301A
MILLIVOLTMETER

TECHNICAL MANUAL

RACAL

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MILLIVOLTMETER TYPE 301A

CONTENTS

TECHNICAL SPECIFICATION

Frequency Range

100Hz to 900MHz:
100Hz to 100kHz using LF input:
50kHz to 900MHz using high impedance probe.

AC Range

300µV to 3V in eight ranges:-
.001, .003, .01, .03, 0.1, 0.3, 1,
3V f.s.d.

AC Accuracy

Range	Free Probe with nose cap fitted	Probe mounted 50 or 75Ω, using correction curves	Probe Mounted LF
1mV Range			
100Hz - 100kHz	-	-	±10% f.s.d.
100Hz - 200MHz	-	±10% f.s.d.	-
50kHz - 200MHz	±10% f.s.d.	-	-
200MHz - 900MHz	±15% f.s.d.	±15% f.s.d.	-
3mV Range and above			
100Hz - 100kHz	-	-	±5% f.s.d.
100Hz - 200MHz	-	±5% f.s.d.	-
50kHz - 200MHz	±5% f.s.d.	-	-
200MHz - 600MHz	±10% f.s.d.	±10% f.s.d.	-
600MHz - 900MHz	±15% f.s.d.	±10% f.s.d.	-

Probe a.c. Input Impedance

At 100kHz - 100kΩ and 3pF
At 10MHz - 50kΩ and 3pF
At 200MHz - 3kΩ and 3pF

These are approximate figures at an input level of 0.1V r.m.s.

Coaxial Input

50 and 75Ω input impedances are available by using an adaptor unit on the front panel. The connectors used are BNC type.

VSWR	V.S.W.R. not greater than 1.5 on both 50Ω and 75Ω terminations, up to 900 MHz.
DC Ranges	100μV to 10V in ten ranges:- .0003, .001, .003, .01, .03, 0.1, 0.3, 1, 3, 10V f.s.d.
DC Accuracy	.001V range and above - better than ±5% f.s.d. .0003V range - better than ±10% f.s.d.
DC Input Impedance	Exceeds 5MΩ.
Stability	For a 10% mains variation, the change in meter reading is not greater than ±1.1/2% f.s.d. on all ranges.
Valves	1 off ECC83, EF86 12AT7, 150C4, 6X4
Ambient Temperature	The instrument is suitable for use in ambient temperatures from 0°C to +40°C.
Power Supplies	50Hz a.c. mains. Mains tapping panel for 110, 125, 210, 230 and 250V. Consumption approximately 20 watts.
Dimensions	8" wide by 11.1/2" high by 14" deep, over projections (21 by 29 by 36cm).
Finish	Light grey panels, blue grey stoved textured vinyl.
Weight	19 lb (8.75kg).

SECTION 1

OPERATION

INTRODUCTION

1.1 The Millivoltmeter Type 301A is a lightweight, mains operated, easily transportable instrument for measuring voltages from 300μV to 3V in the frequency range 100Hz to 900MHz, and 100μV to 10V d.c.

The d.c. inputs are amplified by a chopper type d.c. amplifier and applied to the meter circuit. The a.c. inputs are rectified in a probe, which, for low frequency measurements, may be plugged into a holder on the front panel to introduce additional d.c. blocking capacitance; alternative positions on the holder provide 75 or 50Ω coaxial inputs terminated in matched loads. The rectified output is displayed on a 4.1/2" scale meter.

INITIAL ADJUSTMENTS

1.2 The instrument leaves the Works with the voltage tapping panel set for operation from 230V a.c. mains. If the supply voltage differs from this, alter the voltage selector accordingly. (The voltage selector is at the back of the instrument). For operation from 110 - 130V mains, change the fuse for one of 2A rating. (The fuseholder is adjacent to the voltage selector.)

OPERATION

General

1.3 All the controls and inputs are located on the front panel of the instrument. When not in use, the probe may be stowed by feeding the cable and probe back through the aperture in the front panel. Stowage for the probe cap and also four bollards for stowing the mains lead are provided on the rear panel. A tilt stand is provided under the bottom cover. This stand is erected by lifting the instrument and pulling the stand forward on its hinges.

D.C. MEASUREMENT

1.4 Set the a.c. range selector (marked AC) to DC and the d.c. range selector to the appropriate value of full scale deflection. Connect the input to the DC INPUT socket. Adjust for minimum residual reading by using the DC BALANCE control. This control must be turned slowly to avoid an overshoot effect during setting.

