5 in)
	Height	55mm	(2.2 in)
	Depth	120mm	(4.7 in)
WEIGHT	Approx.	0.7kg	(1.5 lb)

3.0 OPERATING INSTRUCTIONS

3.1 MAINS OPERATION

Check that the rear switch with reversible locking plate is set correctly (115V or 230V). B424 instruments are supplied either for 50Hz or for 60Hz operation (both are dual-voltage). Operation from supplies of the wrong frequency may cause display flicker. Wire the free end of the mains lead as follows:-

Yellow/Green to Earth (Ground); Brown to Live;
Blue to Neutral.

If the mains plug is fused, a 3-amp fuse should be fitted. The internal mains primary circuit fuse is fitted at the extreme end of the rear panel. It is a 1-amp slow blow fuse (20 x 5mm, 1A-T).

Note that the front panel SUPPLY switch is connected in the low-voltage d.c. output side of the power supply circuit and there are therefore components in this circuit which remain live even when the SUPPLY switch is off. The B424 should always be unplugged from the mains when it is not in use.

3.2 BATTERY OPERATION

The B424 used alone (without CA4 or LU4) can be operated from battery supplies of between 12 and 20 volts, and consumes 30-45mA depending on the range in use. Two batteries type PP9 (or equivalent) in series will provide 50-100 hours operation. Connect + and - to the red and black DC SUPPLY sockets, respectively. (The instrument has reverse polarity protection.) Operation from dry batteries is not recommended when either CA4* or LU4 is in use, but a 12-volt lead-acid battery can be used.

The battery input circuit is separately fused by a 1-amp slow blow fuse (20 x 5mm, 1A-T) located immediately adjacent

---

* The connection facilities can be used, but not the limits facilities. See para 3.13.9.

to the battery input sockets. On/off switching is at the front panel, as for mains operation, but the 'On' indicator will <u>not</u> light on battery operation. The B424 automatically disconnects itself when the battery voltage falls below 11.5 volts.

3.3 COMPONENT MEASUREMENT

3.3.1 Press C, L or R as required.

3.3.2a If the approximate value of the component is known, refer to the range table below and set the range switch accordingly (Range 1 is fully counter-clockwise).

Range	1	2	3	4	5	6	7	8	9
C	20mF	2mF	200μF	20μF	2μF	200nF	20nF	2nF	200pF
L	200μH	2mH	20mH	200mH	2H	20H	200H	2kH	-
R	-	20Ω	200Ω	2kΩ	20kΩ	200kΩ	2MΩ	20MΩ	-

3.3.2b If the approximate value of the component is not known, set the range switch as follows:-

C measurements - Range 6
R or L measurements - Range 5

3.3.3 Connect the component to be tested. The rear switch on the B424 must be set to 'NORMAL OP' (unless CA4 or LU4 are connected - see 3.13). Further information on component connection is in sections 3.4 to 3.11.

3.3.4 Any necessary range-changing is indicated by a flashing pointer.

▲ Turn range switch clockwise*

▼ Turn range switch counter-clockwise

* Giving a lower C range or a higher range of L or R, and conversely for counter-clockwise rotation.

Turn the switch only one step at a time and pause at the new setting, for a second or two, before assuming any further change is necessary.

3.3.5 When no pointers flash, the component value can be read directly from the display, including the decimal point in position and the units of measurement.

A hinged stand on the underside of the instrument can be lowered to provide an alternative viewing angle.

3.4 USE OF TERMINALS AND LEADS

The use of unscreened leads should be limited to a maximum length of about 15cm. Longer leads should be screened, with both screens connected to the GUARD terminal. If the component has a large area of metal not connected to its measured terminals, e.g. a screen or core, this should be separately connected to GUARD.

If the component has a relatively large, unscreened metal surface which is connected to one of its measured terminals, e.g. an air-spaced tuning capacitor, this should be connected to the left-hand MEASURE terminal. Keep inductors (air-cored or iron-cored) clear of metal objects.

3.5 POLARISING ELECTROLYTIC CAPACITORS

Three terminals are provided on the back of the B424 for applying a bias voltage to electrolytic capacitors during test. Connect a wire link between the central and left-hand terminals (viewed from the rear) to produce a 2-volt polarising potential at the MEASURE terminals (positive on the left-hand MEASURE terminal).

Where a polarising potential exceeding 2 volts is required, remove the wire link and apply up to 50 volts d.c. (as required) with the positive lead to the central rear terminal and negative to the right-hand terminal (viewed from the rear). Note that this right-hand (-) terminal is connected internally to mains earth when the B424 is plugged into a mains supply socket.

When a polarising voltage is used, (either the internal 2 volts or from an external supply), it appears at the MEASURE terminals (+ve on the left) on all capacitance ranges but does not appear when the B424 is switched to R or L.

The polarising voltage (internal or external) is applied via an internal 330-ohm resistor. The charging time can become significant: also values change as the electrolyte re-forms. To speed testing, particularly of the larger-value capacitors, polarisation before connection is desirable (as well as during test). The B424 is designed to accept connection of pre-charged capacitors, on all ranges, as follows:-

Capacitors up to 2µF: up to 500V
Capacitors above 2µF: up to 50V

3.6 MEASURING SMALL-VALUE CAPACITORS

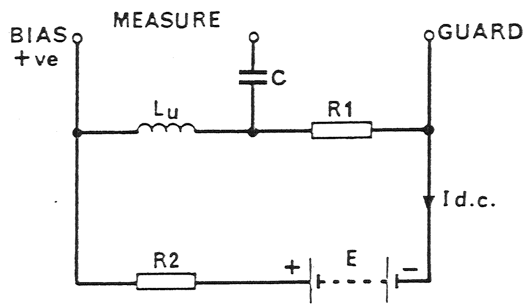
Variations in the self-capacitance of connecting leads or measuring jigs can affect capacitance readings on Range 9 (switch fully clockwise). To cancel these self-capacitances, connect the leads - including any screens - and position them as they will be for the test, but do NOT connect the capacitor. Adjust the front-panel pre-set control, TRIM C, for a reading of 00.0pF (a small screwdriver can be used). Note that, owing to the manner in which the display is derived, readings corresponding to -00.1, -00.2, -00.3 etc. actually appear as 09.9, 09.8, 09.7 etc. respectively. The capacitor can now be connected and measured in the normal way.

3.7 MEASURING H.F. INDUCTORS

It must be appreciated that an inductor, when measured at a frequency much lower than that for which is it designed, will tend to behave as an inductive resistor (i.e. it will have a very low Q). Checking such inductors may cause blanking of the display digits and flashing of the up-range arrow even when the correct nominal L range is selected. This is due to the large R term causing overloading (see 3.11). In such cases an approximate measurement of the inductance can usually be obtained by switching to the next higher range and ignoring the down-range arrow which will then flash.

3.8 INDUCTORS PASSING DC

Particularly with iron-cored inductors, the effective value can vary widely with the magnetisation. Ideally, they should be measured at the frequency of use, with the same a.c. and d.c. levels as apply in use. However, valuable results - especially comparative values - can usually be obtained by passing a direct current through the inductor whilst under test. The essential requirements are to prevent this current entering the B424 measurement circuits and to minimise the effect of the d.c. supply components on the component under test. Various arrangements are possible: the simplest is shown below.



Before connecting this circuit, ensure that there are no BIAS connections on the rear of the B424, and that the L button is pressed.

IMPORTANT The DC supply, or battery, E, must not exceed 50V and it must be borne in mind that when the B424 is connected to an AC supply the Guard terminal is internally connected to Earth (Ground).

The supply components introduce a slight error. To keep this to less than 1%, the conditions shown in the table should be met. Values of R1 and R2 can be chosen to produce the required current (I dc) and the resistance of the inductor can be assumed to contribute to the value of R1. The distribution of resistance between R1 and R2 is not important provided that the minimum values are observed for both. Their wattage rating must be calculated to suit the current and resistance ($W=I^2R$).

RANGE	MAX Lu	MIN C	MIN R1	MIN R2	MAX I dc
1	200μH	16000μF	8Ω	1Ω	5A
2	2mH	16000μF	8Ω	10Ω	3A
3	20mH	10000μF	10Ω	33Ω	1.5A
4	200mH	1000μF	100Ω	220Ω	150mA
5-8	2H-2kH	100μF	1kΩ	2.2kΩ	15mA

3.9 LEAD IMPEDANCE CORRECTIONS

For the great majority of measurements the full accuracy of the B424 is realised without the application of any correction or calibration procedures. However, when measuring very small values of resistance or inductance - particularly when longer measurement leads are used - the impedance of the leads can become significant. To correct for this, substitute a short circuit for the resistor or inductor under test, note the B424 reading and subtract this amount from subsequent measured values.

3.10 MEASUREMENT CONDITIONS

The frequency and amplitude of the test signal depends on the type of measurement (C, L or R), the range in use and (except with capacitors) the value of the component. All measurements are made at either 1kHz or 100Hz (120Hz on 60Hz instruments) and the levels for every range are tabulated in the specification.

Automatic selection of a series or parallel mode of measurement further ensures that the most useful results are given at all times. Thus electrolytic capacitors are measured at 100Hz, series mode, and capacitors below 200nF at 1kHz, parallel mode. Small inductors which have predominantly series loss at audio frequencies are measured at 1kHz, series mode. Audio inductors (>2H) are measured at 100Hz parallel mode.

3.11 MINOR TERM MEASUREMENTS

The B424 is designed, primarily, for measuring the major term of components. However, it can often provide a valuable indication of the series or shunt loss associated with capacitors or inductors. (The table in section 4.1.3 identifies the 'series' and 'parallel' ranges.)

Measure the C or L value in the normal way and then press the R button. It is often necessary to change range to obtain the optimum R reading: on the other hand it is possible that all efforts to measure the minor term cause an overload, blanking the display. In all minor term measurements, the range-change arrows should be ignored.

Note that loss terms are frequency-dependent, so that values obtained at 1kHz (e.g. the R term of electrolytics) will not be the same as values published for 100Hz. However, comparative values obtained during batch testing will quickly expose any defective components.

3.12 DISPLAY CHARACTERISTICS

The B424 is designed to blank the display if, for any reason, an overload condition exists (the blanking will not affect the thousand '1' which is controlled outside the 'blanking' circuit). This feature prevents incorrect values being displayed.

The down-range arrow operates (except on extreme ranges) when the reading displayed falls below 100. The ranges using 1kHz can measure to zero, but ranges using 100Hz may not measure below 20 (1% f.s.d.). However, this is not a limitation since the smaller values of L, C and R are measured at 1kHz.

Exceptionally, components on the higher or lower ranges may produce no numerical readout and no range-change arrow. In this event, turn the range switch to 6 (for C) or 5 (for R or L) - as described in 3.3.2b.

Excessive hum or noise levels, due to inadequately screened test leads, will cause the last one or two digits to flicker. Section 3.4 describes the correct screening procedures.

3.13 COMPONENT ADAPTOR CA4

3.13.1 This unit has a dual purpose: it provides quick and convenient connection arrangements to suit various types of component, and it has built-in limits circuits giving immediate indication of High, Low or Pass at levels set by the user.

3.13.2 Insert the 9-pin plug from the CA4 into the socket at the rear of the B424 and set the switch above the socket to LIMITS UNIT.

3.13.3 Connect the 3-tag connector block - tags uppermost, cable emerging to the right - to the MEASURE and GUARD terminals of the B424.

3.13.4 If small values of capacitance are to be measured, adjust the C TRIM control as described in section 3.6 before setting the limits.

3.13.5 If small values of resistance or inductance are to be measured, make allowance for lead impedance. This is less than 40mΩ and 1.0μH: exact values can be established as described in section 3.9. Add this quantity to the proposed Low and High values when setting the limits.

3.13.6 To set the limit values, switch the B424 to the function and range required (see 3.3.2a and 3.3.2b) and connect a component (on the CA4) whose value lies within that range. The exact value is quite unimportant: the requirement is simply to place the B424 measurement circuits in a normal operating condition.

3.13.7 Press and hold in the LOW (left-hand) push-button on the CA4 and adjust the associated potentiometer until the B424 display indicates the required LOW pass limit. Release the button and repeat the process for the HIGH limit, using the right-hand push-button and potentiometer. Remove the component.

3.13.8 The equipment is now ready for use. As each component is connected, the CA4 provides a very fast indication of LOW, PASS or HIGH.* If a polarising voltage is required

---

* It is worth noting that this speed is faster than the LCD display.

during the measurement of electrolytic capacitors, the procedure is the same as that given in section 3.5 for the B424 used alone. ("A" indicates Bias +ve.) Similarly, the notes on measuring HF inductors (section 3.7) also apply.

3.13.9 Where the convenience of the component connection systems of the CA4 are required, but NOT the limits facilities, battery operation of the B424 is quite in order, provided that the B424 is switched to NORMAL OP.

