Thurlby SINCLAIR

1503 and 1504 high resolution multimeters

SERVICE MANUAL

1530

INDEX

1. INTRODUCTION

This manual is intended to assist skilled personnel in the maintenance and repair of the 1503, 1503-HA and 1504 multimeters.

Knowledge of electronic theory and practice, and access to precision test equipment, is assumed.

2. OPERATING INSTRUCTIONS

Refer to Instruction Manual.

3. SPECIFICATIONS

Refer to Instruction Manual.

4. PRINCIPLES OF OPERATION

The circuit of the 1503 is most conveniently broken down into four sections. These are:-

1. The power supply and reference generators.
2. The Signal conditioning circuitry.
3. The Analogue to Digital (A/D) Converter.
4. The Count/Display Module.

4.1. The power supply and reference generators

The 1503 operates from a source of DC voltage between 6.3 volts and 15 volts at a current of 21mA ± 3mA at 9V. The source may be either disposable cells, rechargeable cells, or an AC line adaptor producing a suitable DC output.

The power supply produces four regulated outputs from the unregulated DC input.

V+ (+6.2V nominal), V_R (+2.45V nominal), I_R (6.6µA nominal), V-(-7.0V nominal).

V+ is produced by the series regulator TR25, IC14a and defined as $V_R \times \frac{R91 + R92}{R92}$. V_R is derived from a high stability band-gap reference diode D40, selected for temperature coefficient better than 25ppm/°C. (±15 ppm for 1503-HA).

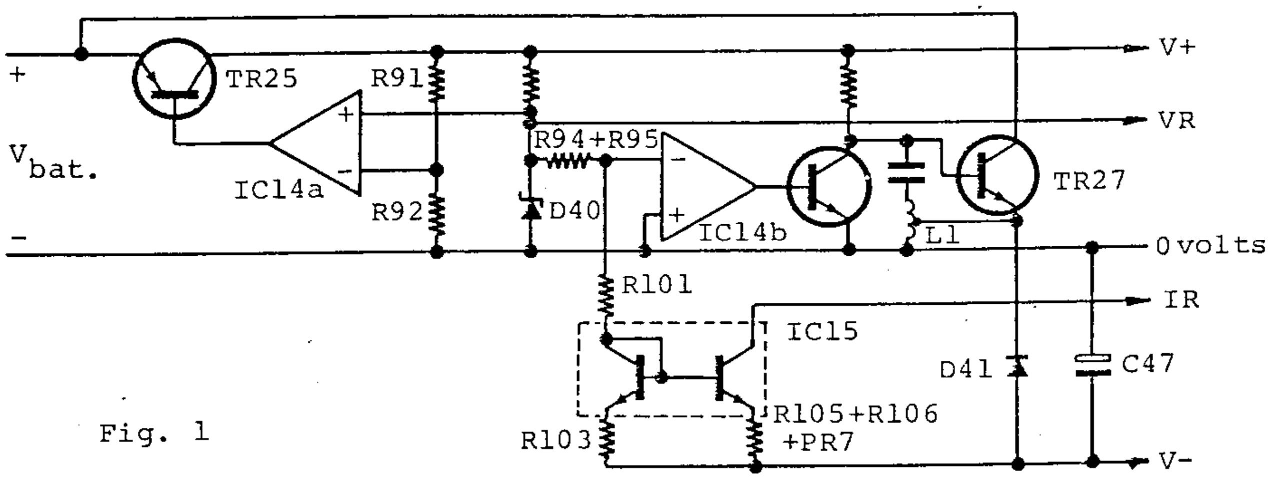

Fig. 1

Op-amp IC14b controls a switching inverter TR27 which generates V- equal to $V_R \times \frac{R101 + R103}{R94 + R95} + 0.65$. The current mirror circuit IC15 generates a precision current I_R equal to

$$\frac{V_R}{R94 + R95} \times \frac{R102}{PR7 + R105 + R106}$$

Transistor TR24 detects low battery (less than 6.8 volts), though operation is not impaired until Vin falls below 6 volts. The collector of TR24 is taken to pin 5 of IC13a. Early versions have links LK2 and LK4 fitted, and show low battery by permanent blanking of the least significant digit via M1 pin 6. Later versions have links LK1 and LK3 fitted instead, and low battery indication is by the display legend LW (M1 pin 24).

4.2 The Signal Conditioning Circuitry

The signal conditioning circuitry converts DC voltage up to 1200 volts, AC voltage up to 750 volts, DC current up to 25 amps, AC current up to 25 amps, and Resistance up to 32MΩ into a DC voltage of a suitable level to be measured by the A to D converter.

DC Voltage

DC voltage is applied to resistor pack RP1 via S3B and S4B. RP1 contains a chain of five resistors totalling 10MΩ with taps at 1MΩ, 100K, 10K and 1K. On the 320mV and 3200mV ranges the voltage is taken directly from the top of the chain, whilst on higher ranges it is taken from taps on the chain. The voltage is applied to the A/D converter via S4A, S3A and S2A.

AC Voltage

AC voltage takes the same route as DC voltage, but the A/D converter input is taken from the junction of R16 and C11 rather than from the voltage divider chain. With S2 depressed, IC1 is configured as an AC to DC converter. The AC signal is applied to its input via protection resistor R1, and diodes D3 and D4 feed back the -ve and +ve portions of the signal respectively to the inverting input. The attenuators formed by R11 and R12 with R13 plus R14 result in a negative voltage proportional to the AC input appearing on C7 and an equal positive voltage appearing on C8. The latter is smoothed by R15, C10, R16, C11 and the resultant DC output is adjusted by PR1 to have a level equal to the rms value of the sinusoidal input that caused it.

DC Current

DC current up to 800mA is applied via fuse FS1 to the current shunt resistor pack RP2. RP2 contains a chain of four resistors totalling 1KΩ with taps at 100Ω, 10Ω and 1Ω. A current flowing in a shunt resistor generates a voltage at the top of the chain which is fed to the A to D converter via S4A, S3A and S2A. Diodes D7 to D12 in conjunction with FS1 provide protection against overloads.

Currents up to 25 amps are applied directly to the 10mΩ shunt resistor R22. The voltage generated is applied in series with RP2. R21 is included to compensate for the additional resistance R22 adds to RP2.

AC Current

AC current follows the same route as DC current but the voltage generated is applied to the AC to DC converter as in 'AC voltage'.

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Resistance

With S2 and S3 released, IC1 is configured as a precision current source.

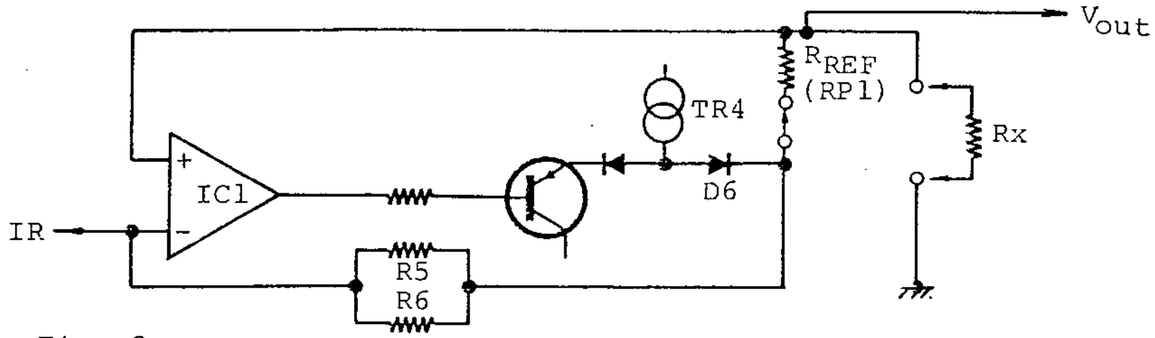

Fig. 2

The current output is equal to $\frac{Iref \times R5//R6 + VosIC1}{Rref}$ and since Iref x R5//R6 + VosIC1 is made equal to 1 volt, Vout = $\frac{RX}{Rref}$ volts.
Thus a voltage is generated across the unknown resistor RX which is then measured by the A to D converter. By making Rref equal to 1K, 10K, etc. up to 10MΩ, direct readings in Ωs are obtained.