AC Measurement

WARNING: To avoid damage to the probe diodes, observe the following precautions:-

(a) AC input level - Do not exceed 3V r.m.s.

(b) Superimposed d.c. - When using the 50 or 75Ω input socket, the applied a.c. signal must have zero d.c. component. When using the probe with the nose cap fitted, or when the probe is inserted in the LF adaptor, do not exceed ±250V d.c.

(c) Do not use the probe free without the nose cap.

1.5 Set the d.c. range selector (marked DC) to AC and the a.c. range selector to the appropriate value of full scale deflection.

1.6 Inputs in the frequency range 50kHz to 900MHz may be connected either directly to the projecting tips of the probe cap, or to the 50 or 75Ω adaptors by plugging the probe into the appropriate position in the adaptor unit. (Remove the probe nose cap before plugging in.) At frequencies above 300MHz, it is recommended that either the 50Ω or 75Ω adaptors be used in conjunction with the calibration curves supplied on the side of the instrument. The appropriate correction factor may be interpolated for signal levels up to 300mV, resulting in an overall accuracy of measurement of ±10% f.s.d.

1.7 For inputs in the frequency range 100Hz - 50kHz the probe is normally used in the LF position on the adaptor, but the 50Ω or 75Ω terminations may be used provided that there is no d.c. component present on the signal.

NOTE

If a film of moisture is allowed to form on the silicon fibreglass insulatting disc which carries the LF probe contact in the RF block, it may be impossible to obtain a low level AC BALANCE when using the LF connection. If this occurs, normal conditions may be quickly restored by placing the instrument in a warm dry atmosphere, or alternatively directing a current of warm dry air at the insulating disc for a few minutes. The low impedance 50Ω and 75Ω inputs are NOT affected by similar conditions of humidity.

1.8 On the 30mV and higher ranges the AC BALANCE control does not need adjustment. On the 3mV and 1mV ranges, adjust the AC BALANCE control for minimum scale reading before applying the input. On the 1mV range the minimum residual reading should be at least 3/8" below the lowest calibration mark on the scale.

1.9 Because of the high sensitivity and extremely wide bandwidth of the instrument, strict precautions must be observed in making the connections between the probe or probe adaptors and the equipment under test when working at low a.c. input levels. The adaptor positions are particularly sensitive to spurious mains frequency voltages developed along the earth line.

1.10 Higher frequency components may also be picked up on the probe circuit and produce an excessive residual reading on the meter, particularly on the 1mV a.c. range. The recommended procedure is to plug the probe into the adaptor socket, with all input connections removed, and adjust the balance control for an acceptably low residual reading. When this has been done, connect the input to the probe or adaptor as required, reduce the source voltage to zero, and recheck the residual reading. In adverse locations (e.g. where the stray radiation level is high), local screening for the probe or complete isolation of the equipment in a screened room may be found to be essential.

NOTES

1. When adjusting for minimum residual reading, turn the AC BALANCE control slowly to avoid overshooting the minimum.

2. The two locked adjustment screws on the RF adaptor block are factory preset for optimum VSWR, and require no adjustment in normal use.

SECTION 2

CIRCUIT DESCRIPTION

2.1 The Circuit Diagram is shown at Figure 1 and the Component List at Table 1. Figures 2 and 3 give the position of the major components, and Figure 4 is a graph showing approximate probe impedance/frequency characteristics.

2.2 50Ω and 75Ω terminations are available by plugging the high impedance probe into the appropriate adaptor SKTC or SKTB on the front panel. The a.c. input is rectified by the germanium diodes MR1 and MR2 in the probe, and the balanced d.c. output is fed via the attenuator and switch SA to the 50 Hz synchronous chopper CH1. The AC BALANCE control RV1 permits the residual reading on the 1mV and 3mV a.c. ranges to be partly balanced out by injecting a d.c. signal at the input to the attenuator.

2.3 The LF adaptor extends the frequency range at high input impedance from 50 kHz to 100 kHz by replacing the probe nose cap capacitor C2 by capacitor C1. The diode protection circuit MR8, MR9, MR10, MR11 limits the surge when d.c. is superimposed on the a.c. signal.