3.14 LIMITS UNIT LU4

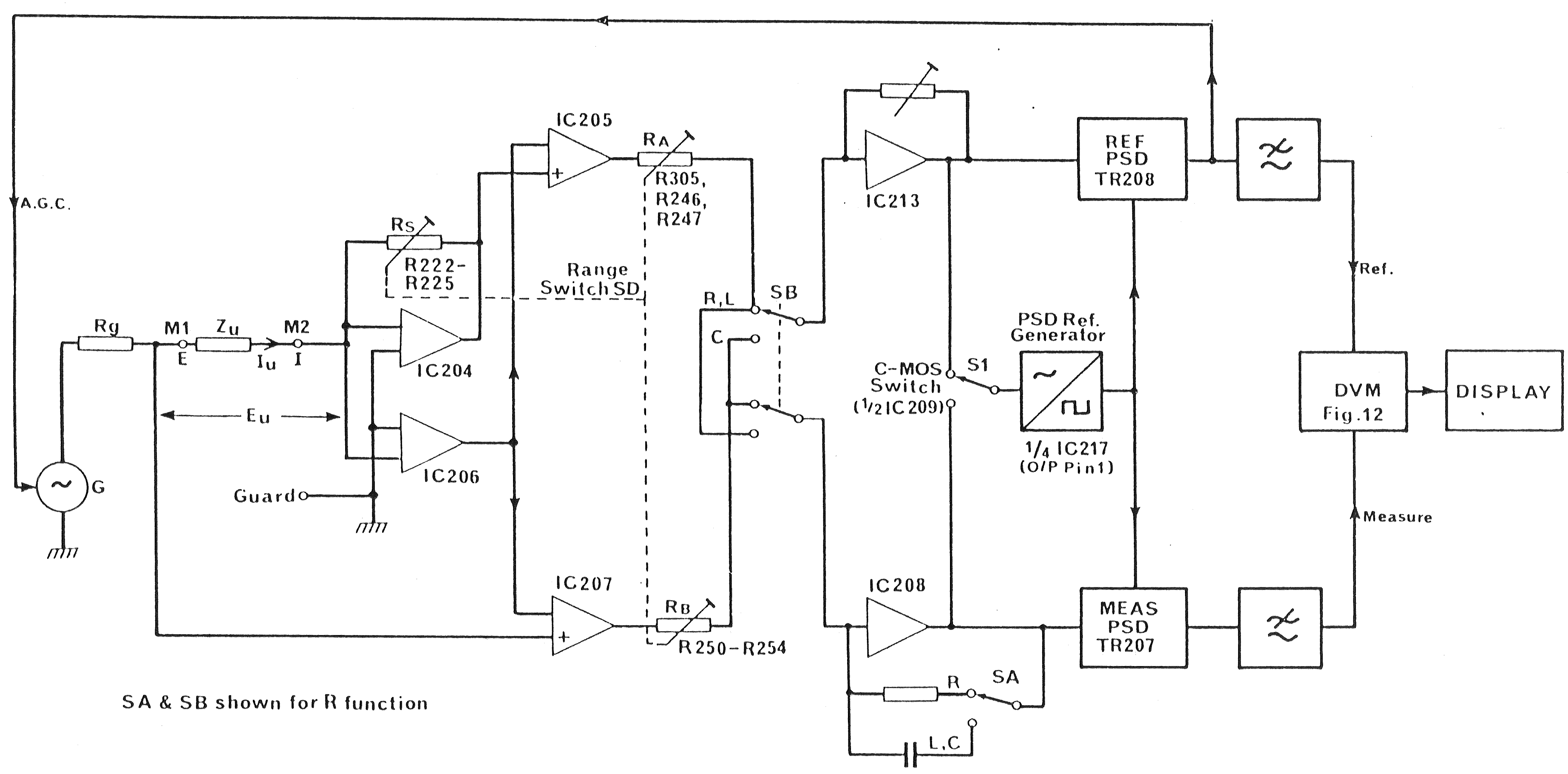
The operation of this item, except for the fact that component connection is made to the B424, is identical to that of the CA4. With this exception, sections 3.13.1 to 3.13.7 apply (3.13.3, of course, is not applicable).

3.15 B424 OUTPUTS

The nine-way socket on the rear of the B424 (SKG on Fig. 14) is designed for immediate connection of CA4 or LU4. However, it may also be used to drive pen recorders or analog metering systems (using pins 2 and 6) with an absolute accuracy of 1-2 per cent.† A further application would be in association with automatic component handling and batching systems, or limits units other than CA4/LU4. The connections provided by SKG are as follows:

Pin 1	+5V. Regulated, unswitched, 10mA max.
2	OV.
3	(Strapped internally to pin 2.)
4	Ref. signal. 1.3V nominal into $\nless$ 1kΩ.
5	-5V. Regulated, unswitched, 10mA max.
6	Meas.signal output. Proportional to reading, nominal value 1.3V at fsd, into $\nless$ 1kΩ.
7	Meas. input to DVM.
8	Not connected.
9	+15V. Unregulated, switched, 200mA max.

† This lower figure arises since the Ref. signal will not, normally, be used externally to offset any slight absolute changes in Meas. levels due to drift, etc.



SA & SB shown for R function

Fig. 1 SIMPLIFIED BLOCK DIAGRAM

4.0 CIRCUIT DESCRIPTION

4.1 BASIC PRINCIPLES

4.1.1 A simplified block diagram of the B424 is shown in Fig.1. The component under test is Zu, and the test signal (100Hz or 1kHz) is represented by generator G with its source resistance Rg. Buffer amplifier IC206 provides a common input to the two differential amplifiers IC205 and IC207. Amplifier IC204 establishes a virtual earth at M2, so that the current through the standard Rs is equal to the current through Zu. Thus IC205 non-inverting input receives a signal proportional to Iu, whilst the corresponding input to IC207 is proportional to Eu.

4.1.2 After suitable amplification and processing, via the Reference channel (ICs 213-215) and the Measure channel (ICs 208, 210, 211) equivalents of Iu and Eu are applied to the Reference and Measure inputs of a dual-slope integrator (DVM). The ratio Eu/Iu = Zu is the basis of resistance and inductance measurements; by interchanging the signals applied to the Reference and Measure channels (by SB) the ratio Iu/Eu is obtained as the basis of capacitance measurements. For resistance measurements, switch SA will be in the position shown in Fig. 1; the alternative position introduces a 90° phase shift for inductance and capacitance measurements. Range switching operates on resistors Rs, RA and RB.

4.1.3 According to the function (R, L or C) and range selected, there is automatic change-over from 100Hz to 1kHz test signals and from a series to a parallel mode of measurement. Frequency change and mode change are made by separate C-MOS switches: that for frequency is not represented on Fig. 1 but is referred to in section 4.4. The series/parallel switching is achieved by selecting 'voltage' or 'current' as the input to the phase-sensitive detector (PSD) reference generator. Frequency and mode selection are summarised in the following table ('Up' and 'Down' for S1 refer to Fig. 1). It can be seen that S1 is always 'Up' for 1kHz measurements, and conversely.

	RANGES	FREQ	REF I/P	MEAS I/P	S1	PSD REF	READOUT
R	2-5	1kHz	Current	Voltage	Up	Current	Series
	6-8	100Hz	Current	Voltage	Down	Voltage	Parallel
L	1-5	1kHz	Current	Voltage	Up	Current	Series
	6-8	100Hz	Current	Voltage	Down	Voltage	Parallel
C	1-5	100Hz	Voltage	Current	Down	Current	Series
	6-9	1kHz	Voltage	Current	Up	Voltage	Parallel

It should be remembered that, on capacitance only, the largest values are measured on Range 1 and the smallest values on Range 9.

4.2 POWER SUPPLY

Three illustrations apply:-

Location is shown on Fig. 2.
P.C.B. Layout is Fig. 3.
Circuit Diagram is included on Fig. 14 (Interconnections.)

Details of fuses are in sections 3.1 and 3.2. The circuit is conventional in providing for 115- and 230-volt operation but B424 instruments are supplied in two versions: one for 50Hz supplies and one for 60Hz (see 3.1). Diode D4 protects the instrument from damage if battery connections are made with reversed polarity. Output from the power supply, in addition to being taken to the rear connector (SKG) on B424 for a Limits Unit (CA4 or LU4) is connected to the Regulator Circuit (next section).

4.3 REGULATOR SUPPLY

Location: Fig. 2.
PCB Layout: included on Fig. 11 (Digital PCB).
Circuit Diagram: Fig. 4.

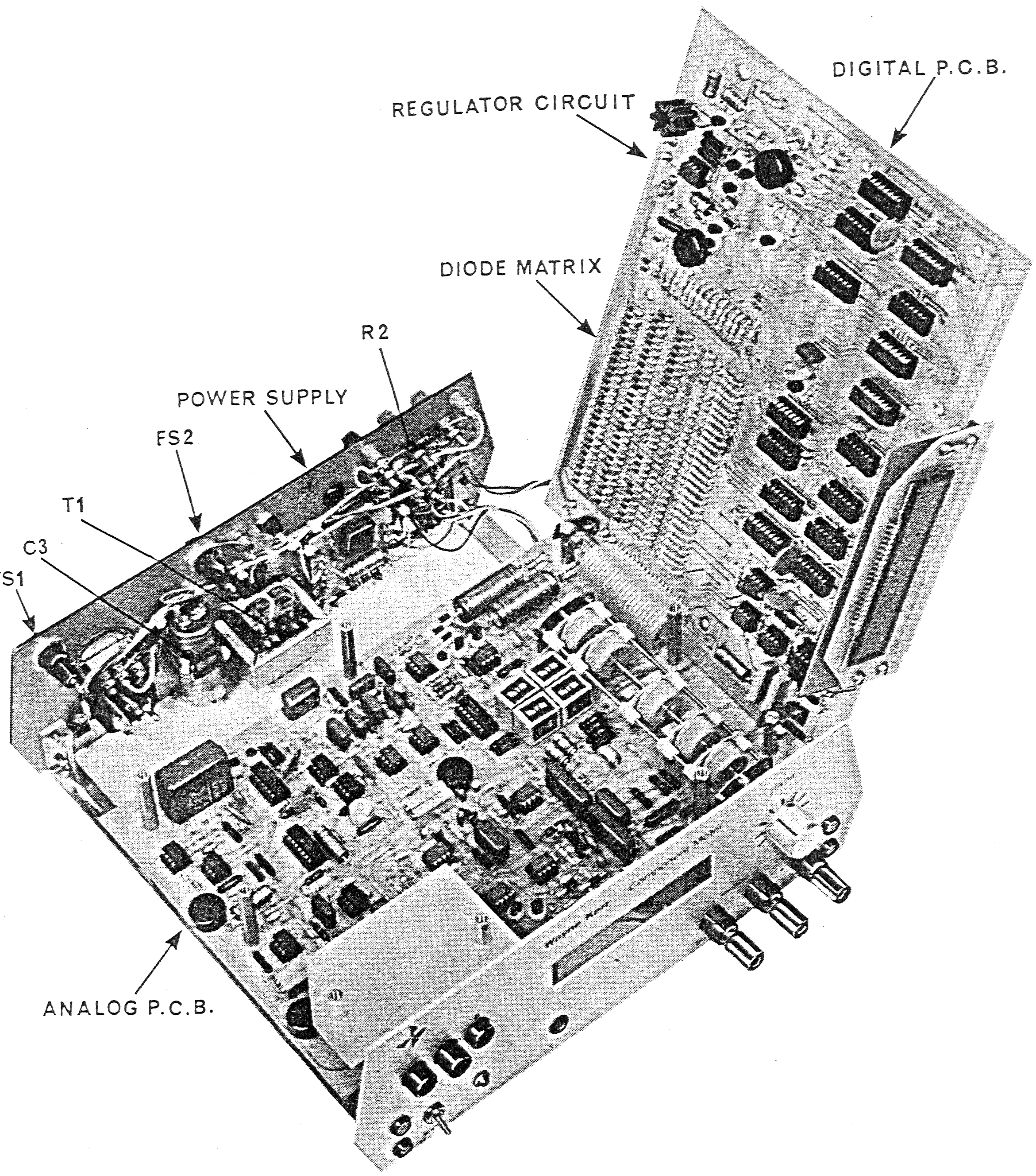
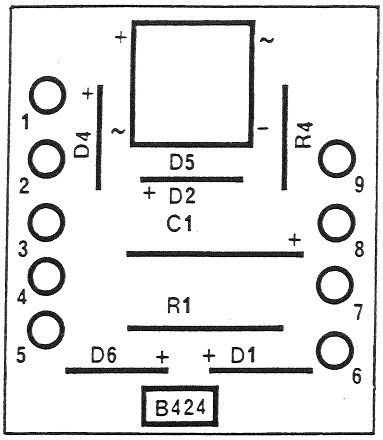
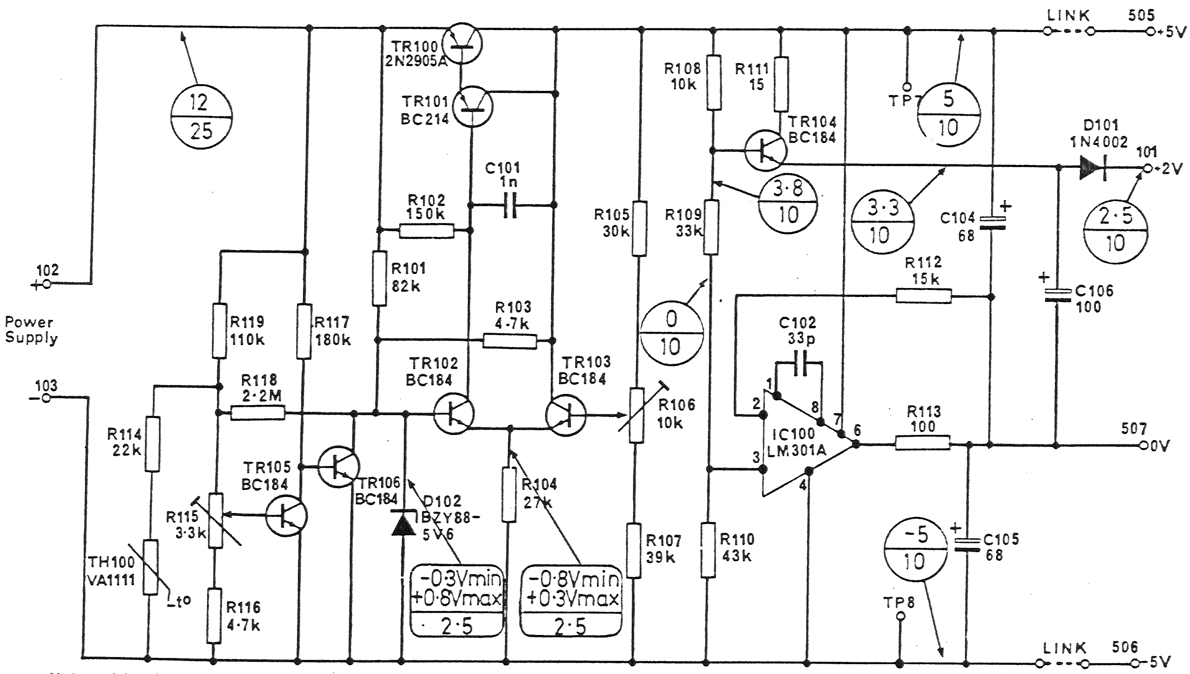