Protection against voltage overload is provided by high voltage diodes D5 and D6 and high voltage transistor TR4.

Scale length control

On DC voltage or current, overrange is indicated at 32,768 counts. On AC voltage, S2B provides a high level to IC7 pin 5 causing overrange indication at 16,384 counts. On DC or AC current S4C provides a high level to IC7 pin 13 causing overrange indication at 8,192 counts.

Sensitivity control

With S5 depressed, S5A pulls R53 low and releases R46 causing the A to D converter to switch into 10μV/count sensitivity. With S5 released, S5A pulls R46 low and releases R53 causing the A to D converter to return to 100μV/count sensitivity.

Decimal point selection

Sections a, b and c of IC2 drive the three decimal points on the liquid crystal display. One input of each is driven from the LCD backplane signal whilst the other is normally pulled high. This results in an in-phase drive to each decimal point which leaves them turned off. The range switching pulls one of the control inputs low resulting in an out-of-phase signal to the appropriate decimal point which turns it on.

Sections a, b and c of IC13 operate in a similar way for drive of the display legends.

Section d of IC2 provides a delayed signal at switch-on which ensures that the A to D converter is started in the correct mode.

4.3 The A/D Converter

Basic System

The A/D converter uses the dual slope principle. The voltage to be measured is used to charge a capacitor for a fixed time period, then a reference voltage is used to discharge this capacitor, and the time taken to return to the initial level is measured and displayed.

The conversion time periods are generated by the binary divider IC3 which is driven from a 50Hz signal generated on M1.

The voltage to be measured (Vin) is integrated for an 80msec time period defined by pin 6 low, pin 9 high. This is 'Integrate' or phase A. The 'De-integrate' period, phase B, lasts between 0 and 160 msec with pin 6 high. Following this are two autozero periods during which system offsets are removed, phase C lasts for 160msec less the phase B time, whilst phase D lasts for a fixed 80msec defined by pin 6 low, pin 9 low.

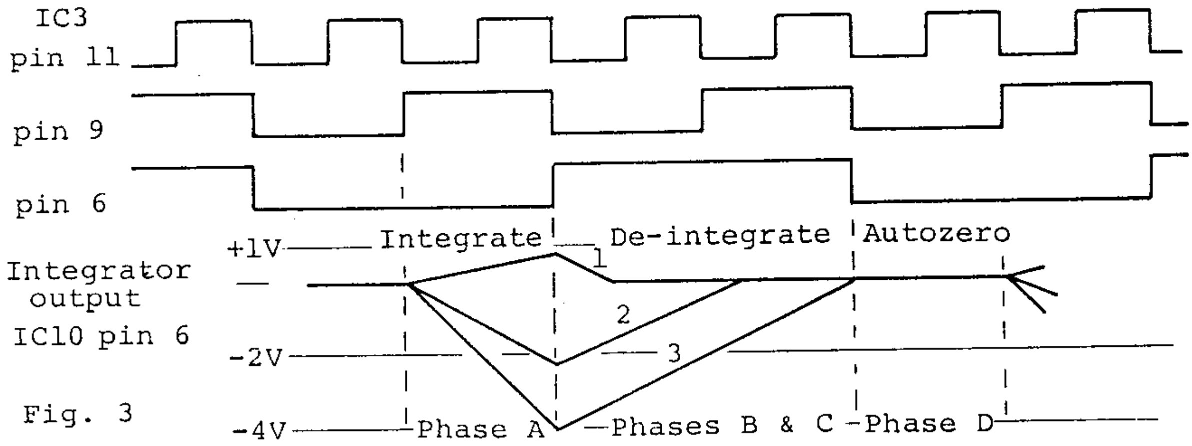

Fig. 3

1. negative input ~ 1/10 full scale (reading - 3,000 digits)

2. positive input ~ 2/3 full scale (reading 20,000 digits)

3. positive input ~ full scale (reading 32,000 digits)

Analogue System

During Autozero the integrator output is held at the theshold of the comparator (TR14 to TR22) which is approximately 0 volts. At this time, IC5 sections a and d, and IC6 sections b, c and d are closed. This grounds the buffer amplifier IC9 and produces a negative feedback loop around IC9, IC10 and the comparator, which causes the system offset voltages to be stored on C26 and C27. At the same time, C23 is charged to the reference voltage on the slider of PR3. This voltage is adjusted to be 1.6384 volts.

During Integrate (phase A), IC5c is closed, connecting Vin to the buffer input causing C30 to charge via R59.

/continued...

During De-integrate (phase B), either IC5b or IC6a is closed depending on the polarity of Vin. This causes the buffer input to be taken to +1.6384 or -1.6384 volts respectively and C30 is discharged back to the comparator theshold.

For most ranges the sensitivity of the converter is 100μV/count and the buffer has a fixed gain of unity. On the most sensitive ranges, (320mV, 320mΩ, 80μA), sensitivity is increased to 10μV/count by closing IC6c rather than IC6b during integrate, thus giving the buffer a gain of X10 during phase A. The switching for IC6b and c is performed by TR10 under the control of TR11 and TR12.

Digital Control

The analogue switches IC5 and IC6 are driven by transistors TR5, TR8, TR12, TR13, TR23. These transistors provide level translation between the digital circuitry, which operates between 0 and V+, and the analogue circuitry which operates between V- and V+. TR5 is controlled directly from the binary divider IC3 via IC4. TR12 and 13 are controlled by IC4 in conjunction with the polarity detector bistable IC11a. TR8 is controlled from the sensitivity selection switch in conjunction with the zero crossing detector bistable IC11b. TR23 is controlled by IC11b directly.

Polarity Bistable

At the end of phase A, the integrator output has a polarity opposite to that of Vin. The comparator inverts and amplifies this level (by about -10,000) resulting in TR22 collector being at either V+ for Vin +ve, or 0 volts for Vin -ve. At this time IC3 pin 6 goes positive clocking the D type bistable IC11a and latching the polarity information as Q high or $\overline{Q}$ high respectively. This is used to select the correct polarity of reference via IC4, and to control the negative symbol on the display via IC13c.

Zero Crossing Bistable

At the end of phase B the integrator output returns to zero causing the comparator output to change state. The comparator output is fed to an exclusive OR gate IC13d along with the polarity bistable output. The output of this gate goes high when the comparator changes state regardless of input polarity, thus taking the data input of D type bistable IC11b high and causing the Q output to be latched high on the next clock edge.
With Q low, the converter is switched into autozero by TR23.

At the start of phase A, IC11b is reset by TR5 via D34.

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Count/Display Module Control

The Count/Display Module M1 has three basic control signals. 'Reset' holds the counter at zero when high.

'Hold' freezes the display when high, and enables a transfer of new data into the display latches when low.

'Count Input' clocks the counter via a divide by 8 prescaler.