2.4 The d.c. input from socket SKTD is fed via the step attenuator and the DC switch SB to the synchronous chopper CH1 and thence to the amplifier on alternate half cycles. The potential divider circuit RV2 (DC BALANCE), R33, R34 and R36 provides a voltage developed across R36 to equalise for positive and negative inputs to the instrument.

2.5 The output from the chopper is amplified by a 4-stage 50 Hz amplifier. L1, C18 form a shunt resonant circuit tuned to 50 Hz, used only on the 1mV AC range. The gain of the amplifier is switched for each of the a.c. ranges by switching the negative feedback applied to valve pairs V1a, V1b, and V2, V3. Potentiometers RV11, RV21 and RV22 give a preset adjustment of the gain for the d.c. ranges.

2.6 The output of the cathode follower stage V3b is rectified by MR3, MR4 and MR6 and fed to the meter M1. On the a.c. ranges, the non-linearity of the probe diodes MR1 and MR2 is compensated by diodes MR5 and MR12 and the appropriate preset potentiometers shunting the meter circuit.

2.7 The power supply consists of a full wave rectifier V6 with R - C smoothing. Neon valve V5 provides a stabilised +150V supply, and rectifier MR7 provides a d.c. heater supply for V1 and V2.

SECTION 3

SERVICING

3.1 Valves, rectifiers, pilot lamp, fuse and synchronous chopper are the only servicing changes normally required. Positions of major components are shown in Figures 2 and 3.

3.2 The use of switch cleaning lubricant on the wafer switches in this instrument is not recommended.

Pilot Lamp

3.3 The pilot lamp (ILP1) is removed by unsoldering the black and red leads and removing the circular clip around the body of the lamp.

Valves and Rectifier

3.4 Rectifiers MR3, MR4, MR6, MR7, MR8, MR9, MR10 MR11, MR13 and valves V5 and V6 may be changed without affecting the calibration.

3.5 Changing V1, V2, V3, MR1, MR2, MR5 or MR12 may affect the calibration of the instrument. Details of the readjustments necessary are given below.

A.C. Calibration

3.6 The Millivoltmeter should be calibrated against a 1% instrument at a frequency of approximately 100kHz. The calibration for each range is adjusted by two potentiometers, details of which are given in the table below. One potentiometer determines the gain at 1/3 f.s.d. and the other determines the indication at f.s.d. The adjustment at 1/3 f.s.d. must be done first in each case.

Range	Adjust at 1/3 f.s.d.	Adjust at f.s.d.
1mV	RV10	RV17
3mV	RV9	RV20
10mV	RV8	RV16
30mV	RV7	RV15
100mV	RV6	RV14
300mV	RV5	RV13
1V	RV4	RV19
3V	RV3	RV12

D.C. Calibration

3.7 Inputs of 300μV and 1mV, and 3mV are required for calibrating the d.c. ranges. Set the DC switch to 300μV and connect to a 300μV source. Adjust RV11 until the meter reads 300μV.

3.8 Set the DC switch to 1mV and connect the input to a 1mV source. Adjust RV21 until the meter indicates 1mV.

3.9 Set the DC switch to 3mV and connect the input to a 3mV source. Adjust RV22 until the meter indicates 3mV.

3.10 No further calibration is required for the remaining (higher) ranges.

NOTE- Set the DC Balance potentiometer RV2 so that the same deflection is obtained for equal positive and negative inputs in each case.

Synchronous Chopper

3.11 Remove the upper dust cover and the chopper retaining bracket, and take out the plug from the top of the chopper. The chopper may then be removed.

Valve V1

3.12 V1 is located in the screened box behind the front panel. To gain access to it, remove the plug from the chopper, take out the three screws on each side of the screened box top cover, and then remove the top cover itself.

Probe diodes MR1, MR2

3.13 Exercise extreme care in soldering in new diodes. Use a heat shunt, apply the absolute minimum amount of heat necessary to ensure a satisfactory joint, and position them exactly as before. Re-setting of the VSWR adjustment screws may be necessary when diodes are replaced, and this requires the use of a slotted line.