Fig. 2 INTERNAL VIEW



Circuit diagram included
on Fig.14

Fig. 3 POWER SUPPLY



Note: This circuit is located on the Digital PCB. For layout see Fig.11

For cross-connections see Digital Board on Fig.14

Fig. 4 REGULATOR SUPPLY

TR100 to TR103 form a 10-volt regulator whose output is centre-tapped by IC100 to give positive and negative 5-volt supplies. The 2-volt positive bias supply provided from TR104 incorporates D101 to protect the circuit against reverse connection of polarised capacitors. TR105 and TR106 provide a temperature-compensated voltage sensing circuit to cut off supplies to the instrument whenever the input falls below 11.5 volts.

4.4 OSCILLATOR

Part of Analog Board.
PCB Layout: Fig. 9
Circuit Diagram: Fig. 8.

The Wien Bridge oscillator circuit is based on IC201 with output boosters TR202 and 203. Frequency selection (1kHz or 100Hz) is by the C-MOS analog switch IC202, controlled by a decoded 'LF' logic signal from the diode matrix (Fig. 13). Automatic gain control is provided by IC203 feeding TR201. Protection of the oscillator circuit from damage due to steady or transient voltages applied to the measurement terminals (bias, or pre-charged capacitors) is provided by C208, C209 with diodes D201-D204. Resistors R216-R219 provide a necessary adjustment of oscillator source impedance (Rg on Fig. 1) to suit different measurement ranges.

4.5 Eu/Iu SENSING

PCB Layout: Fig. 9.
Circuit Diagram: Fig. 8.

Derivation of the signals proportional to the current through, and voltage across, the Unknown was described in 4.1.1. The Unknown current signal from IC205, and Unknown voltage signal from IC207, are applied to gain switching networks R245-R249 (see Fig. 10) and R250-R258 respectively. (The switches SD/2 and SD/3 are part of the range switch assembly.) Switches SB/6 and SB/4 perform the selection of current and voltage for the Reference and Measure channels (see 4.1.2).

4.6 REFERENCE AND MEASURE CHANNELS

PCB Layout: Fig. 9.
Circuit Diagram: Fig. 10.

4.6.1 The two channels are similar and the functions of each stage are summarised below:

FUNCTION	REF. CHANNEL	MEAS. CHANNEL
High Gain Amplifier	IC 213	IC 208
Inverting Amplifier	IC 214	IC 210
Phase-sensitive Detector	TR 208	TR 207
Summing Amplifier	IC 215	IC 211
200Hz Ripple Filter	R298-300, C257-259	R274-276, C246-248
Buffer Amplifier	IC 216	IC 212

4.6.2 Prime function of the two channels is to provide the Reference and Measure inputs to the digital circuits (Fig. 12 and para 4.8.1). An output from IC215 provides the input to the oscillator AGC circuit (para 4.4). For inductance and capacitance measurements, IC208 is converted to an integrator, with a decoupled d.c. feedback network (R261,C230). The small calibration error introduced by the network is maintained constant at the two operating frequencies by the automatic switch-over of time-constants provided by IC209 (pins 12-14).

4.6.3 The PSD's and summing amplifiers provide full-wave rectification of the Reference (and Measure) signals as follows. The PSD TR208 (TR207) switches the current obtained via R294 (R269) from the inverting amplifier IC214 (IC210). This half-wave switched current is added to a non-inverted current fed in via R290 (R267), and the resulting full-wave rectified signal is summed at the virtual earth input of IC215 (IC211).

4.6.4 To compensate for a small change in PSD offset voltage when the operating frequency is altered, a small d.c. correction voltage, derived from the 'LF' logic signal via R282 and R317, is applied to the Measure PSD (TR207).

4.6.5 The buffer amplifier in the Reference channel (IC216) receives a small correction voltage, on 100Hz capacitance ranges, via R333, R335. This is switched in by ¼ of IC217, on the appropriate ranges, to compensate for stray signal pick-up.

4.7 PSD REFERENCE GENERATOR

PCB Layout: Fig. 9.
Circuit Diagram: Fig. 10.

The basic function of this circuit was described in section 4.1.3. The square-wave reference for the PSD's is generated by IC217 with its input selected automatically from 'Reference' or 'Measure' by IC209 (pins 1, 3, 5). This C-MOS switch is controlled by the 'LF' signal from the diode matrix (Fig. 13).

4.8 DVM

PCB Layout: Fig. 11.
Digital Circuit Diagram: Fig. 12.
Diode Matrix Circuit Diagram: Fig. 13

4.8.1 Special-purpose digital chip IC505 comprises a clock oscillator, counter and control logic for a dual-slope DVM, and provides multiplexed BCD outputs. Electronic switching between the Reference and Measure signals is by IC501. The Reference input is direct from IC216. The Measure signal from IC212 is routed direct to IC501 (by SE/1, Fig. 14) when the B424 is used on its own. If either of the Limits Units (CA4 or LU4) is in use, the Measure signal is routed via such Unit to provide for (a) its comparison with pre-set levels for Low and High measurement limits established by the user, and (b) substitution of limit signals while these limits are being set (the values being shown on the B424 display). For identification purposes on the circuit diagrams, the signal leaving IC212 is labelled MEAS; after the switching/routing described above, the connection is labelled DVM. Details of the Limits circuit are in section 4.12.

4.8.2 To maintain accurate operation with signals near zero, a steady positive bias is introduced at IC501 output (via R508) and a count of 100 is subtracted (in IC505) from the final reading. To ensure that the bias remains equivalent to exactly 100 counts even when the Reference level changes, it is derived from an inverted version of the Reference voltage (by IC502) and set exactly by R509.

4.8.3 Output from IC501 is applied to integrator IC503 and, in turn, to comparator IC504 and to the special-purpose digital chip (IC505). The multiplexed BCD outputs from the chip are fed to three quad latch decoders (IC's 506, 507, 508) whose outputs control the hundreds, tens and units of the LCD display. (IC505 also provides the thousand '1' but this is not multiplexed.)

4.9 DISPLAY DRIVE

Layout and Circuit: Fig. 12

4.9.1 The liquid crystal display requires a drive with no d.c. content. To achieve this, a 0 to +5V square-wave is applied to the common back plane connection and to any other segments which are 'off'. To turn a segment 'on' its 90Hz square-wave drive is phase shifted by 180°, giving a 10V pk-pk waveform across this segment. To eliminate d.c., the mark-space ratio of the drive waveform must be accurately defined. This is achieved by use of a clock oscillator and 14-stage binary counter (IC517) which also provides outputs at 1.4Hz and 0.7Hz for DVM update and range-change arrow flashing, respectively.

4.9.2 Derivation of the drive signal to the numerical part of the display was described in section 4.8.3 and the sections preceding it. The information for the units display (mΩ, μF, etc.) is established in the diode matrix (Fig. 13) and applied to the display via exclusive OR gates (Fig. 12).

4.10 RANGE POINTERS

4.10.1 Logic circuits, with inputs derived from the analog and digital parts of the circuit, generate the control signal for an up-range or down-range arrow to flash on the display. The logic circuits take into account whether or not the Reference or Measure channels are overloaded, whether the DVM measurement is overrange, and inhibit one arrow on extreme ranges. They also transpose the arrows appearing on C ranges (relative to L and R) since the capacitance ranges appear in reverse order (i.e. all ranges are in ascending order of impedance for clockwise rotation of the switch).

4.10.2 The "up range" arrow information is derived as follows. Two overload detectors (each ¼ IC217, Fig. 10) provide monitoring of the Reference (pin 8) and Measure (pin 10) signals. These signals, together with a digital overrange output from IC505 (Fig. 12), constitute inputs to the logic circuits shown on Fig. 12 using gates H, J and B. The function of TR502 with C510 is to convert the pulsed $\overline{\text{OR}}$ signal to a steady Measure overload output ($\overline{\text{M O/L}}$).

4.10.3 The "down range" arrow operates whenever the display reading falls below 100. This information is obtained by interrogating the display drive for zero in the first two digits (IC506, pins 14, 15 and associated gates C, A, B etc.).

4.10.4 Reversal of the 'up' and 'down' signals on capacitance ranges is provided by IC519. The diode matrix (Fig. 13) derives the UD or DD signals to disable the inapplicable 'up' or 'down' arrow on extreme ranges (these signals are fed into the two NOR gates (type J) preceding IC519 - see Fig. 12).

4.11 DISPLAY BLANKING

The B424 is designed to prevent the display giving incorrect information which could otherwise occur when, for example, a lossy capacitor or coil was tested, giving an excessive minor term. According to the function and range in use, this causes either a Measure overload (which can be cleared when a higher range is available) or a Reference overload (R O/L) which cannot be cleared. It is not possible to obtain both Measure and Reference overloads together (nor, obviously, a Measure underload and overload - M U/L and M O/L - together). Omitting these conditions, the truth table for the range arrows and display blanking is as follows:

INPUT STATES			OUTPUT STATES		
M U/L	M O/L	R O/L	BLANK	DOWN RANGE ▼R,L ▲C	UP RANGE ▲R,L ▼C
1	0	0	0	1*	0
0	1	0	1	0	1*
0	0	1	1	0	0
1	0	1	1	0	0
0	0	0	0	0	0

* Except on extreme ranges.

The last line of the table is the normal situation when a measured value is displayed.

4.12 LIMITS CIRCUITS (CA4, LU4)

PCB Layout: Fig. 5
Circuit Diagram: Fig. 6

4.12.1 The circuits used for indicating LOW, PASS or HIGH are identical in Component Adaptor CA4 and Limits Unit LU4. The reference signal (from IC216, Fig. 10) is inverted and amplified by ¼IC1 (2) to produce a d.c. level of the same polarity and greater than the Measure signal (from IC212, Fig. 10). Potentiometers R5 and R6 set the High and Low pass limits: their outputs are compared directly with the Measure signal by quarters (1) and (4) of IC1, respectively. Their outputs feed the LED drive circuits (for High and Low indication). Section (3) of IC1 triggers the Pass circuit when neither High nor Low is activated.

4.12.2 For setting either limit, the appropriate push-button is held in while the corresponding potentiometer is adjusted (see section 4.8.1). During such setting, sections (1) and (4) of IC1 are re-arranged to become voltage followers.

4.12.3 The voltage levels on the LED's are available as C-MOS compatible logic outputs on the internal Molex connector PLA.

4.12.4 The power supply regulator circuit associated with TR4 isolates the relatively large LED currents from the main B424 supplies.