The counter is reset to zero by C18 at the start of phase A. During phase A the count input is inhibited by D27, D29. At the start of phase B, this inhibit is removed and the counter starts to accumulate. The count input is fed with 1.6384 MHz generated by a IC12 which divides the 6.5536MHz signal from M1. The internal ÷ 8 prescale results in an accumulation rate of 204.8KHz. At the end of phase B, the zero-crossing bistable inhibits the count input via D30, and pulses the Hold input low via C39, causing the new count to be transferred to the display.

Overrange Detection

The instrument has three different overrange points corresponding to 8192, 16384, or 32768 counts. The time for these is provided by IC3 via IC7c, IC7d, or R39 respectively according to the setting of the function switches. The selected +ve edge clocks the D type bistable IC8a and overrange condition is detected if $\overline{Q}$ of IC11b is still high at this time (showing that zero crossing has not taken place). In this case, IC8a $\overline{Q}$ goes low, triggering monostable TR16 and causing M1 pin 6 to go high, thus blanking the least significant digit. The monostable time constant is about 250msec and during this period IC3 is reset and the system waits for zero crossing to occur before switching to phase D.

Conversion Equations

The displayed count is given by fc x T_B where fc is the equivalent count frequency (204.8KHz) and T_B is the length of the de-integrate phase (phase B).

$$T_B = TA \times \frac{Vin}{Vref} \quad \text{where } TA = \text{Integrate period (80msec)}, \; Vref = \text{Reference voltage (1.6384 volts)}$$

$$\text{Thus displayed count} = 204.8 \times 10^{3} \times 80 \times 10^{-3} \times \frac{Vin}{1.6384} = \frac{16384}{1.6384}$$

$$= 10{,}000 \times Vin \quad \text{or} \quad 100\mu\text{Volts per count.}$$

On high sensitivity ranges, the buffer is given a gain of 10 during Phase A resulting in a displayed count of 100,000 x Vin or 10µV/count.

N.B. On the 1504 the overange point for AC voltage is set at 32,768 counts instead of 16,384 for the 1503 and 1503-HA. This is achieved by omitting diode D18.

4.4 Count/Display Module

The liquid crystal display, counter circuit and crystal oscillator are assembled as a module which is mounted at right angles to the main PCB. Connections to the module (M1) are via a 16 way right-angled strip connector plus several colour coded wires.

M1 has two basic modes of operation, as a prescaled unit counter, or as a prescaled frequency meter.

The module is switched into unit counter mode by taking control line S2 high. This mode is used for conventional multimeter operation whereby the number of input pulses accumulated during the A to D converter de-integrate period is stored and displayed by means of the hold and reset inputs.

Frequency Meter Operation

With S2 taken low, the module becomes a self-contained frequency meter with an internally defined 80msec gate period and an input prescale division of 8. This results in a resolution of 1 digit equals 0.1KHz.

The changeover from multimeter to frequency meter mode is activated by the frequency input socket SK1. Fitting a 3.5mm jack plug into this socket releases the line FE (Frequency Enable) causing pin 6 of IC7 to go high which causes pins 9 and 12 to go low. This takes M1 control line S2 low and disconnects M1 count input from the A/D converter clock. FE also disables the A/D converter by placing it into permanent autozero mode via D26 and D31.

The frequency input is applied from SK1 via protection components C35, R82, D38, D39. The count input of M1 goes to a centre biased CMOS inverting amplifier whose output feeds an edge triggered bistable. Since the input is centre-biased, it will tend to be noise triggered with no input signal and therefore show a random reading. Also, since there is no Schmitt trigger or pulse shaping circuit, slow rising edges can lead to multiple triggering giving unstable or inaccurate readings. For this reason, signals with a rise time below 0.25 volts per µsecond must be converted to a pulse waveform before being measured. In practice, this tends to means that sine wave signals below 50KHz cannot be measured directly.

The accuracy of the frequency meter is defined by a crystal oscillator and no re-calibration should normally be necessary. If it is desired to adjust the crystal frequency, however, this can be achieved via the miniature trimmer capacitor mounted just below the crystal.

Other connections to the module

In addition to those already mentioned, other connections are made to the module. D1, D2 and D3 form a blanking input for the LSD which is used in overrange indication. The decimal points and display legends on the LCD are driven by CMOS gates on the main PCB. The 50Hz backplane signal and the 6.5536MHz crystal signal are both taken to the main PCB.

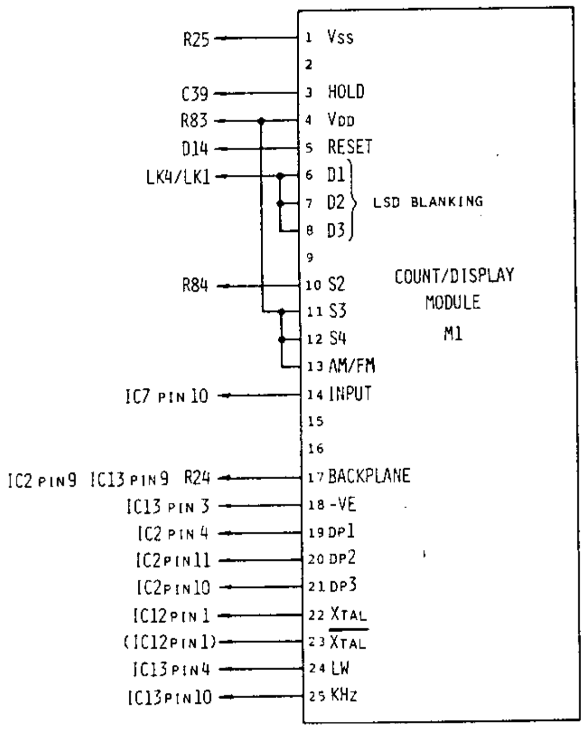
5. CIRCUIT DIAGRAMS

The circuit diagrams are marked up with both a component reference number and a value in the case of resistors and capacitors, or a type number in the case of ICs. Unless otherwise marked, all NPN transistors are type ZTX239, all PNP transistors are type ZTX214, and all diodes are type 1N4148.