TABLE 1

MILLIVOLTMETER TYPE 301A

COMPONENT LIST

Circuit Reference	Details			Type
	Resistance Ω	Tolerance ±%	Rating W	
Resistors				
R1	52	0.5	1/8	Plessey Metalux AFL/F AFL/F
R2	75	0.5	1/8	Plessey Metalux AFL
R3,4.	470	10	0.1	Erie 15
R5,6.	22M	10	1/4	Dubilier BTT
R7	47k	10	1/4	RMA9 Erie
R8,9.	10k	10	1/4	RMA9 Erie
R10,11.	330k	5	1/2	C21 Welwyn
R12,13.	4.7M	5	1/4	C21 Welwyn
R14,15.	560k	5	1/4	C21 Welwyn
R16,17.	47k	5	1/4	C21 Welwyn
R18,19.	6.8k	5	1/4	C21 Welwyn
R20,21.	1.5k	5	1/4	C21 Welwyn
R22,23	680	5	1/4	C21 Welwyn
R24	4.6M	2	1/2	C21 Welwyn
R25	1.64M	2	1/4	C21 Welwyn
R26	494k	2	1/4	C21 Welwyn
R27	152k	2	1/4	C21 Welwyn
R28	47.5k	2	1/4	C21 Welwyn
R29	15k	2	1/4	C21 Welwyn
R30	4.75k	2	1/4	C21 Welwyn
R31	2.19k	2	1/4	C21 Welwyn
R32	10M	5	1/2	C22 Welwyn
R33	100k	10	1/4	RMA9 Erie
R34	1k	10	1/4	RMA9 Erie

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COMPONENT LIST

Circuit Reference	Details			Type
	Resistance Ω	Tolerance ±%	Rating W	
Resistors				
R35	4.7M	5	1/4	C21 Welwyn
R36	10	10	1/4	RMA9 Erie
R37	2.2k	5	1/4	C21 Welwyn
R38	10	10	1/4	RMA9 Erie
R39	10M	10	1/4	RMA9 Erie
R40	47k	10	1/2	RMA8 Erie
R41	4.7M	5	1/4	C21 Welwyn
R42	1k	5	1/4	C21 Welwyn
R43	47k	10	1/4	RMA9 Erie
R44	1M	5	1/4	Electrosil CJ42
R45	Not used			
R46	Not used			
R47	10k	5	1/4	C21 Welwyn
R48	470k	10	0.1	Erie 15
R49	1M	5	1/2	C21 Welwyn
R50	470k	10	0.1	Erie 15
R51	470k	5	1/4	C21 Welwyn
R52	6.8k	5	1/4	C21 Welwyn
R53	470k	10		Erie 15
R54	2.2M	10	1/4	Erie RMA9
R55	470k	5	1/2	C22 Welwyn
R56	Not used			
R57	220k	5	1/2	C23 Welwyn
R58	1M	10	1/4	RMA9 Erie
R59	100	10	1/4	RMA9 Erie

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COMPONENT LIST

Circuit Reference	Details			Type
	Resistance Ω	Tolerance ±%	Rating W	
Resistors				
R60	2.2k	5	1/4	C21 Welwyn
R61	820k	5	1/2	C22 Welwyn
R62	2.2k	5	1/4	C21 Welwyn
R63	100k	5	1/4	C21 Welwyn
R64	470	10	1/4	Dubilier BTT
R65	18k	5	1/2W	C22 Welwyn
R66-R69	Not used			
R70	470k	10	1/4	Dubilier BTT
R71	68k	5	1/4	C21 Welwyn
R72	4.7k	10	1/2	RMA8 Erie
R73	6.8k	5	6	Welwyn W24
R74	1k	5	4	Welwyn W22
R75	10	5	10	Welwyn W24
R76	Not used			
R77	1M	10	1/4	Erie 16
R78,79.	150	10	0.1	Morganite XL
R80,81.	Not used			
R82	39k	5	1/4	C21 Welwyn
R83	5.9k	5	1/4	C21 Welwyn
R84	2.2M	10	1/4	RMA9 Erie
R85	2.7M	5	1/2	C22 Welwyn
R86	820k	5	1/2	C22 Welwyn
R87	470k	5	1/4	C21 Welwyn
R88	3.9k	5	1/4	Erie MOG60
R89	150k	5	1/4	C21 Welwyn