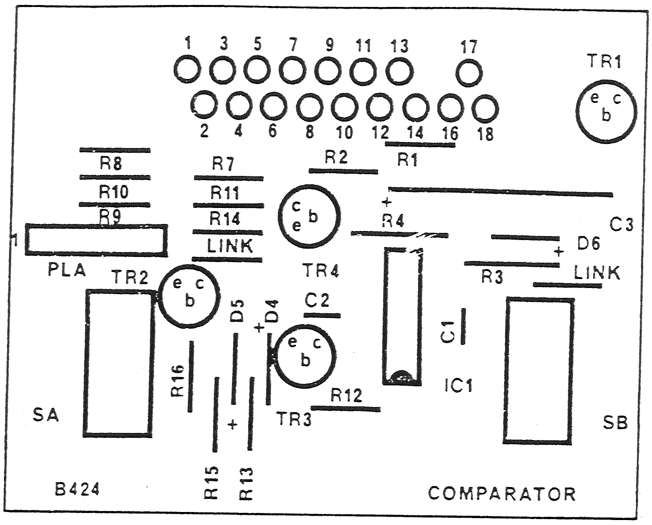


Fig. 5 LIMITS COMPARATOR

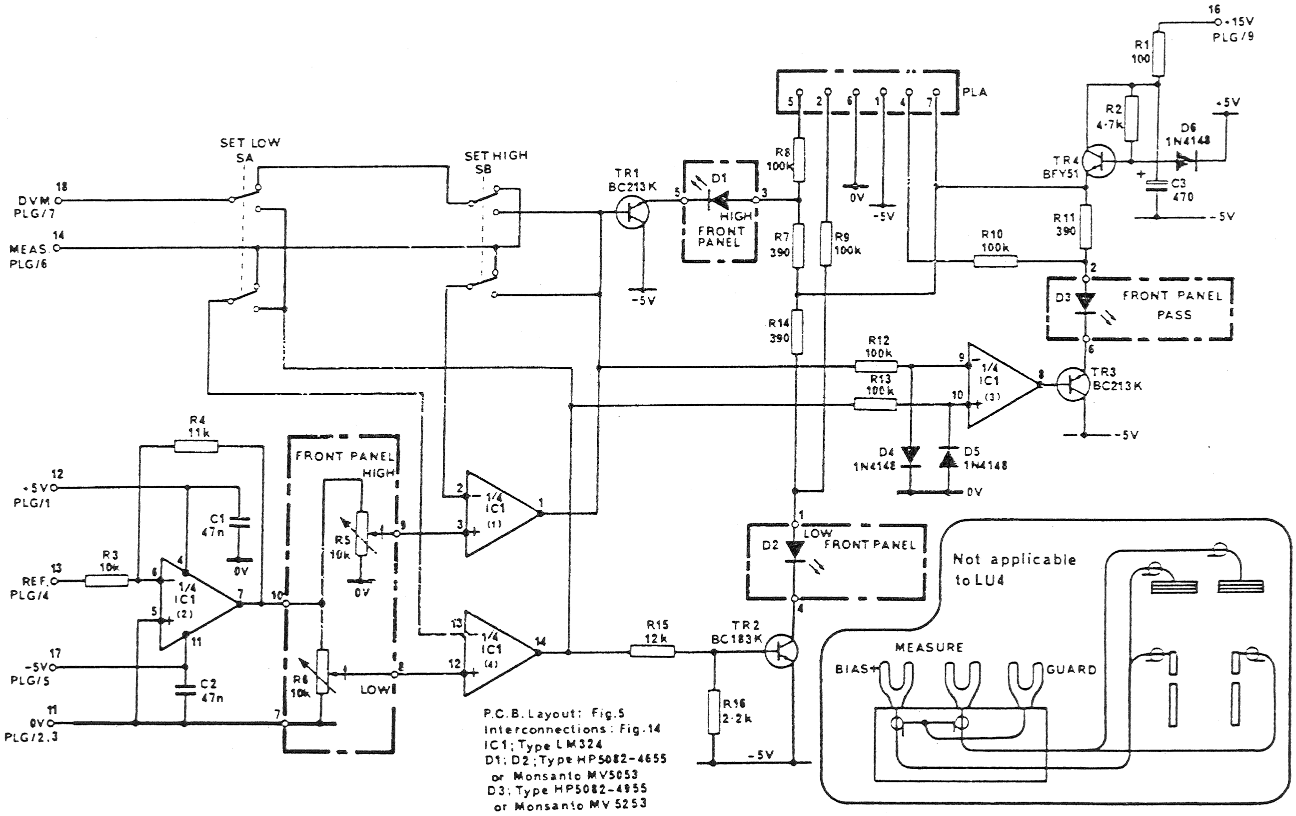


Fig. 6 LIMITS COMPARATOR

5.0 TEST VOLTAGES

These are shown, in position, on the circuit diagrams. Readings were taken with an Avo model 8, (20,000Ω/V) with the B424 set to R range 5 and with a 10kΩ resistor connected across the MEASURE terminals. The instrument was powered from 240V a.c.

Values are given as a guide: some variations are to be expected. Figures in the lower part of the circles are the meter range used.

Voltages and waveforms are taken with respect to 0V.

6.0 SETTING-UP INSTRUCTIONS

6.1 GENERAL

The B424 is an accurate measuring instrument and its internal circuits should not be adjusted except by suitably qualified staff who have available the test equipment and Standard components detailed in the next section.

6.2 TEST EQUIPMENT REQUIRED

Item 1 Digital Voltmeter, DC, coverage to 25V, discrimination 10μV, accuracy 0.05%, input resistance $\nless$ 10MΩ.

Item 2 Digital Voltmeter, as Item 1.

Item 3 DC Power Supply, fine adjustment (discrimination 10mV) from 9 to 15V, 150mA load.

Item 4 Frequency Counter to measure 50 or 60kHz (for 50 or 60Hz models of B424) to an accuracy of 0.1%.

Item 5 Standard resistors*: 18Ω, 180Ω, 1.8kΩ, 18kΩ, 180kΩ, 1.8MΩ and 18MΩ.

Item 6 Transfer Standards*: 180nF, 180pF and 180mH ($Q \nless 10$). See para 6.8.

Item 7 Components: All ± 5% tolerance: 4.7Ω, 820Ω, 180nF and 1.8μF.

6.3 REMOVAL FROM CASE

Disconnect the B424 from any AC or DC supply and lay it upside-down on a soft surface. Remove all seven pan-head screws from the underside (this includes two in each runner).

Carefully slide the unit out of its case (front or back) and place it right way up on the bench. Remove the five larger pan-head screws from the top PCB (leave two smaller ones near front and back of right-hand side). Also remove the two screws holding the LCD bracket. The upper (digital) PCB can now be raised as shown in Fig. 2.

6.4 REGULATOR CIRCUIT

6.4.1 Power the instrument from the D.C. Power Supply (Item 3) set to 15 ± 0.5V d.c. (see section 3.2).

6.4.2 Connect the DVM (Item 1) + to TP7 and - to TP8 (see Fig. 11) and adjust R106 (SET 5V) for a reading of 10V (two 5V supplies are derived from this 10V).

6.4.3 Leaving Item 1 connected, monitor the 15V d.c. input to B424 with the DVM (Item 2). Reduce this input to 11V (at which Item 1 should read near zero). Slowly increase the input voltage until the regulated supply (on Item 1) is re-established. Note the reading of Item 2 at this point. Now slowly reduce the input and note the input voltage at which the regulator turns off. These two voltages should be 11.25 to 11.35V and 10.99 to 11.01V respectively. If necessary, adjust R115 (SET TRIP, Fig. 11) slightly until

---

* Absolute values are not critical but must be known to ±0.05% or better (measured recently on a precision 1kHz bridge). Values (R, C & L) between 15 and 20 - and the appropriate multiples - would be satisfactory.

the correct 'on' and 'off' levels are obtained. Switch off the supply and disconnect both DVMs.

6.5 BIAS CONDITIONS

<u>NOTE</u> This section is the beginning of the analog circuit calibration. The complete sequence of operations must be performed in the order given to avoid interaction between settings.

6.5.1 With the instrument un-powered, remove IC201 (Fig. 9). Switch on (D.C. input 15V from Item 3) and set the rear B424 switch to NORMAL OP.

6.5.2 Using DVM (Item 1) with the 'low' connected to OV (TP5, Fig. 9):

Adjust R302 (I BIAS) for OV at TP3
Adjust R303 (E BIAS) for OV at TP4.

6.5.3 Select L range 2 and, using the DVM as in 6.5.2, adjust R326 (MEAS BIAS) for 450-550mV at TP1.

6.5.4 Select C range 2 and adjust R311 (REF BIAS) for 450-550mV at TP2.

6.5.5 Switch off the power, replace IC201, swing the digital PCB into its normal (closed) position and fit the screw for the left-hand bracket of the LCD display.

6.6 ZERO SETTING

Select R range 5 and connect a 4.7-ohm 5% resistor (Item 7) to the Measure terminals. Adjust R509 (TRIM, Fig. 11) for a B424 reading of 001, then rotate very slowly clockwise until the reading just changes to 000 (or fluctuates between these two readings). During this test it is normal for the 'down' arrow to flash. Remove the resistor.

6.7 RANGE CALIBRATION (using R standards)

6.7.1 Select R range 4, connect the 1.8kΩ Standard resistor (Item 5) to the Measure terminals and adjust R501 (CAL, Fig. 11) to obtain a reading of 1800Ω* on the LCD display.

---

* Or other known value of the Standard

NOTE The correct adjustment, on this and on subsequent tests, is the one mid-way between the settings giving the next higher, and the next lower, readings on the display.

6.7.2 Leaving the 1.8kΩ resistor in position, connect the Frequency Counter (Item 4) earth to TP1 and input to TP4. Adjust trimmer C506 for a reading of 50kHz (50Hz models) or 60kHz (60Hz models). Component C507 is selected on manufacture and is usually 220pF (50Hz models), 180pF (60Hz models). If necessary, change C507 to 180pF (50Hz) or 150pF (60Hz). Disconnect the Frequency Counter.

6.7.3 Select R range 6, connect the 180kΩ Standard resistor (Item 5) to the Measure terminals and adjust R253 (SET 200kΩ, Fig. 9) to obtain a reading of 180.0kΩ*.

6.7.4 Select R range 2, connect the 18-ohm Standard resistor (Item 5) to the Measure terminals and adjust R245 (SET 20Ω) to obtain a reading of 18.00Ω*.

6.7.5 Select R ranges 3, 5, 7 and 8, in sequence, using 180Ω, 18kΩ, 1.8MΩ, and 18MΩ (Item 5), respectively, connected to the Measure terminals. Check that the readings displayed lie within ± 4 digits of the Standard value. On range 8, some noise (± 2 or 3 digits) is to be expected.

6.8 C & L TRANSFER STANDARDS

The range multipliers set up in 6.7 for R values are used also for capacitance and inductance ranges. Thus a single mid-range adjustment of Standard for C and one for L serves for all ranges, except for one further adjustment on the smallest (200pF) capacitance range. The procedure is described in the next section but it must be pointed out that the B424 is an accurate instrument and the careful setting-up made originally should not be disturbed unless proper C and L Transfer Standards are available, together with a precision (± 0.05% or better) 1kHz bridge. The usual precautions must be observed concerning the layout and screening of leads. If 4mm plugs are used to connect the 180pF Transfer Standard to the B424 terminals, and the plugs were screened

---

* Or other known value of the Standard.

for the precision bridge calibration, add 0.1pF to the expected value on B424.

6.9 C & L CALIBRATION

6.9.1 Select C range 9 and, with no connection to the Measure terminals, adjust R3 (C TRIM, front panel) for a reading of 00.0pF.

6.9.2 Select C range 6, connect the 180nF Transfer Standard (Item 6) to the Measure terminals and adjust R287 (C CAL, Fig. 9) for the known value to be correctly displayed.

6.9.3 Select C range 9, connect the 180pF Transfer Standard (Item 6) and adjust R255 (SET 200pF, Fig. 9) for the known value to be correctly displayed.

6.9.4 Select L range 4, connect the 180mH Transfer Standard (Item 6) and adjust R288 (L CAL, Fig. 9) for the known value to be correctly displayed.

6.10 QUADRATURE REJECTION

This section covers 1kHz rejection (6.10.1-2) and 100/120Hz rejection (6.10.3-4).

6.10.1 Remove the screw from the LCD bracket and raise the digital PCB. Select C range 6 and connect a 180nF ±5% capacitor (Item 7) to the Measure terminals. Note the B424 reading.

6.10.2 Connect an 820-ohm ±5% resistor (Item 7) in parallel with the capacitor, and adjust C240 (PHASE, Fig. 9) to restore the reading noted in 6.10.1. Capacitor C241 (33pF) is fitted to some instruments: if the range of C240 is found insufficient, C241 should be fitted/removed/replaced as necessary. Remove the two components from the Measure terminals.

6.10.3 Select C range 5, and connect 1.8μF ±5% and 820Ω ±5% (Item 7) in series across the Measure terminals. Short-circuit the resistor and note the B424 reading.