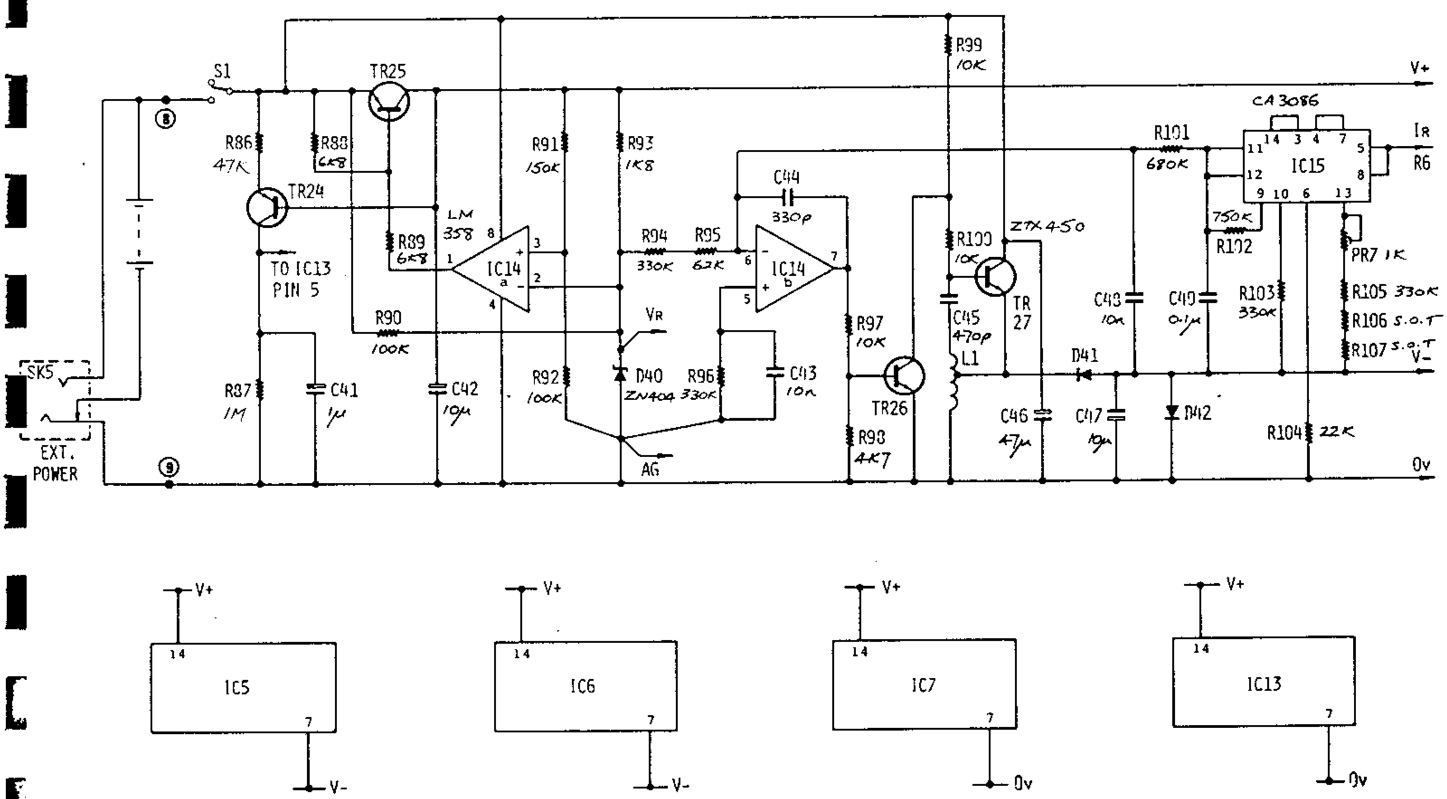
Fuller information on each component with a reference number is given in the electrical parts lists in section 8.

The circuit diagrams for the 1503 and 1503-HA multimeters are the same, the only differences are the tolerance and stability of certain components.

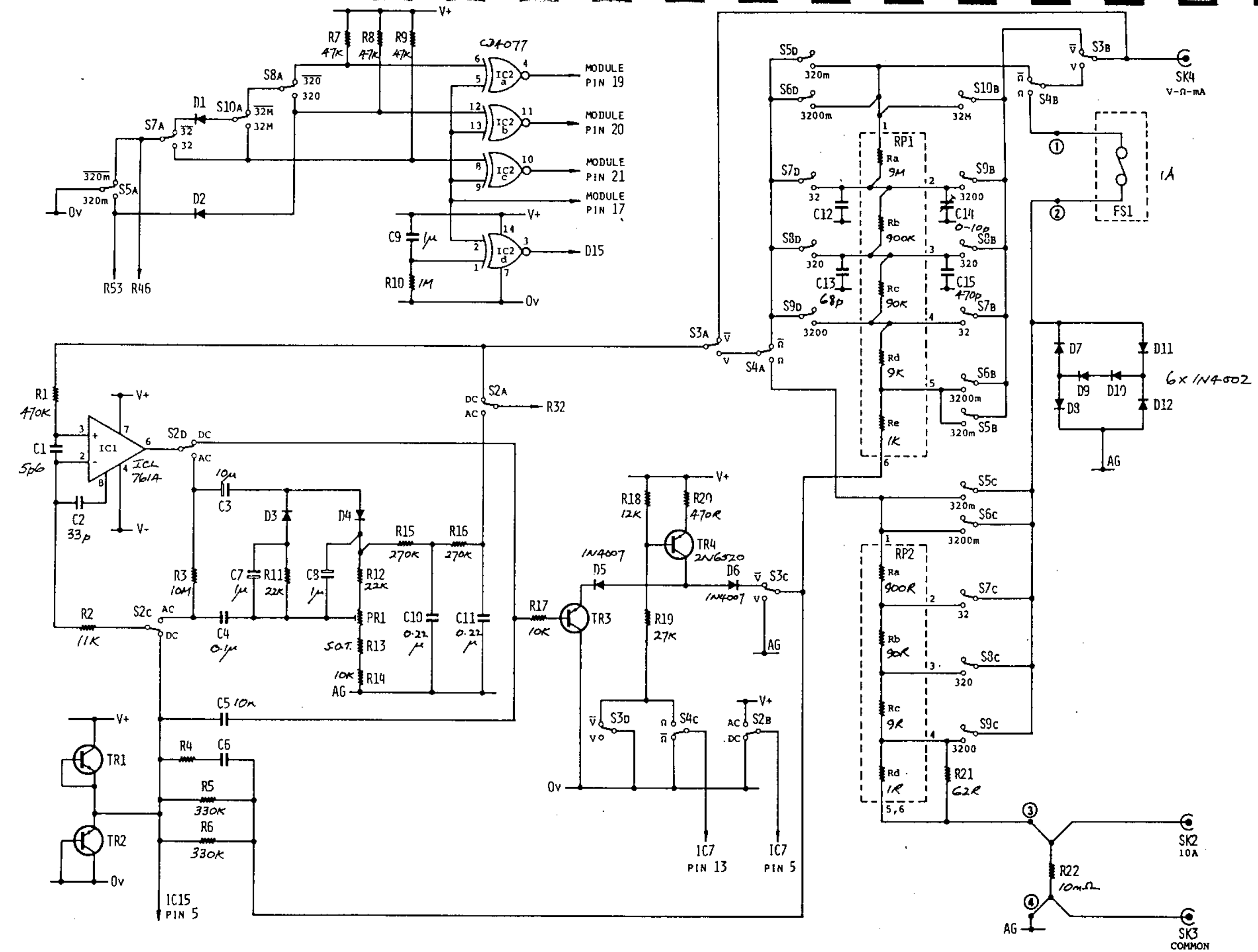
The circuit diagrams for the 1504 differ only in respect of the signal conditioning circuitry, the modified schematic for which appears at the end of this section.