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COMPONENT LIST

Circuit Reference	Details			Type
	Resistance Ω	Tolerance ±%	Rating W	
Resistors				
R90	1.5k	5	1/4	Dubilier B.T.T.
R91	27k (A.O.C.)	10	1/4	Dubilier B.T.T.
Variable Resistors				
RV1	100k carbon, lin. preset	10	1/4	Davall 83
RV2	1k carbon, lin. preset	10	1/4	Davall 83
RV3-RV6, RV8, RV9	2.5k carbon, lin. preset	20	1/4	E.P. Plessey
RV7	2.5k w.w. linear	10	1	CLR/1106/11S Colvern
RV10	500 w.w. linear	10	1	CLR/1106/11S Colvern
RV11	1 M carbon, lin. preset	20	1/4	E.P. Plessey
RV12	250k carbon, lin. preset	20	1/4	E.P. Plessey
RV13	25k carbon, lin. preset.	20	1/4	E.P. Plessey
RV14	5k carbon, lin. preset.	20	1/4	E.P. Plessey
RV15,16,17.	2.5k carbon, lin. preset.	20	1/4	E.P. Plessey
RV18	Not used			
RV19	25k carbon, lin. preset.	20	1/4	E.P. Plessey

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COMPONENT LIST

Circuit Reference	Details			Type
	Resistance Ω	Tolerance ±%	Rating W	
Variable Resistors				
RV20	2.5k carbon, lin. preset	20	1/4	E.P. Plessey
RV21	250k carbon, lin. preset	20	1/4	E.P. Plessey
RV22	50k carbon, lin. preset	20	1/4	E.P. Plessey
Capacitors	Capacitance F			
C1	0.5μ	20	350	Hunts 301/1
C2	1000p	+50-20	350	K350081/831 Erie
C3,4	1000p feed through	-	500	K120051/700B Erie
C5-9	0.1μ	10	150	GEC PFT
C10	200μ	+100-20	6	Plessey 402/1/01284/001
C11	0.003μ	10	150	GEC PFT
C12	0.022μ	10	125	Mullard C296AA/A22K
C13	Not used			
C14	16+32+32μ	+50-20	350	Hunts KB268T
C15	0.005μ	25	350	Plessey 436/1/80310/010
C16	100μ	+100-20	6	Plessey 402/1/01207/001
C17	50μ	+100-20	6	Plessey CE1227/1
C18	0.2μ	5	150	GEC Polyester
C19	100μ	+100-20	6	Plessey 402/1/01207/001
C20	0.1μ	10	400	C296AC/A100K Mullard
C21,22,23	0.001μ	20	500	K350081-831 Erie
C24	0.1μ	20	250	Hunts 301/1
C25	0.1μ	25	150	Hunts 48A300
C26	50μ	+100-20	6	Plessey 402/1/01227/001
C27	0.01μ	20	350	Plessey 436/1/80320/010

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COMPONENT LIST

Circuit Reference	Details			Type
	Capacitance F	Tolerance ±%	Rating V	
C28,29	1.0μ	25	150	Hunts W48/A300
C30	50μ	+100-20	6	Plessey 402/1/01227/01
C31	50+50+8μ	+50-20	350	Plessey 402/1/08193/600
C32	1000+1000μ	+50-20	12	Plessey 402/1/17122/000
C33	1μF	20	350	Hunts 301/1
C34	Not used			
C35	200μ	+100-20	6	Plessey 402/1/01284/001
C36	Not used			
C37	5000μ	+50-20	12	Plessey 402/1/01203/001

	Details	
Valves		
V1		Telefunken ECC83
V2		Mullard EF86
V3		Mullard ECC88
V4	Not used	
V5		Mullard 150C4
V6		Brimar 6X4
Rectifiers		
MR1,2	Germanium diode	Transitron S5706
MR3,4	Germanium diode	Mullard OA.81
MR5	Silicon diode	Mullard OA.202
MR6	Germanium diode	Mullard OA.81
MR7	Rectifier	Westinghouse LT.61
MR8,9	Silicon diode	Int. Rectifiers SD/915
MR10,11	Zener diode	Mullard OAZ.206
MR12	Silicon diode	Mullard OA.202
MR13	Zener diode	Mullard OAZ.223