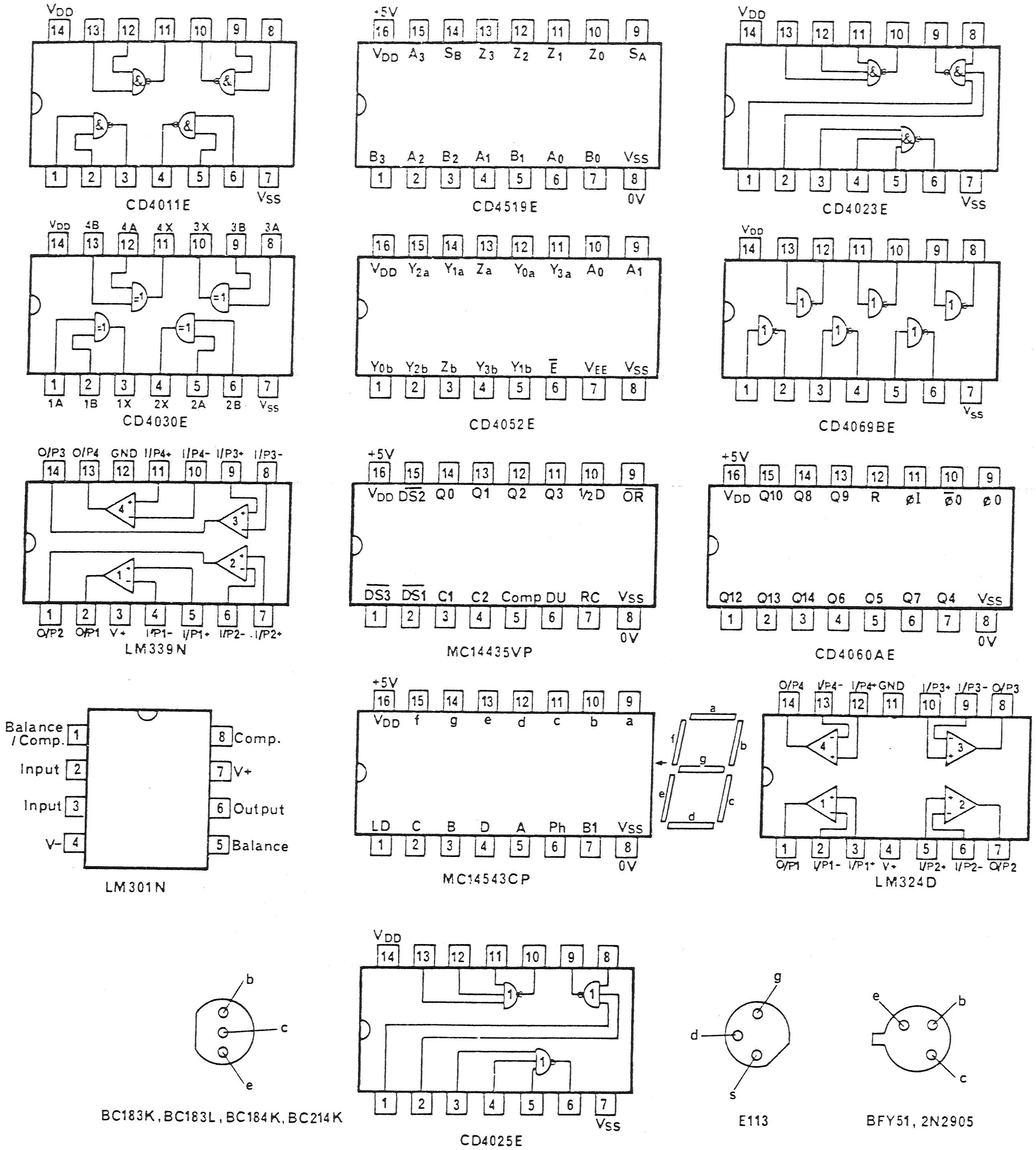
6.10.4 Remove the short-circuit and adjust R230 (LF PHASE, Fig. 9) to restore the reading noted in 6.10.3. Remove the two components.

6.11 C TRIM RANGE

Select C range 9 and, with no component connected to the Measure terminals, check the range of adjustment provided by the front-panel C TRIM control. It should be from at least 30 digits negative (displayed as 07.0pF or numerically smaller) to at least 3 digits positive (reading 00.3pF). If the range is displaced negatively (i.e. does not reach + 3 digits), remove capacitor C271 (Fig. 9).

The setting-up procedure is now complete. To replace the B424 unit, reverse the procedure given in 6.3, noting that the two rubber-feet runners are reversible left-to-right but not front to back (place them with the shorter hole-to-end distance to the front). Also, longer screws are provided for these runners.

Component Adaptor CA4 and Limits Unit LU4 do not have any pre-set controls.



Integrated circuits: Top view
Transistors: Bottom view

Fig. 7 IC & TRANSISTOR
Base Connections

LIST OF COMPONENTS (B424)

Resistors

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R 1	3k3	5		Carbon Film	Piher RCF 1.0
R 2	330	5		Wire Wound	Welwyn W23
R 3	50k	20		Variable	Colvern CLR1106/9S
R 4	470	5		Carbon Film	Mullard CR25
R101	82K	5		Carbon Film	Mullard CR25
R102	150k	5		Carbon Film	Mullard CR25
R103	4k7	5		Carbon Film	Mullard CR25
R104	27k	5		Carbon Film	Mullard CR25
R105	30k	2		Metal Oxide	Electrosil TR5
R106	10k	20	Lin	Carbon	Erie 81/P
R107	39k	2		Metal Oxide	Electrosil TR5
R108	10k	1	100ppm	Metal Film	Allen Bradley FC65
R109	33k	1	100ppm	Metal Film	Allen Bradley FC65
R110	43k	1	100ppm	Metal Film	Allen Bradley FC65
R111	15	5		Carbon Film	Mullard CR25
R112	15k	5		Carbon Film	Mullard CR25
R113	100	5		Carbon Film	Mullard CR25
R114	22k	5		Carbon Film	Mullard CR25
R115	3k3	20	Lin	Carbon	Erie 81/P
R116	4k7	5		Carbon Film	Mullard CR25
R117	180k	5		Carbon Film	Mullard CR25
R118	2M2	10		Carbon Film	Mullard CR25
R119	110k	2		Metal Oxide	Electrosil TR5
R120					
R200	9k53	0.25	50ppm	Metal Film	Allen Bradley FC65
R201	20k	0.25	50ppm	Metal Film	Allen Bradley FC65
R202	1k2	5		Carbon Film	Mullard CR25
R203	10k	5		Carbon Film	Mullard CR25
R204	4k42	0.25	50ppm	Metal Film	Allen Bradley FC65
R205	44k2 ø	0.25	50ppm	Metal Film	Allen Bradley FC65

ø 36k8 on 60Hz instruments

Resistors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R206	4k42	0.25	50ppm	Metal Film	Allen Bradley FC65
R207	44k2 ∅	0.25	50ppm	Metal Film	Allen Bradley FC65
R208	1M0	5		Carbon Film	Mullard CR25
R209	120k	2		Metal Oxide	Electrosil TR5
R210	82k	5		Carbon Film	Mullard CR25
R211	330k	2		Metal Oxide	Electrosil TR5
R212	47	5		Carbon Film	Piher RCF 1.0
R213	220k	5		Carbon Film	Mullard CR25
R214	100k	5		Carbon Film	Mullard CR25
R215	12k	5		Carbon Film	Mullard CR25
R216	560	5		Carbon Film	Mullard CR25
R217	1k5	5		Carbon Film	Mullard CR25
R218	3k9	5		Carbon Film	Mullard CR25
R219	6k8	5		Carbon Film	Mullard CR25
R220	Not Used				
R221	1k0	5		Carbon Film	Mullard CR25
R222	51	0.1	15ppm	Metal Film	Allen Bradley FC70
R223	510	0.05	15ppm	Metal Film	Allen Bradley FC65
R224	5k1	0.1	15ppm	Metal Film	Allen Bradley FC65
R225	51k	0.1	15ppm	Metal Film	Allen Bradley FC65
R226	1k0	5		Carbon Film	Mullard CR25
R227	150k	2		Metal Oxide	Electrosil TR5
R228	150k	2		Metal Oxide	Electrosil TR5
R229	Not Used				
R230	220k	20	Lin	Carbon	Erie 81/P
R231	Not Used				
R232	150k	2		Metal Oxide	Electrosil TR5
R233	100k	5		Carbon Film	Mullard CR25
R234	10k	0.1	25ppm	Metal Film	Allen Bradley FC65
R235	1k0	0.1	25ppm	Metal Film	Allen Bradley FC65
R236	10k	5		Carbon Film	Mullard CR25
R237	1k0	0.1	25ppm	Metal Film	Allen Bradley FC65
R238	1k0	5		Carbon Film	Mullard CR25
R239	10k	5		Carbon Film	Mullard CR25

∅ 36k8 on 60Hz instruments

Resistors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R240	10k2	0.1	25ppm	Metal Film	Allen Bradley FC65
R241	10k	5		Carbon Film	Mullard CR25
R242	10k	0.1	25ppm	Metal Film	Allen Bradley FC65
R243	47k	2		Metal Oxide	Electrosil TR5
R244	1k0	0.1	25ppm	Metal Film	Allen Bradley FC65
R245	10k	10	Lin	Wire Wound	Spectrol 47P
R246	9k09	0.25	15ppm	Metal Film	Allen Bradley FC65
R247	909	0.25	15ppm	Metal Film	Allen Bradley FC65
R248	820	5		Carbon Film	Mullard CR25
R249	10k	5		Carbon Film	Mullard CR25
R250	442	0.25	15ppm	Metal Film	Allen Bradley FC65
R251	1k78	0.25	15ppm	Metal Film	Allen Bradley FC65
R252	17k4	0.25	15ppm	Metal Film	Allen Bradley FC65
R253	1k0	10	Lin	Wire Wound	Spectrol 47P
R254	174k	0.25	15ppm	Metal Film	Allen Bradley FC65
R255	10k	10	Lin	Wire Wound	Spectrol 47P
R256	560	5		Carbon Film	Mullard CR25
R257	18k	5		Carbon Film	Mullard CR25
R258	10k	5		Carbon Film	Mullard CR25
R259	3k3	5		Carbon Film	Mullard CR25
R260	10k	0.25	15ppm	Metal Film	Allen Bradley FC65
R261	150k	2		Metal Oxide	Electrosil TR5
R262	15k	2		Metal Oxide	Electrosil TR5
R263	1M5*	5		Metal Glaze	Mullard VR37
R264	12k	0.25	15ppm	Metal Film	Allen Bradley FC65
R265	5k6	5		Carbon Film	Mullard CR25
R266	12k1	0.25	15ppm	Metal Film	Allen Bradley FC65
R267	20k	0.25	50ppm	Metal Film	Allen Bradley FC65
R268	3k3	5		Carbon Film	Mullard CR25
R269	10k	0.25	15ppm	Metal Film	Allen Bradley FC65
R270	220k	5		Carbon Film	Mullard CR25
R271	36k5	0.25	15ppm	Metal Film	Allen Bradley FC65
R272	4k7	5		Carbon Film	Mullard CR25
R273	12k	5		Carbon Film	Mullard CR25

* 1M0 on 60Hz instruments

Resistors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R274	7k5†	2		Metal Oxide	Electrosil TR5
R275	7k5†	2		Metal Oxide	Electrosil TR5
R276	3k9*	2		Metal Oxide	Electrosil TR5
R277	15k	5		Carbon Film	Mullard CR25
R278	180k	2		Metal Oxide	Electrosil TR5
R279	220k	2		Metal Oxide	Electrosil TR5
R280	100k	5		Carbon Film	Mullard CR25
R281	4k7	5		Carbon Film	Mullard CR25
R282	10M	10		Carbon Film	Mullard CR25
R283	220k	5		Carbon Film	Mullard CR25
R284	Not Used				
R285	196k	0.25	15ppm	Metal Film	Allen Bradley FC65
R286	3k9	5		Carbon Film	Mullard CR25
R287	10k	10	Lin	Wire Wound	Spectrol 47P
R288	10k	10	Lin	Wire Wound	Spectrol 47P
R289	47k	5		Carbon Film	Mullard CR25
R290	20k	0.25	50ppm	Metal Film	Allen Bradley FC65
R291	12k1	0.25	15ppm	Metal Film	Allen Bradley FC65
R292	3k3	5		Carbon Film	Mullard CR25
R293	5k6	5		Carbon Film	Mullard CR25
R294	10k	0.25	15ppm	Metal Film	Allen Bradley FC65
R295	36k5	0.25	15ppm	Metal Film	Allen Bradley FC65
R296	4k7	5		Carbon Film	Mullard CR25
R297	12k	5		Carbon Film	Mullard CR25
R298	7k5†	2		Metal Oxide	Electrosil TR5
R299	7k5†	2		Metal Oxide	Electrosil TR5
R300	3k9*	2		Metal Oxide	Electrosil TR5
R301	15k	5		Carbon Film	Mullard CR25
R302	20k	10	Lin	Wire Wound	Spectrol 47P
R303	20k	10	Lin	Wire Wound	Spectrol 47P
R304	47k	2		Metal Oxide	Electrosil TR5
R305	220k	0.25	15ppm	Metal Film	Allen Bradley FC65
R306	12k	0.25	15ppm	Metal Film	Allen Bradley FC65

† 6k2 on 60Hz instruments
* 3k3 on 60Hz instruments

Resistors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R307	100k	5		Carbon Film	Mullard CR25
R308	100k	5		Carbon Film	Mullard CR25
R309	10k	5		Carbon Film	Mullard CR25
R310	330	5		Carbon Film	Mullard CR25
R311	68k	20	Lin	Carbon	Erie 81/P
R312	220k	5		Carbon Film	Mullard CR25
R313	330	5		Carbon Film	Mullard CR25
R314	100k	5		Carbon Film	Mullard CR25
R315	10k	5		Carbon Film	Mullard CR25
R316	22k	5		Carbon Film	Mullard CR25
R317	1M0	5		Carbon Film	Mullard CR25
R318	1k0	5		Carbon Film	Mullard CR25
R319	47k	5		Carbon Film	Mullard CR25
R320	68k	5		Carbon Film	Mullard CR25
R321	68k	5		Carbon Film	Mullard CR25
R322	Not Used				
R323	220k	5		Carbon Film	Mullard CR25
R324	Not Used				
R325	330	5		Carbon Film	Mullard CR25
R326	68k	20	Lin	Carbon	Erie 81/P
R327	10M	10		Carbon Film	Mullard CR25
R328	10M	10		Carbon Film	Mullard CR25
R329	220k	2		Metal Oxide	Electrosil TR5
R330	1k8	2		Metal Oxide	Electrosil TR5
R331	68k	2		Metal Oxide	Electrosil TR5
R332	220k	2		Metal Oxide	Electrosil TR5
R333	33k	5		Carbon Film	Mullard CR25
R334	22k	5		Carbon Film	Mullard CR25
R335	10M	10		Carbon Film	Mullard CR25
R501	20k	10	Lin	Wire Wound	Spectrol 47P
R502	12k1	0.25	15ppm		Allen Bradley FC65
R503	20k	0.25	15ppm		Allen Bradley FC65
R504	68k	5		Carbon Film	Mullard CR25
R505	4k7	5		Carbon Film	Mullard CR25