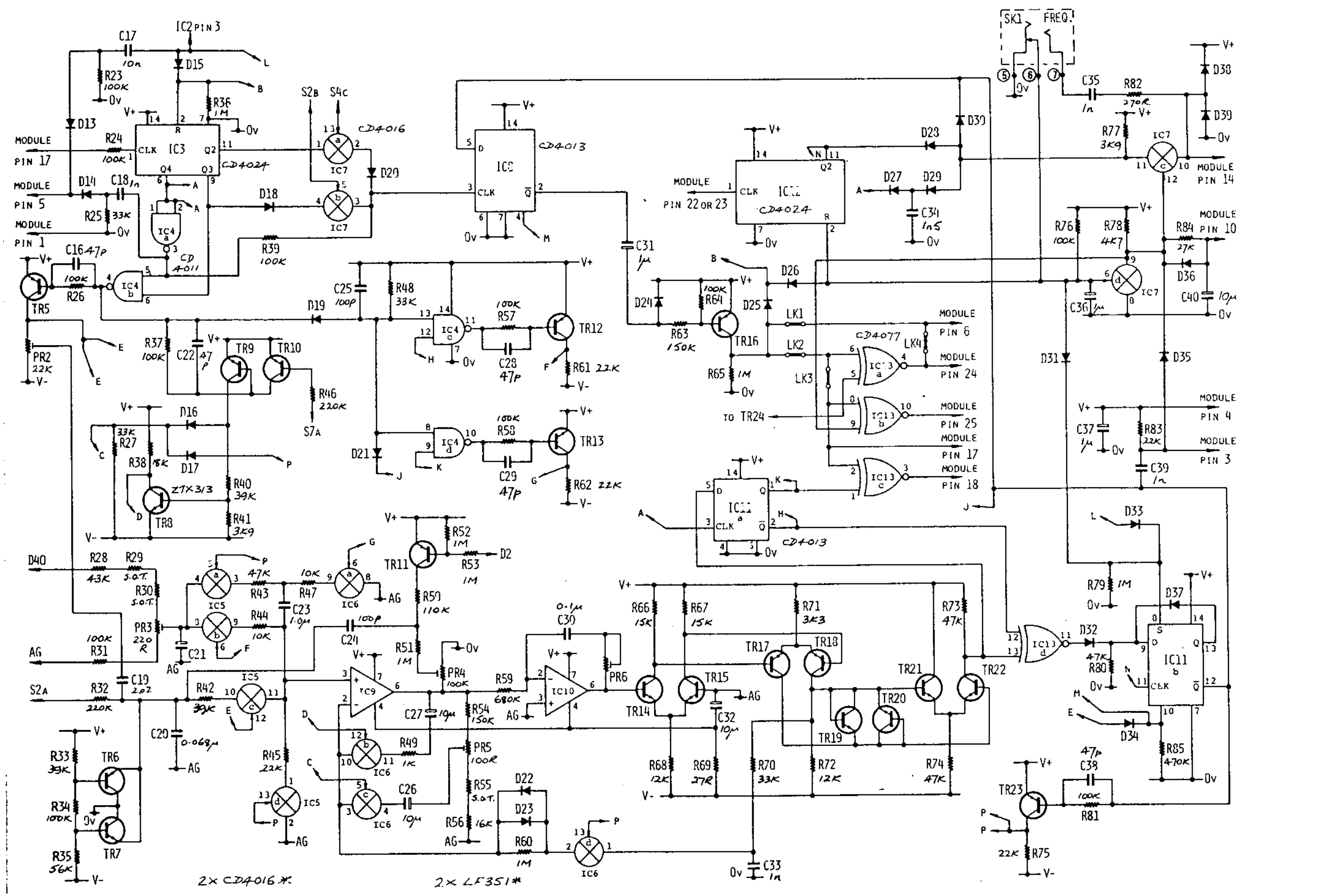
1503 MULTIMETER - COUNT/DISPLAY MODULE



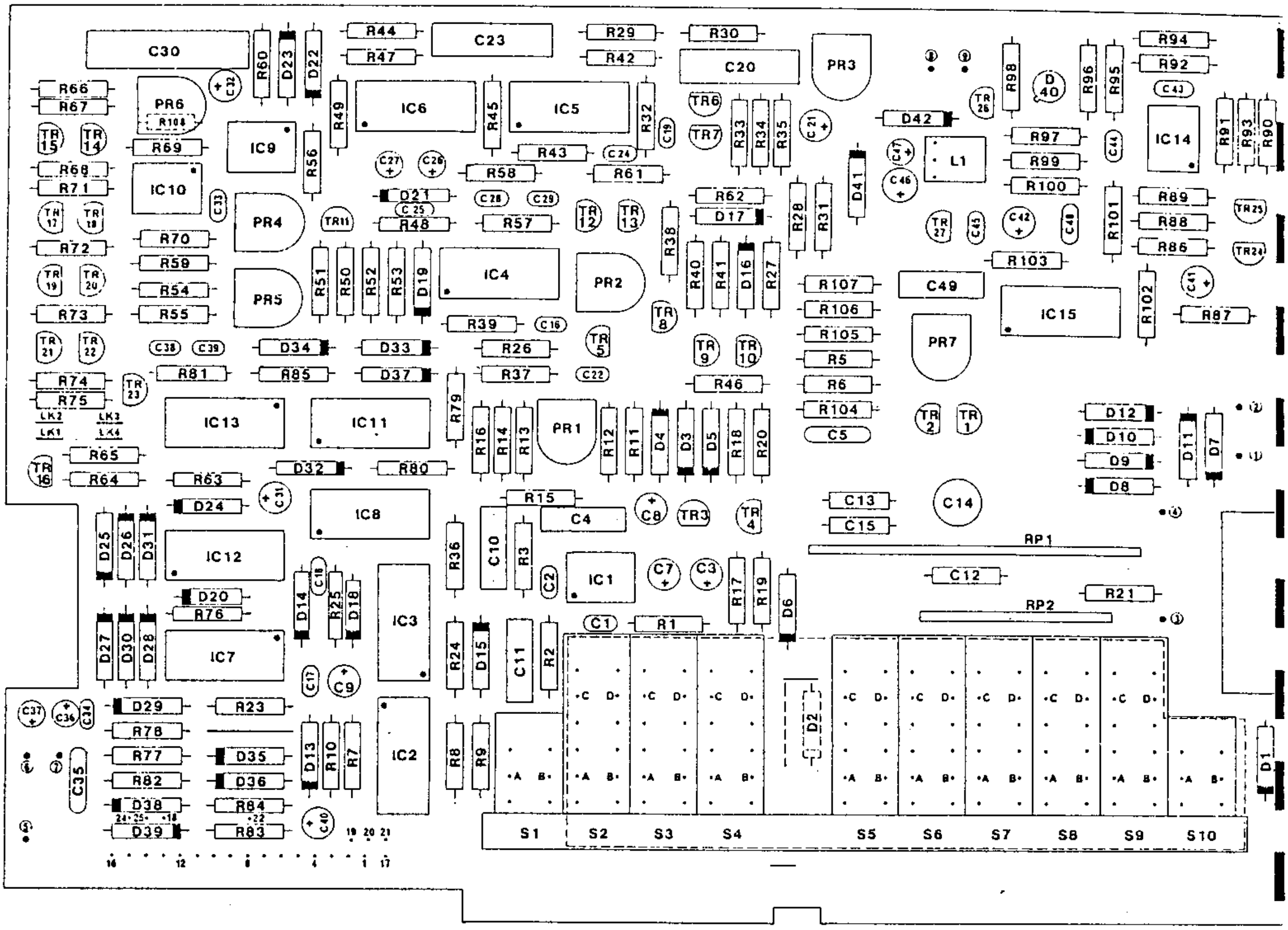
1503 MULTIMETER - POWER SUPPLY & REFERENCE GENERATORS