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COMPONENTS LIST

Circuit Reference	Details	Type
Inductors and Transformers		
L1	Inductor Assembly	Airmec 6658-290
T1	Transformer Assembly	Airmec 6658-225
Switches		
SA	Wafer 5 way 10 position	NSF/Airmec 6658-454
SB	Wafer 3 way 12 position	NSF/Airmec 6658-455
SC	Slide Switch DP	Carr Fastener 81/811
Plug and Sockets		
LKA	Voltage Selector	Carr Fastener 81/1185 Bk
SKTA, SKTC	Socket Coaxial	BNC
SKTB	Socket Coaxial fixed 75Ω	BNC
SKTD	Socket Coaxial fixed 50Ω	Greenpar GE 35062
	Plug free, 50Ω matched	Greenpar 35070C/12
	Plug free 75Ω matched	Greenpar 37570C/12
Miscellaneous		
CH1	Synchronous Chopper 6.5V	AEI CK.3.
FS1	Fuse miniature cartridge 2.5A	Belling Lee 562/2.5A
ILP1	Neon 100V - 260V	West Hyde Developments 30PC/D
M1	Meter 200μA f.s.d. (Grey Case)	Weston Sangamo S157 Scale to Airmec 6658-242 Resistance 1.25 kΩ ± 15%