Resistors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R506	10k	1	100ppm	Metal Film	Allen Bradley FC65
R507	10k	1	100ppm	Metal Film	Allen Bradley FC65
R508	200k	1	100ppm	Metal Film	Allen Bradley FC65
R509	20k	10	Lin	Wire Wound	Spectrol 47P
R510	820k	5		Carbon Film	Mullard CR25
R511	68k	5		Carbon Film	Mullard CR25
R512	100k	5		Carbon Film	Mullard CR25
R513	100k	5		Carbon Film	Mullard CR25
R514	1MO	5		Carbon Film	Mullard CR25
R515	100k	5		Carbon Film	Mullard CR25
R516	56k	5		Carbon Film	Mullard CR25
R517	560k	5		Carbon Film	Mullard CR25
R518	39k	5		Carbon Film	Mullard CR25
R519	1MO	5		Carbon Film	Mullard CR25
R520	39k	5		Carbon Film	Mullard CR25
R521	10M	10		Carbon Film	Mullard CR25
R522	1MO	5		Carbon Film	Mullard CR25
R523	1MO	5		Carbon Film	Mullard CR25
R601-R627	100k	5		Carbon Film	Mullard CR25
R628-R644	10M	5		Carbon Film	Mullard CR25

Capacitors

Ref	Value	Tol	Rating	Type	Supplier & Type No.
C 1	15µ		63V		Mullard 01618159
C 3	2200µ		25V		Mullard 071 1622Z
C101	1n0	2½	160V	Polystyrene	LCR Type FSC
C102	33p	2½	160V	Polystyrene	LCR Type FSC
C103	Not Used				
C104	68µ		6.3V	Electrolytic	Mullard 01513689
C105	68µ		6.3V	Electrolytic	Mullard 01513689
C106	100µ		4V	Electrolytic	Mullard 01512101
C201	330p	2½	160V	Polystyrene	LCR Type FSC
C202	33p	2½	160V	Polystyrene	LCR Type FSC
C203	33p	2½	160V	Polystyrene	LCR Type FSC
C204	36n	1	63V	Polycarbonate	MFD OPR 36n F63
C205	36n	1	63V	Polycarbonate	MFD OPR 36n F63
C206	36n	1	63V	Polycarbonate	MFD OPR 36n F63
C207	36n	1	63V	Polycarbonate	MFD OPR 36n F63
C208	68µ		63V	Electrolytic	Mullard 01718689
C209	68µ		63V	Electrolytic	Mullard 01718689
C210	10µ		25V	Electrolytic	Mullard 01516109
C211	33p	2½	160V	Polystyrene	LCR Type FSC
C212	47n		40V	Ceramic Disc	Erie 811T40V
C213	47n		40V	Ceramic Disc	Erie 811T40V
C214	680n	5	250V	Polyester	Wima MKS
C215	680n	5	250V	Polyester	Wima MKS
C216	680n	5	100V	Polyester	Wima MKS
C217	680n	5	100V	Polyester	Wima MKS
C218	47µ	20	10V	Tantalum Bead	ITT TAG 47/10
C219	33p	2½	160V	Polystyrene	LCR Type FSC
C220	330p	2½	160V	Polystyrene	LCR Type FSC
C221	33p	2½	160V	Polystyrene	LCR Type FSC
C222	330p	2½	160V	Polystyrene	LCR Type FSC
C223	33p	2½	160V	Polystyrene	LCR Type FSC
C224	330p	2½	160V	Polystyrene	LCR Type FSC
C225	12p	1p	160V	Polystyrene	LCR Type FSC
C226	Not Used				

Capacitors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
C227	3n9	2½	160V	Polystyrene	LCR Type FSC
C228	Not Used				
C229	Not Used				
C230	220n	10	100V	Polyester	Wima MKS
C231	10n	0.5	125V	Silver Mica	Johnson Matthey C203E
C232	33p	2½	160V	Polystyrene	LCR Type FSC
C233	330p	2½	160V	Polystyrene	LCR Type FSC
C234	100μ		10v	Electrolytic	Mullard 01614101
C235	3p	1p	160V	Polystyrene	LCR Type FSC
C236	330p	2½	160V	Polystyrene	LCR Type FSC
C237	100μ		10V	Electrolytic	Mullard 01614101
C238	33p	2½	160V	Polystyrene	LCR Type FSC
C239	330p	2½	160V	Polystyrene	LCR Type FSC
C240	5.5-65p			Preset	Mullard 80801001
C241	33p*	2½	160V	Polystyrene	LCR Type FSC
C242	47n		40V	Ceramic Disc	Erie 811T40V
C243	1μ0	10	100V	Polyester	Wima MKS
C244	150p	2½	160V	Polystyrene	LCR Type FSC
C245	10p	1p	160V	Polystyrene	LCR Type FSC
C246	220n	10	100V	Polyester	Wima MKS
C247	100n	10	100V	Polyester	Wima MKS
C248	100n	10	100V	Polyester	Wima MKS
C249	47n		40V	Ceramic Disc	Erie 811T40V
C250	47n		40V	Ceramic Disc	Erie 811T40V
C251	2μ2		63V	Electrolytic	Mullard 01518228
C252	33p	2½	160V	Polystyrene	LCR Type FSC
C253	330p	2½	160V	Polystyrene	LCR Type FSC
C254	10μ	10	63V	Polyester	Wima MKS
C255	10p	1p	160V	Polystyrene	LCR Type FSC
C256	150p	2½	160V	Polystyrene	LCR Type FSC
C257	220n	10	100V	Polyester	Wima MKS
C258	100n	10	100V	Polyester	Wima MKS
C259	100n	10	100V	Polyester	Wima MKS
C260	33p	2½	160V	Polystyrene	LCR Type FSC

* Selected on test (SOT)

Capacitors continued

Ref	Value	Tol	Rating	Type	Supplier & Type No.
C261	33p	2½	160V	Polystyrene	LCR Type FSC
C262	47n		40V	Ceramic Disc	Erie 811T40V
C263	2μ2		63V	Electrolytic	Mullard 01518228
C264	470p	20	500V	Ceramic Disc	Erie 831/Hi-K
C265	22n		25V	Ceramic Disc	Erie 831T25V
C266	470p	20	500V	Ceramic Disc	Erie 831/Hi-K
C267	2μ2	20	16V	Tantalum Bead	ITT TAG 2.2/16
C268	2μ2	20	16V	Tantalum Bead	ITT TAG 2.2/16
C269	2μ2	20	16V	Tantalum Bead	ITT TAG 2.2/16
C270	2μ2	20	16V	Tantalum Bead	ITT TAG 2.2/16
C271	3p*	1p	160V	Polystyrene	LCR Type FSC
C272	68p	1p	160V	Polystyrene	LCR Type FSC
C501	33p	2½	160V	Polystyrene	LCR Type FSC
C502	33p	2½	160V	Polystyrene	LCR Type FSC
C503	1μ5	10	100V	Polyester	Wima MKS
C504	47n		40V	Ceramic Disc	Erie 811T40V
C505	47n		40V	Ceramic Disc	Erie 811T40V
C506	5.5-65p			Preset	Mullard 80801001
C507	220p†	2½	160V	Polystyrene	LCR Type FSC
C508	1n0	2½	160V	Polystyrene	LCR Type FSC
C509	470p	2½	160V	Polystyrene	LCR Type FSC
C510	33n	10	250V	Polyester	Wima MKS
C511	47n	10	40V	Ceramic Disc	Erie 811T40V
C512	47n	10	40V	Ceramic Disc	Erie 811T40V
C513	47n	10	40V	Ceramic Disc	Erie 811T40V
C514	47n	10	40V	Ceramic Disc	Erie 811T40V
C515	1μ0	20	35V	Tantalum Bead	ITT TAG 1.0/35

* Selected on test (SOT)
† 180p on 60Hz instruments

Diodes

Ref	Type	Supplier & Type No.
D 1	1N 4002	IR
D 2	1N 4148	Mullard
D 3	LED (Mains 'On')	Monsanto MV 5053
D 4	1N 4002	IR
D 5	Rectifier block, 1SB05	IR
D 6	1N 4002	IR
D101	1N 4002	IR
D102	Zener 5.6V	Mullard BZY 88-C5V6
D201	1N 4002	IR
D202	1N 4002	IR
D203	1N 4002	IR
D204	1N 4002	IR
D205	1N 4148	Mullard
D206	1N 4148	Mullard
D207	Zener 5.6V	Mullard BZW 70-5V6
D208	Zener 5.6V	Mullard BZW 70-5V6
D209	1N 4002	IR
D210	1N 4002	IR
D211 - D220	1N 4148	Mullard
D601 - D616 D618 D620 - D652 D654 - D689 D691 - D694 D696 - D717	1N 4148	Mullard

Transistors & IC's

Ref	Type	Supplier & Type No.
TR100	2N2905A	Texas
TR101	BC214	Texas
TR102	BC184	Texas
TR103	BC184	Texas
TR104	BC184	Texas
TR105	BC184	Texas
TR106	BC184	Texas
TR201	E113	Siliconix
TR202	BC183	Texas
TR203	BC213	Texas
TR204	BC183	Texas
TR205	BC183	Texas
TR206	BC213	Texas
TR207	E113	Siliconix
TR208	E113	Siliconix
TR501	BC213	Texas
TR502	BC183	Texas
IC100	LM301AN	National
IC201	LM301AN	National
IC202	CD4052AE	R.C.A.
IC203-208	LM301AN	National
IC209	CD4052AE	R.C.A.
IC210-216	LM301AN	National
IC217	LM339N	National
IC501	CD4052AE	R.C.A.
IC502	LM301AN	National
IC503	LM301AN	National
IC504	LM301AN	National

Transistors & IC's continued

Ref	Type	Supplier & Type No.
IC505	MC14435VP	Motorola
IC506	MC14543CP	Motorola
IC507	MC14543CP	Motorola
IC508	MC14543CP	Motorola
IC509	CD4069BE	R.C.A.
IC510	CD4023AE	R.C.A.
IC511-515	CD4030AE	R.C.A.
IC516	CD4011AE	R.C.A.
IC517	CD4060AE	R.C.A.
IC518	CD4025AE	R.C.A.
IC519	CD4519BE	R.C.A.

Miscellaneous

Ref	Type	Supplier & Type No.
TH100	Thermistor VA 1111	Mullard
T1	Mains Transformer	ITT 9112
SA SB SC	Push button switch assembly (WBE Ref. DC4/24773)	Dialistat
SD	Range Switch	Jean Renaud RBP12SMP
SE	Normal/Limits Unit	Stackpole SS50
SF	110/220V Switch	Stackpole SS50
SG	On-off Switch	MST 216N
FS1	Fuse, 1Amp, slow blow	20 x 5mm
FS2	Fuse, 1Amp, slow blow	20 x 5mm

CA4/LU4

Resistors

Ref	Value	Tol	Rating	Type	Supplier & Type No.
R 1	100	5		Carbon Film	Mullard CR25
R 2	4k7	5		Carbon Film	Mullard CR25
R 3	10k	1	100ppm	Metal Film	Allen Bradley FC65
R 4	11k	1	100ppm	Metal Film	Allen Bradley FC65
R 5	10k				
R 6	10k				
R 7	390	5		Carbon Film	Mullard CR25
R 8	100k	5		Carbon Film	Mullard CR25
R 9	100k	5		Carbon Film	Mullard CR25
R10	100k	5		Carbon Film	Mullard CR25
R11	390	5		Carbon Film	Mullard CR25
R12	100k	5		Carbon Film	Mullard CR25
R13	100k	5		Carbon Film	Mullard CR25
R14	390	5		Carbon Film	Mullard CR25
R15	12k	5		Carbon Film	Mullard CR25
R16	2k2	5		Carbon Film	Mullard CR25