1503 MULTIMETER - SIGNAL CONDITIONING CIRCUITRY

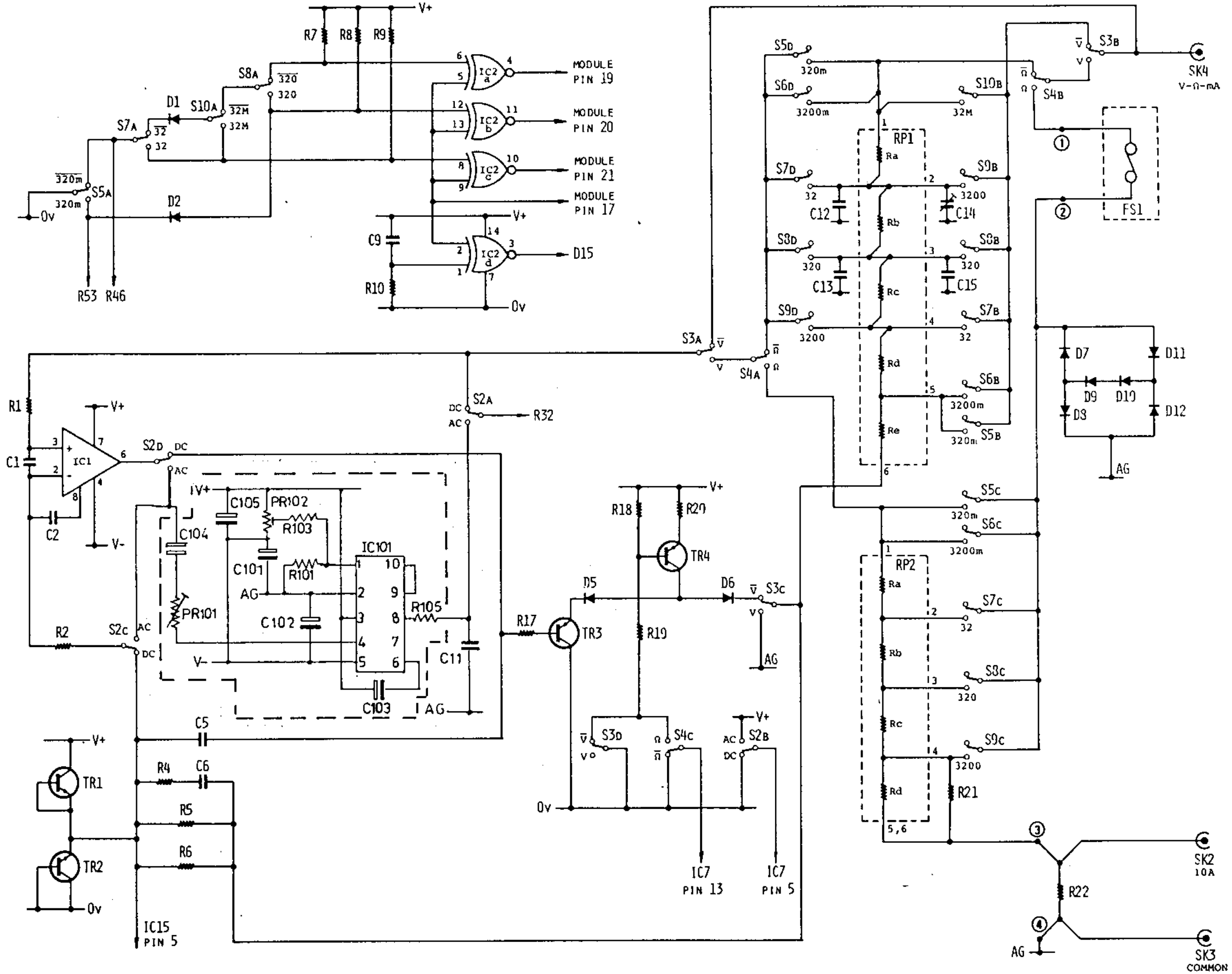


1503 MULTIMETER - A-D CONVERTER



1503 MULTIMETER - PCB COMPONENT LAYOUT

6. COMPONENT LAYOUT



1504 MULTIMETER INPUT CONDITIONING CIRCUITRY

7. MAINTENANCE

The Thurlby 1503 is a high stability instrument which, under normal operating conditions, will maintain its specified accuracy over a period of at least one year.

Following that period of time, persons using the 1503 in applications where maintenance of specified accuracy is of critical importance should arrange to have the calibration checked.

The calibration should also be checked immediately following the instrument being subjected to any serious abnormality in operation conditions, e.g:-

Severe impact.
Severe prolonged vibration.
Exposure to extremes of temperature.
Exposure to moisture or to corrosive gases.
Electrical overloads in excess of those given in section 3.2 of the Instruction Manual.

7.1 Dismantling for Access

The instrument is dismantled by removing the four screws from its feet, and then lifting off the top cover.

The PCB is mounted between two metal screens. Holes in the upper screen enable re-calibration without further dismantling. If access to the PCB for repair work is needed, slide off the centre moulding that mounts the handle, remove the top screen and the four tapped spacers beneath it. This allows the PCB to be lifted out along with the front panel. Take care not to lose the three fibre washers and one star washer on the PCB locating bolts.

7.2 Calibration Check

The following section lists procedures for verifying the conformance to specification of a 1503 multimeter by applying accurately known values of voltage, current and resistance to it and observing the display to within specific limits. These limits only apply where the value of the source is known to within ±1 digit. Where this is not so, the limits must be widened by the error level of the source.

Precise verification of calibration will require sources known to an accuracy at least 5 times better than the meter specification for that function and range.

The procedure should be performed at a temperature of 22°C±3°C in dry conditions.

Switch on the instrument and leave for 15 minutes before commencing the check.

DC Voltage

Range	DC Input	1503/4 Display Limits	1503-HA Display Limits
320mV	Short cct.	-.04 to .04	-.04 to .04
320mV	+200.00mV	199.76 to 200.24	199.80 to 200.20
320mV	-200.00mV	-199.76 to -200.24	-199.80 to 200.2[illegible]
3200mV	2000.0mV	1998.9 to 2001.1	1999.2 to 2000.[illegible]
32V	20.000V	19.81 to 20.019	19.992 to 20.008
320V	200.00V	199.79 to 200.21	199.88 to 200.12
1200V	1000.0V	998.9 to 1001.1	999.3 to 1000.7

AC Voltage *Note 1

Range	AC Input	Frequency	1503/1503-HA Display Limits	1504 Display Limits
1600mV	1000.0mV	50Hz	997.5 to 1002.5	995.4 to 1004.6
1600mV	1000.0mV	400Hz	997.0 to 1003.0	994.4 to 1005.6
1600mV	1000.0mV	5kHz	996.0 to 1004.0	993.4 to 1006.6
1600mV	1000.0mV	10kHz	993.5 to 1006.5	992.4 to 1007.6
16V	10.000V	50Hz	9.970 to 10.030	9.949 to 10.051
16V	10.000V	5kHz	9.740 to 10.260	9.740 to 10.260
160V	100.00V	50Hz	99.70 to 100.30	99.49 to 100.51
160V	100.00V	5kHz	94.90 to 105.10	94.90 to 105.10
750V	500.0V	50Hz	498.2 to 501.8	496.7 to 503.3

DC Current

Range	Input	1503/4 Display Limits	1503-HA Display Limits
80μA	80.00μA	79.80 to 80.20	79.84 to 80.16
800μA	800.0μA	798.7 to 801.3	799.0 to 801.0
8mA	8.000mA	7.987 to 8.013	7.990 to 8.010
80mA	80.00ma	79.87 to 80.13	79.90 to 80.10
800mA	800.0mA	797.5 to 802.5	798.0 to 802.0
10A	5.00A	4.88 to 5.12	4.90 to 5.10

Resistance

Range	Input	1503/4 Display Limits	1503-HA Display Limits
320Ω	200.00Ω * note 2	199.55 to 200.45	199.55 to 200.4[illegible]
3200Ω	2000.0Ω	1997.9 to 2002.1	1997.9 yo 2002.1
32kΩ	20.000kΩ	19.979 to 20.021	19.981 to 20.01[illegible]
320kΩ	200.00kΩ	199.79 to 200.21	199.81 to 200.1[illegible]
3200kΩ	2000.0kΩ	1995.9 to 200.41	1996.9 to 2003.1
32MΩ	20.000MΩ	19.780 to 20.220	19.800 to 20.200

If the instrument fails any of the above checks, re-calibration should be carried out as detailed over.

Note 1 - The source must be sinusoidal with <0.05% distortion.
Note 2 - Resistance of any connecting leads must be subtracted.

7.3 Calibration Procedure

This procedure may be used to re-calibrate an instrument which is outside specification, or to optimise one or more adjustments to place the calibration of a range more centrally within its limits.

Calibration must be carried out using precision sources whose value is known to an accuracy at least 5 times better than the 1503 accuracy specification for that range.

Calibration temperature should be 22°C ± 3°C.

The 1503 has only eight adjustments, the calibration of most ranges being set by precision fixed components. The function of each adjustment is described below:-

A1 - 1504 AC zero: adjust zero of true rms converter (1504 only)

A2 - 320mV zero: adjusts zero reading for the 320mV DC range.

A3 - 320mV set scale: adjusts scale accuracy for the 320mV DC and 320Ω and 80μA ranges.

A4 - 3200mV set scale: adjusts scale accuracy for the 3200mV DC range and all other voltage, current and resistance ranges including those affected by A3.

* A5 - Z in adjust: adjusts A/D converter input impedance. Should not normally require re-setting.

A6 - AC set scale: adjusts scale accuracy for all AC voltage and current ranges.

A7 - HF adjust: adjusts higher frequency scale accuracy for 16V and 160V AC ranges.

A8 - Ωs set scale: adjusts scale accuracy for all resistance ranges.

Take off the plastic top cover by removing the four screws through the feet. Switch the unit on and leave for 15 mins. before commencing calibration. All adjustments should be made with the aluminium top screen in place using a trimmer tool with a non-metallic shaft.

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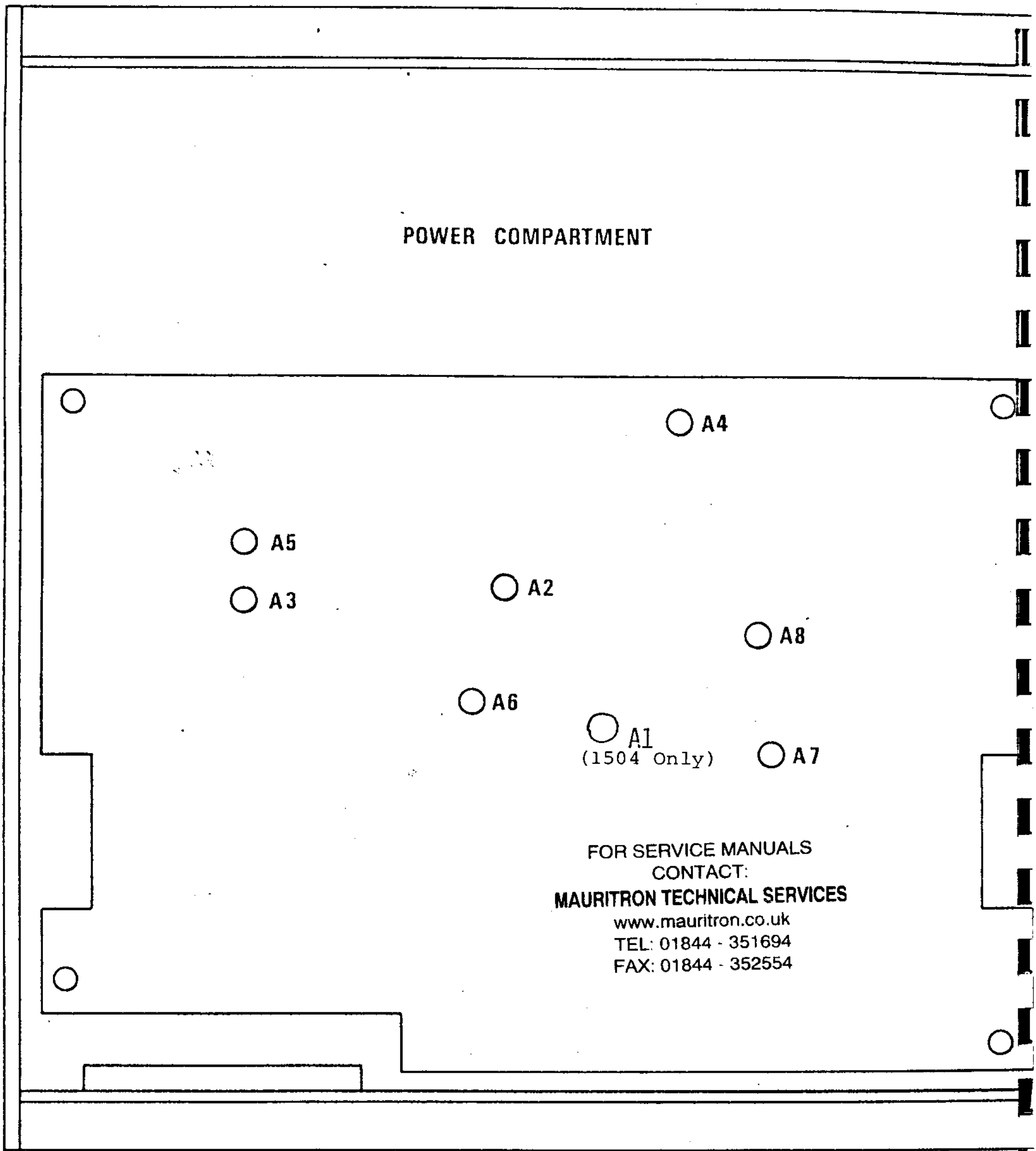
* (A5) For 1503-HA, adjusts accuracy of 32V range).


POWER COMPARTMENT
A4
A5
A3
A2
A8
A6
A1
(1504 Only)
A7

Select Function/Range		Apply	Adjust	For display reading	Tolerance
1.	DCV 320mV	short circuit	A2	.00	Exact
2.	DC 3200mV	2500.0mV	A4	2500.0	Exact
3.	DC 32V	25.000V	A5	25.000*	±1 digit*
4.	DCV 320mV	250.00mV	A3	250.00	±1 digit
5.	ACV 3200mV (1504 only)	short circuit	A1	0.0	±1 digit
6.	ACV 1600mV	1000.0mV 50Hz	A6	1000.0	±1 digit
7.	ACV 16V	10.000V 6kHz	A7	10.000	±30 digits
8.	Ω 32kΩ	20.000kΩ	A8	20.000	Exact

*Applies to 1503-HA only, should not require re-setting on standard 1503.

Following this procedure, the instrument should be subjected to the calibration check listed previously.

7.4 Fault Finding Procedure

General: The following notes refer to the circuit diagrams (section 5) and component layout (section 6). Values for each component reference can be obtained from the parts lists (section 8). Theory of operation is explained in section 4.

Verification of Fault:

1. Is the apparent fault merely an aspect of operation not understood by the user? Refer to Operating Instructions.
2. If batteries are being used, is the battery voltage sufficient? Check by using external AC adaptor.
3. Could the instrument have become excessively damp? If in doubt, open case and dry thoroughly with warm air.
4. If the unit is operating correctly, apart from current ranges, has the back panel fuse been checked?

Important Note: The 1503 multimeter incorporates highly complex electronic circuitry. Fault finding or repair should not be attempted unless the engineer is certain of his competence to do so.

Inexpert repair work performed on units under guarantee may void the guarantee.