Capacitors

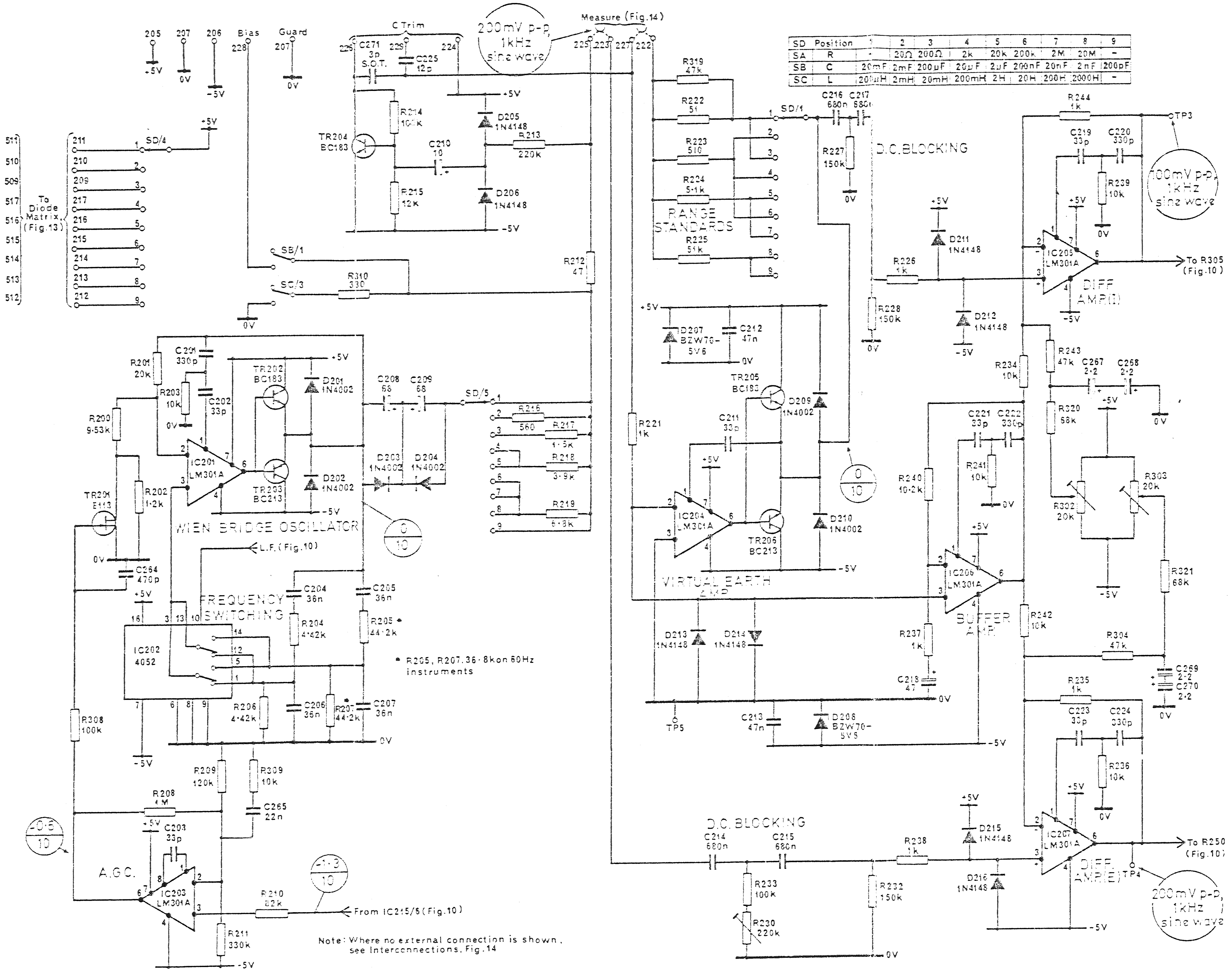
C 1	47n	40V	Ceramic Disc	Erie 811T40V
C 2	47n	40V	Ceramic Disc	Erie 811T40V
C 3	470μ	25V	Electrolytic	Mullard 01716471

Miscellaneous

Ref	Type	Supplier & Type No.
D1, D2	5082-4655 or MV50531	HP or Monsanto, respectively
D3	5082-4955 or MV5253	HP or Monsanto, respectively
D4, 5, 6	1N 4148	Mullard

Miscellaneous continued

Ref	Type	Supplier & Type No.
TR1	BC213K	Texas
TR2	BC183K	Texas
TR3	BC213K	Texas
TR4	BFY51	Mullard
IC1	LM324	National
SA	D.P. Push-button switch	Lipa and Isostat
SB	D.P. Push button switch	Lipa and Isostat



SD	Position	1	2	3	4	5	6	7	8	9
SA	R	-	20Ω	200Ω	2k	20k	200k	2M	20M	-
SB	C	20mF	2mF	200μF	20μF	2μF	200nF	20nF	2nF	200pF
SC	L	200μH	2mH	20mH	200mH	2H	20H	200H	2000H	-