Fault Area Analysis:

	Did the fault occur . . .	Most Likely Fault Area:-
1.	Following high voltage overload on the resistance function?	TR4, RP1, C14, damage to PCB or switch bank.
2.	Following high voltage overload on the voltage function?	RP1, damage to PCB or switch bank.
3.	Following overload on current function?	FS1, R22.
4.	Following overload on current function from an inductive circuit?	FS1, IC2, IC7, damage to PCB or switch bank.
	Is the fault present . . .	
1.	On all functions including frequency?	Power supply or Count/Display Module.
2.	On all functions except frequency?	A/D Converter.
3.	On AC functions only?	AC-DC converter (IC1).
4.	On Resistance function only?	Ωs converter (IC1, TR3, TR4) or Ωs current source (IC15).
5.	On Current functions only?	Fuse FS1, Diodes D7-D12. Resistor pack RP2, shunt R22.
6.	On higher voltage ranges only?	Resistor pack RP1.

8. 1503 MULTIMETER — Electrical Parts List

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

R1	470K
R2	10K
R3	10M
R4	Not fitted
R5	330K 1% 25ppm M.F.
R6	330K 1% 25ppm M.F.
R7	47K
R8	47K
R9	47K
R10	1M
R11	22K
R12	22K 1% 50ppm M.F.
R13	Select-on-test
R14	10K 1% 50ppm M.F.
R15	270K
R16	270K
R17	10K
R18	12K 2% C.F.
R19	27K 2% C.F.
R20	470R
R21	62R 2% C.F.
R22	10mΩ laminated
R23	100K
R24	100K
R25	33K
R26	100K
R27	33K
R28	43K 1% 50ppm M.F.
R29	Select-on-test
R30	Select-on-test
R31	100K 1% 50ppm M.F.
R32	220K
R33	39K
R34	100K
R35	56K
R36	1M
R37	100K
R38	18K
R39	100K
R40	39K
R41	3K9
R42	39K
R43	47K
R44	56K
R45	22K
R46	220K
R47	10K
R48	33K
R49	1K
R50	110K
R51	1M
R52	1M
R53	1M
R54	150K 1% 25ppm M.F.
R55	Select-on-test
R56	16K 1% 25ppm M.F.
R57	100K
R58	100K
R59	680K
R60	1M
R61	22K
R62	22K
R63	150K
R64	100K
R65	1M
R66	15K
R67	15K
R68	12K
R69	27R
R70	33K
R71	3K3
R72	12K
R73	47K
R74	47K
R75	22K
R76	100K
R77	3K9
R78	4K7
R79	1M
R80	47K
R81	100K
R82	270R
R83	22K
R84	27K
R85	470K
R86	47K
R87	1M
R88	6K8
R89	6K8
R90	100K
R91	150K 2% C.F.
R92	100K 2% C.F.
R93	1K8
R94	330K 1% 25ppm M.F.
R95	62K 2% M.F.
R96	330K
R97	10K
R98	4K7
R99	10K
R100	10K
R101	680K 2% C.F.
R102	750K
R103	330K 1% 25ppm M.F.
R104	22K
R105	330K 1% 25ppm M.F.
R106	Select-on-test
R107	Select-on-test
R108	47R

/contd...

1503 Multimeter

C1	5p6 Ceramic
C2	33pF Ceramic
C3	10µf 16V Electrolytic
C4	0.1µF Polyester
C5	10nF Ceramic 5mm pitch
C6	Not fitted
C7	1µF 63V Electrolytic
C8	1µF 63V Electrolytic
C9	1µF 63V Electrolytic
C10	0.22µF Polyester
C11	0.22µF Polyester
C12	Not fitted
C13	68pF 500V Ceramic
C14	0-10pF Trimmer
C15	470pF 400V Polystyrene
C16	47pF Ceramic
C17	10nF Ceramic
C18	1nF Ceramic
C19	2p2 Ceramic
C20	0.068µF Polycarbonate
C21	Not fitted
C22	47pF Ceramic
C23	1.0µF Polyester
C24	100pF Polystyrene
C25	100pF Ceramic
C26	10µF 16V Tantalum
C27	10µF 16V Tantalum
C28	47pF Ceramic
C29	47pF Ceramic
C30	0.1µF Polypropylene
C31	1µF 63V Electrolytic
C32	10µF 16V Electrolytic
C33	1nF Ceramic
C34	1n5 5% Ceramic
C35	1nF 500V Ceramic
C36	1µF 63V Electrolytic
C37	1µF 63V Electrolytic
C38	47pF Ceramic
C39	1nF Ceramic
C40	10µF 16V Electrolytic
C41	1µF 63V Electrolytic
C42	10µF 16V Electrolytic
C43	10nF Ceramic
C44	330pF Ceramic
C45	470pF Ceramic
C46	47µF 16V Electrolytic
C47	10µF 16V Tantalum
C48	10nF Ceramic
C49	0.1µF Polyester
PR1	100R 10mm Horiz. Carbon Preset
PR2	22K 10mm Horiz. Carbon Preset
PR3	220R 10mm Horiz. Cermet Preset
PR4	100K 10mm Horiz. Carbon Preset
PR5	100R 10mm Horiz. Cermet Preset
PR6	Not fitted
PR7	1K 10mm Horiz. Cermet Preset

TR1	ZTX239
TR2	ZTX239
TR3	ZTX214
TR4	2N6520
TR5	ZTX214
TR6	ZTX214
TR7	ZTX239
TR8	ZTX313
TR9	ZTX214
TR10	ZTX214
TR11	ZTX214
TR12	ZTX214
TR13	ZTX214
TR14	ZTX239
TR15	ZTX239
TR16	ZTX214
TR17	ZTX214
TR18	ZTX214
TR19	ZTX239
TR20	ZTX239
TR21	ZTX239
TR22	ZTX239
TR23	ZTX214
TR24	ZTX214
TR25	ZTX214
TR26	ZTX239
TR27	ZTX450
IC1	ICL7614
IC2	CD4077
IC3	CD4024
IC4	CD4011
IC5	CD4016 Selected
IC6	CD4016 Selected
IC7	CD4016
IC8	CD4013
IC9	LF351 Selected
IC10	LF351 Selected
IC11	CD4013
IC12	CD4024
IC13	CD4077
IC14	LM358
IC15	CA3086

/Contd...

1503 Multimeter

D1	1S44
D2	1S44
D3	1S44
D4	1S44
D5	1N4007
D6	1N4007
D7	1N4002
D8	1N4002
D9	1N4002
D10	1N4002
D11	1N4002
D12	1N4002
D13	1S44
D14	1S44
D15	1S44
D16	1S44
D17	1S44
D18	1S44
D19	1S44
D20	1S44
D21	1S44
D22	1S44
D23	1S44
D24	1S44
D25	1S44
D26	1S44
D27	1S44
D28	1S44
D29	1S44
D30	1S44
D31	1S44
D32	1S44
D33	1S44
D34	1S44
D35	1S44
D36	1S44
D37	1S44
D38	1S44
D39	1S44
* D40	ZN404 Selected
D41	1S44
D42	1S44
LK1	Fitted
LK2	Not fitted
LK3	Fitted
LK4	Not fitted
* RP1	Caddock 1776-241
* RP2	Caddock 1787-412

* Items marked thus differ on the 1503-HA where improved tolerance/ stability versions are used.

Additional Components 1504 Multimeter

R101	220R
R103	820K
R105	330K
C101	2μ2 63V Electrolytic
C102	10μ 10V Tantalum
C103	2μ2 63V Electrolytic
C104	22μ 10V Non-Polarized
C105	22μ 16V Electrolytic
PR101	220R 10mm Horiz. Cermet Preset
PR102	100K 10mm Horiz. Carbon Preset
IC101	AD536A