Fig. 8 ANALOG Circuit Diagram, sheet 1

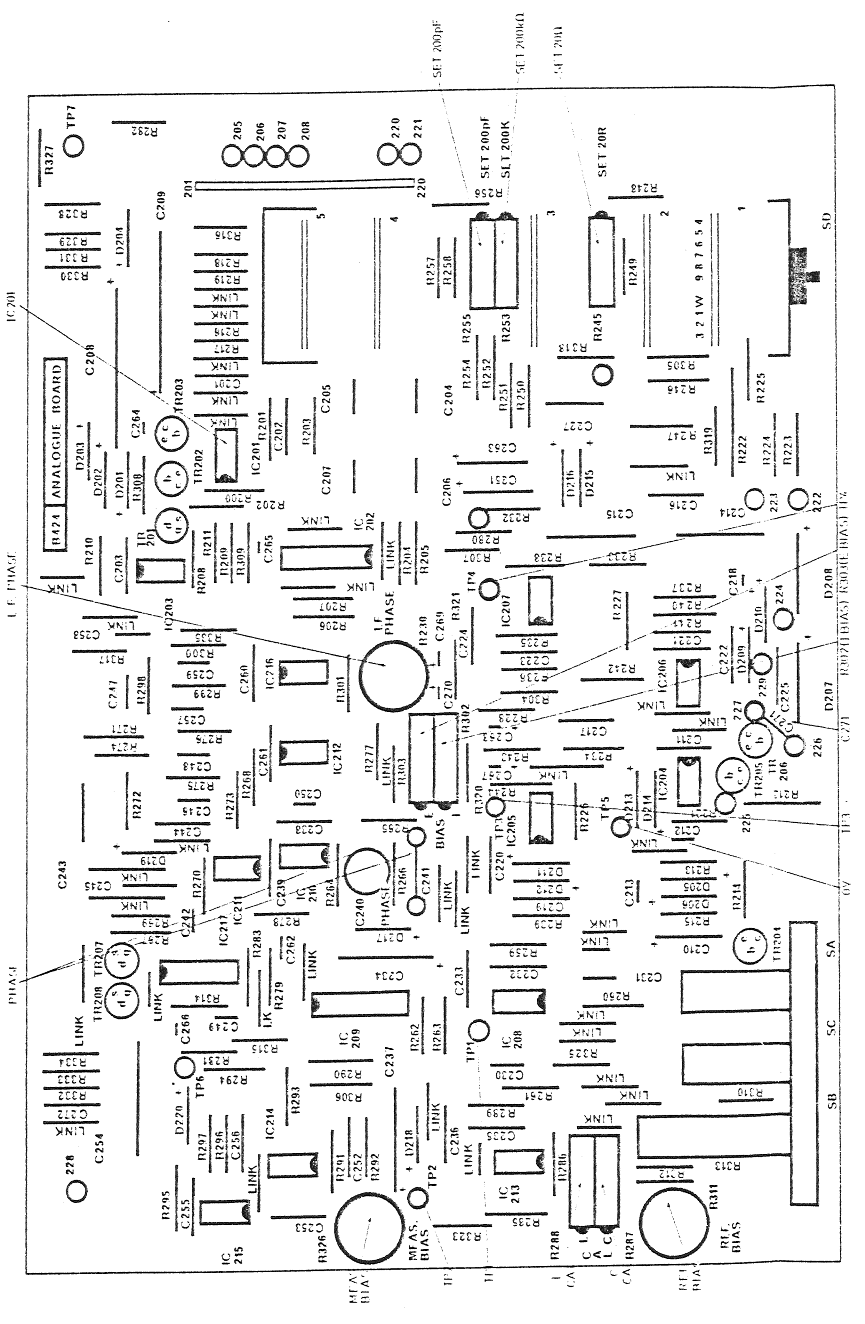


Fig. 9 ANALOG PCB

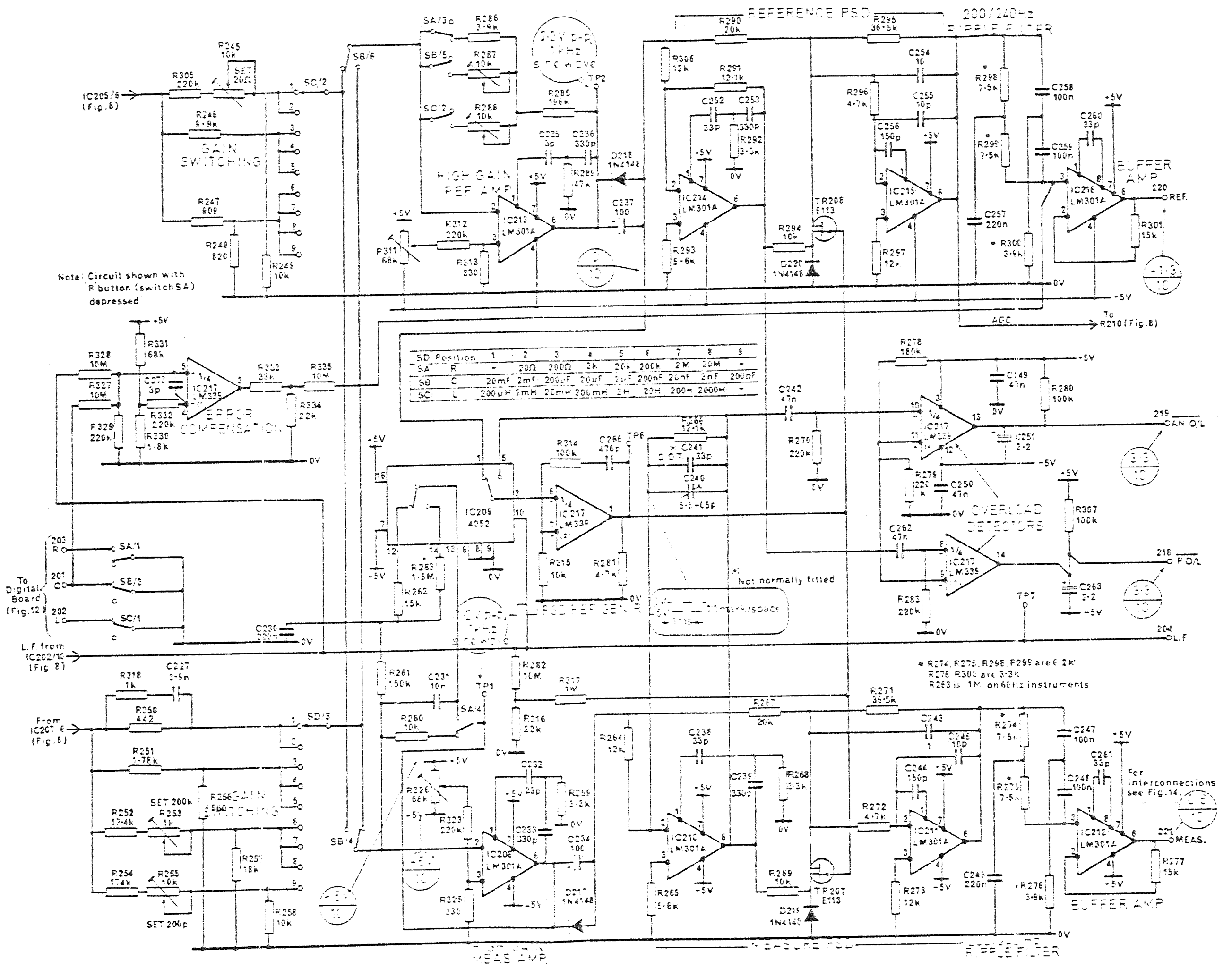


Fig. 10 ANALOG Circuit Diagram, sheet 2

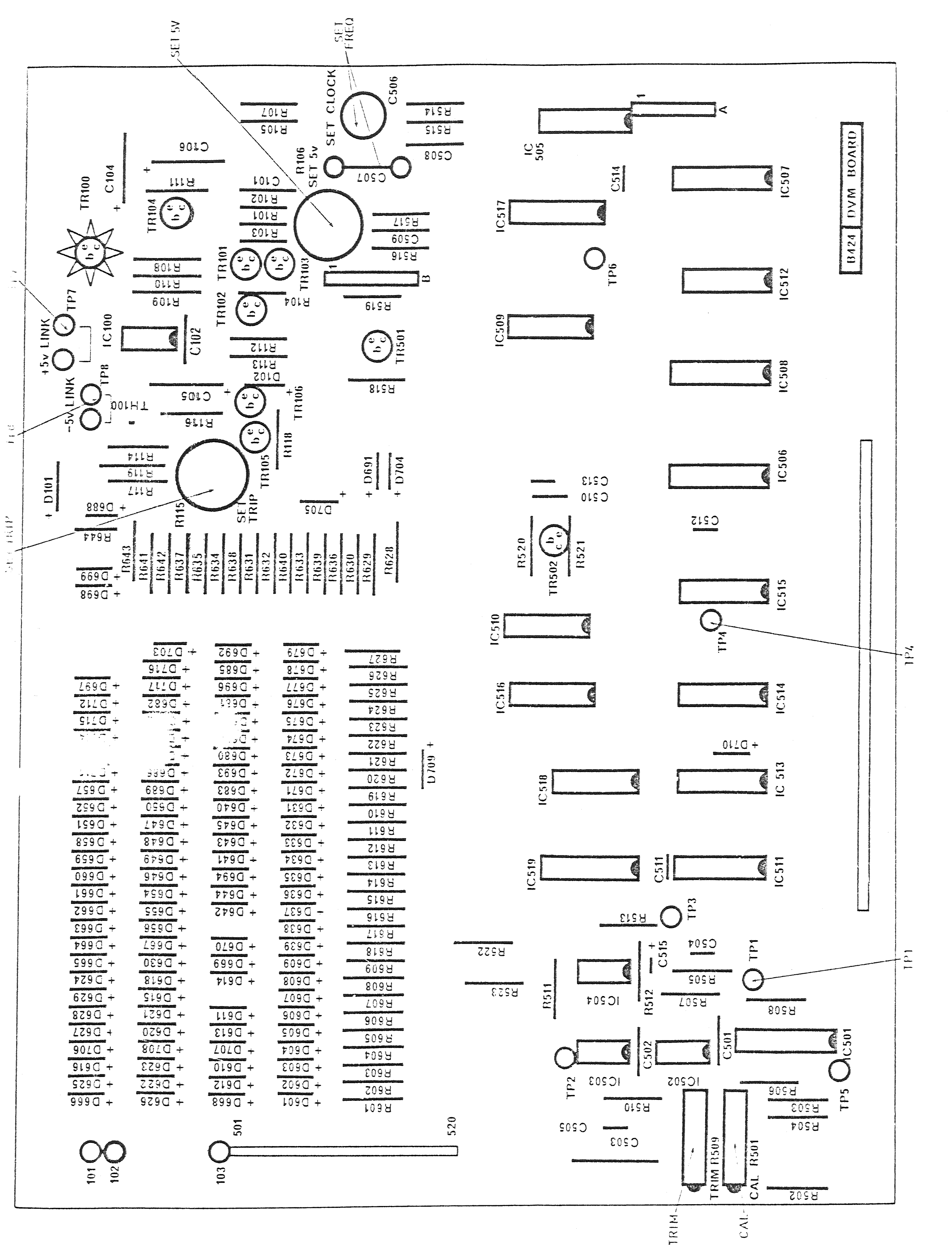
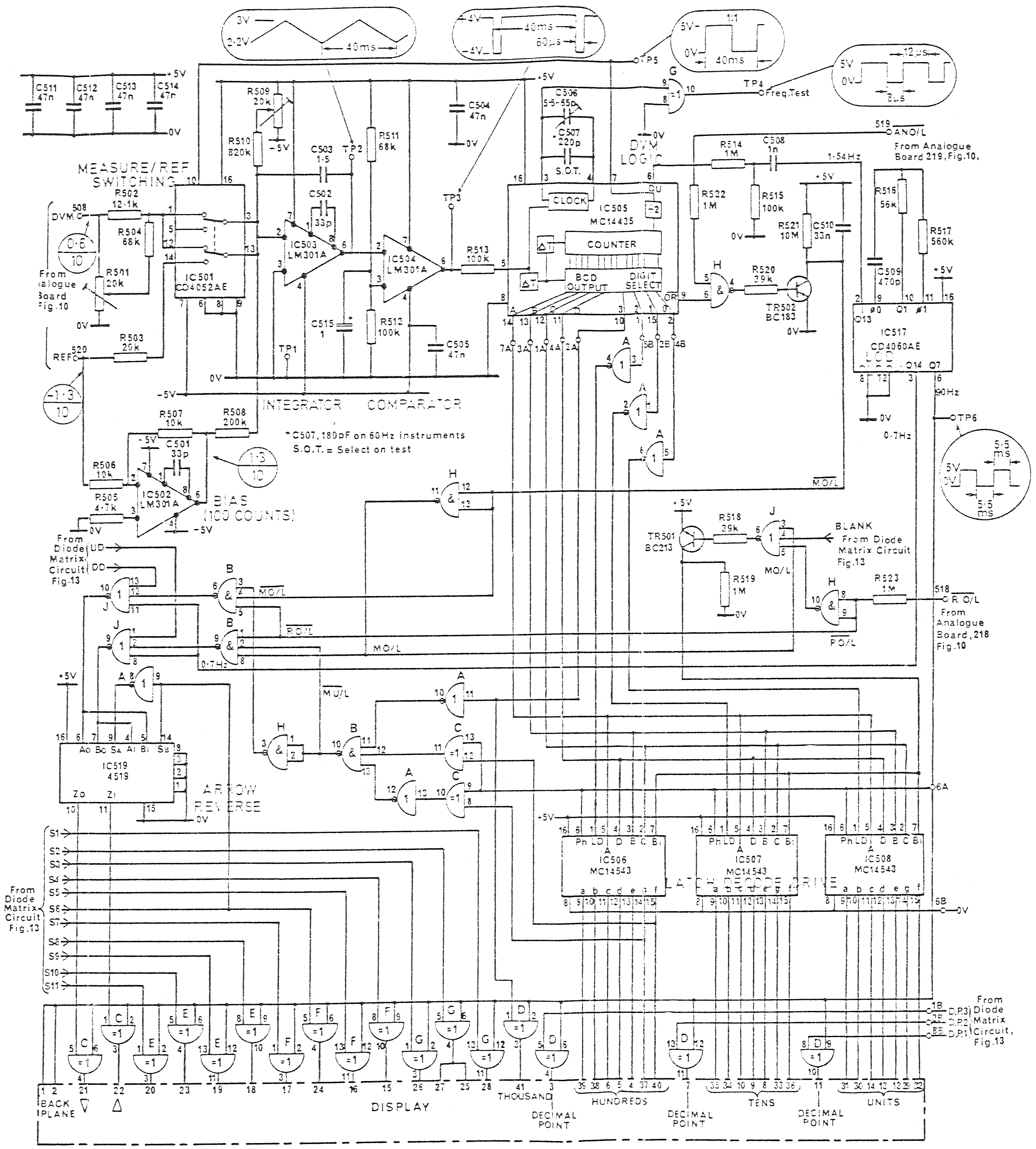


Fig. 11 DIGITAL PCB



DESIGNATION	REFERENCE	TYPE
A	IC509	4069
B	IC510	4023
C	IC511	4030
D	IC512	4030
E	IC513	4030
F	IC514	4030
G	IC515	4030
H	IC516	4011
J	IC518	4025

Pin 14, + 5V   Pin 7, 0V

Fig. 12 DIGITAL PCB Circuit Diagram

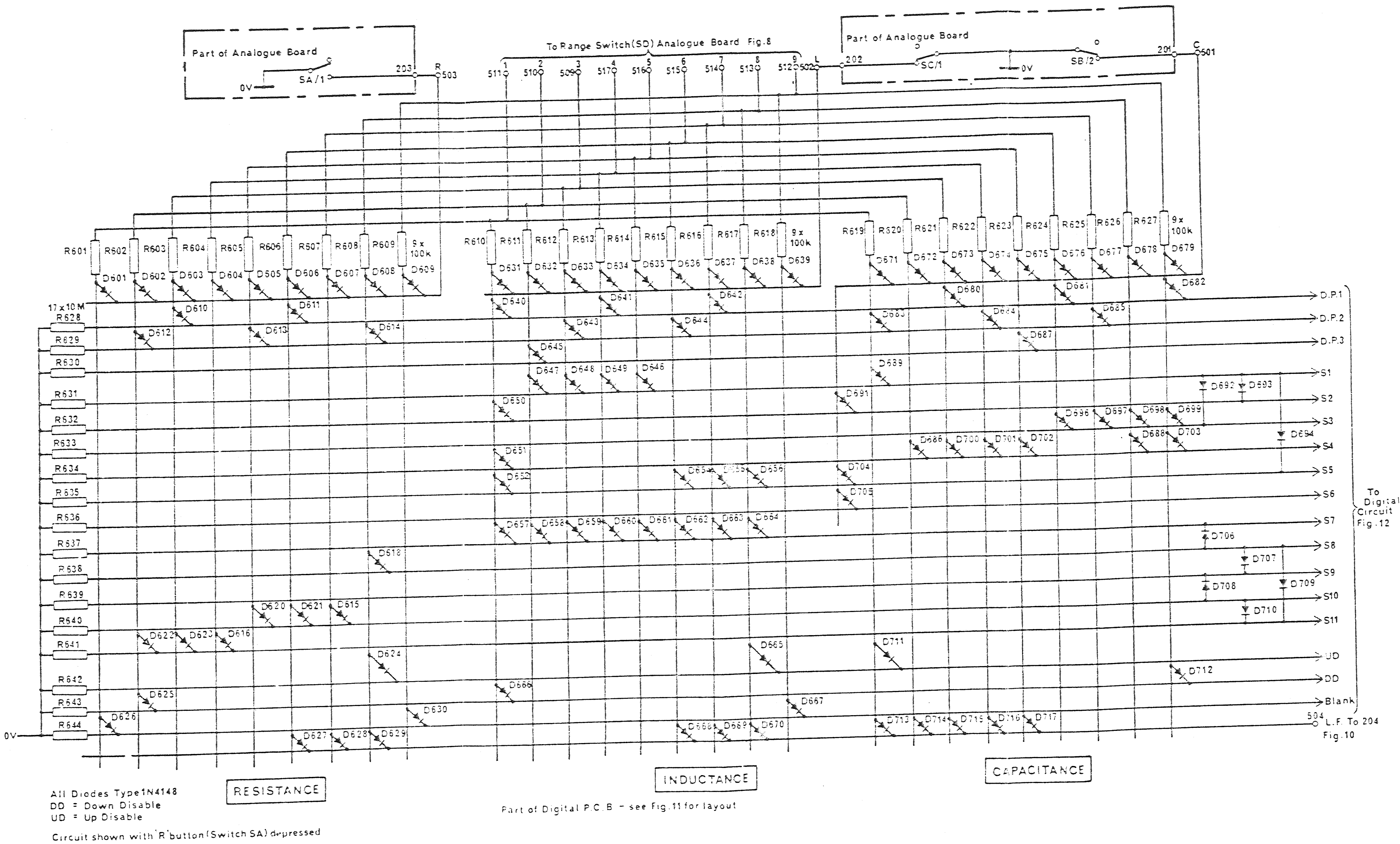


Fig. 13 DIODE MATRIX

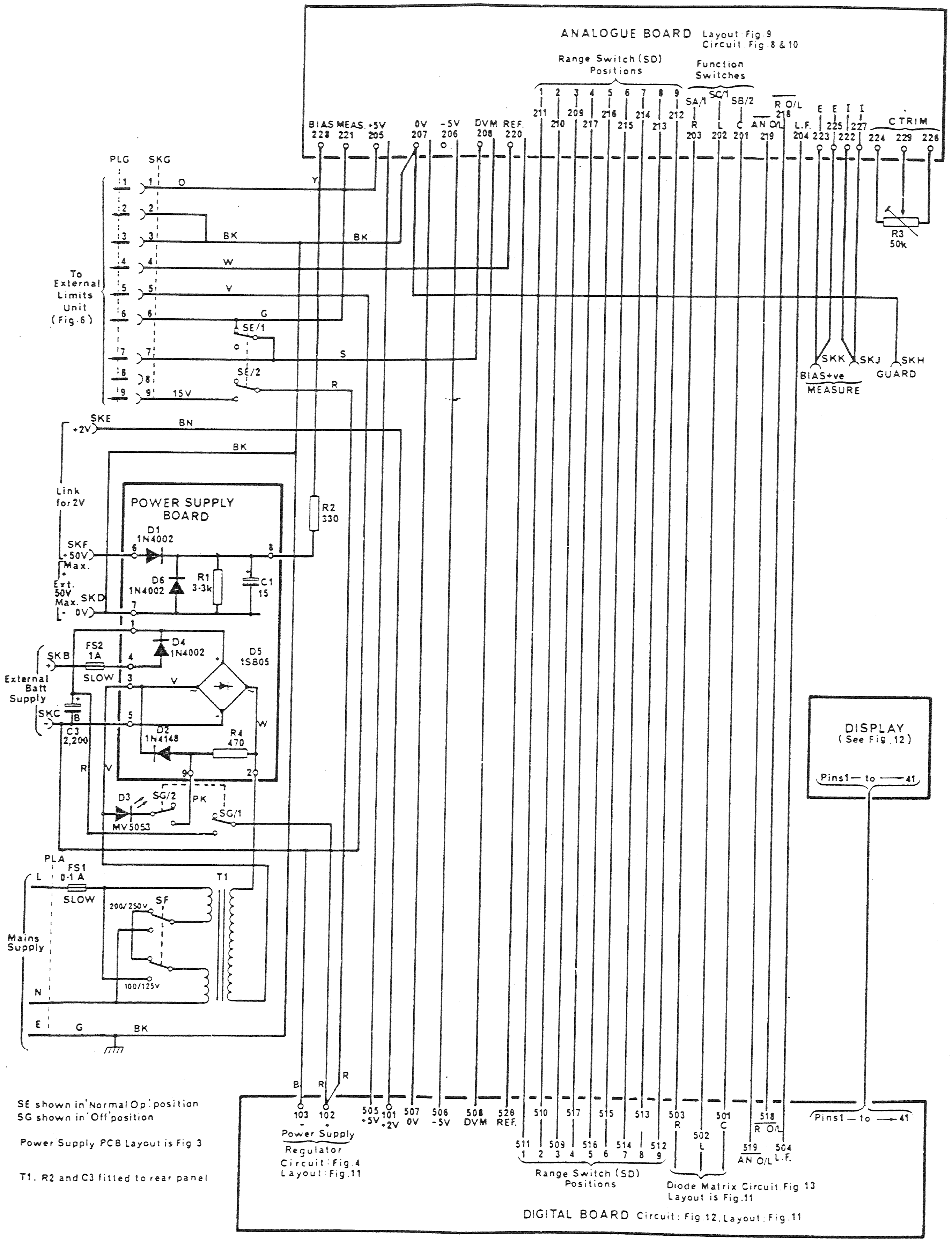


Fig. 14 INTERCONNECTIONS