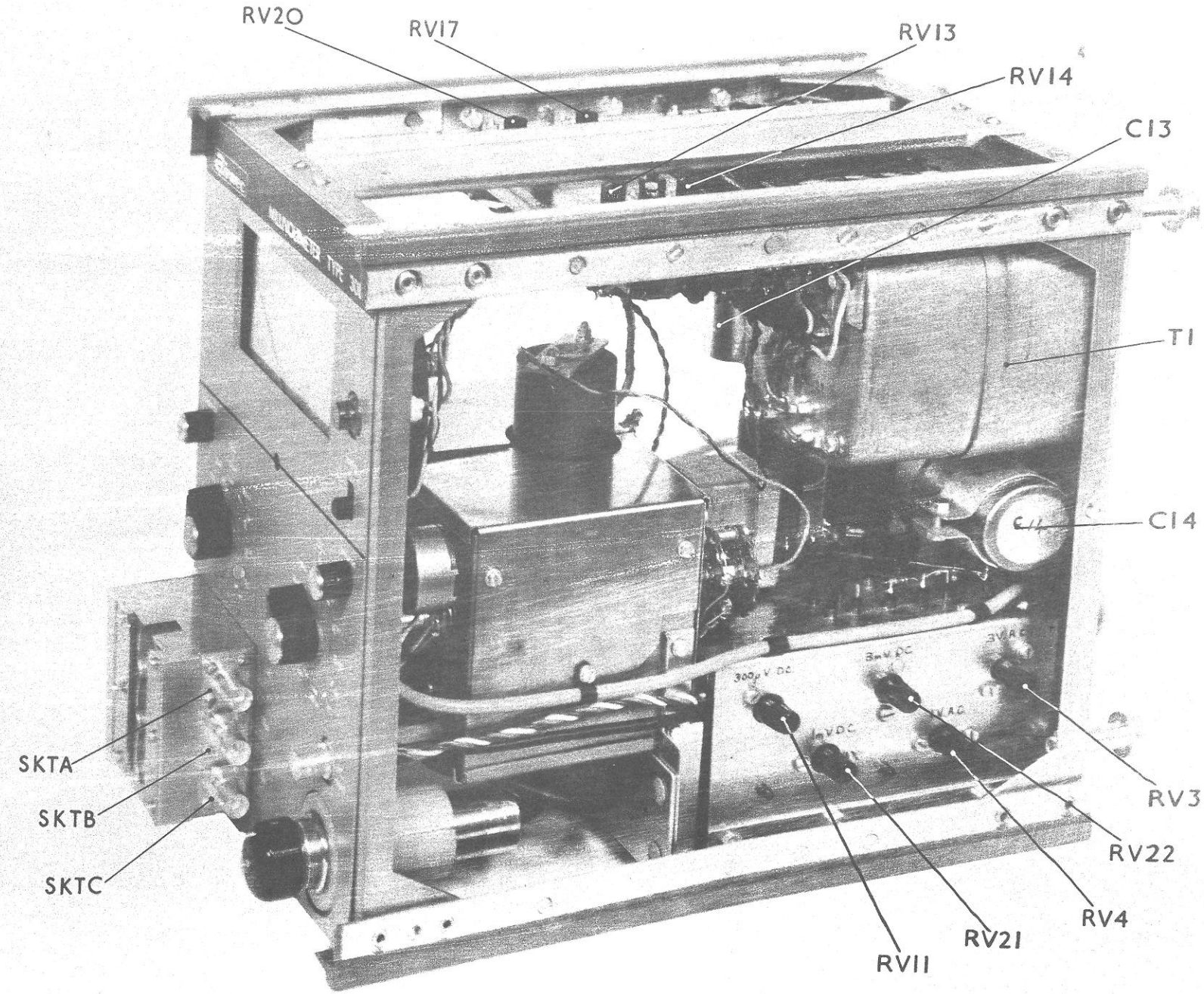


FIG.2. RIGHT HAND VIEW - COMPONENT LOCATION

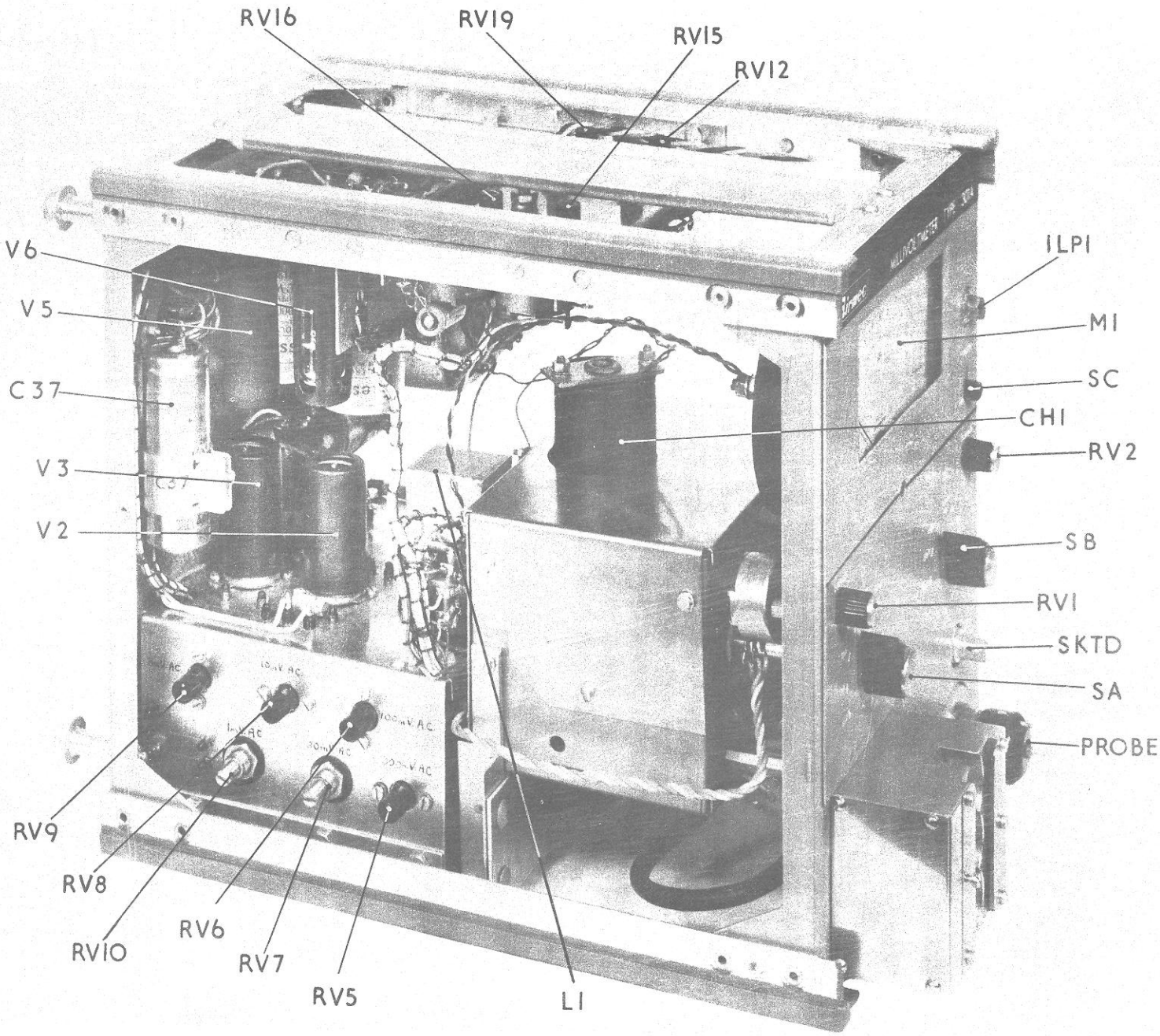
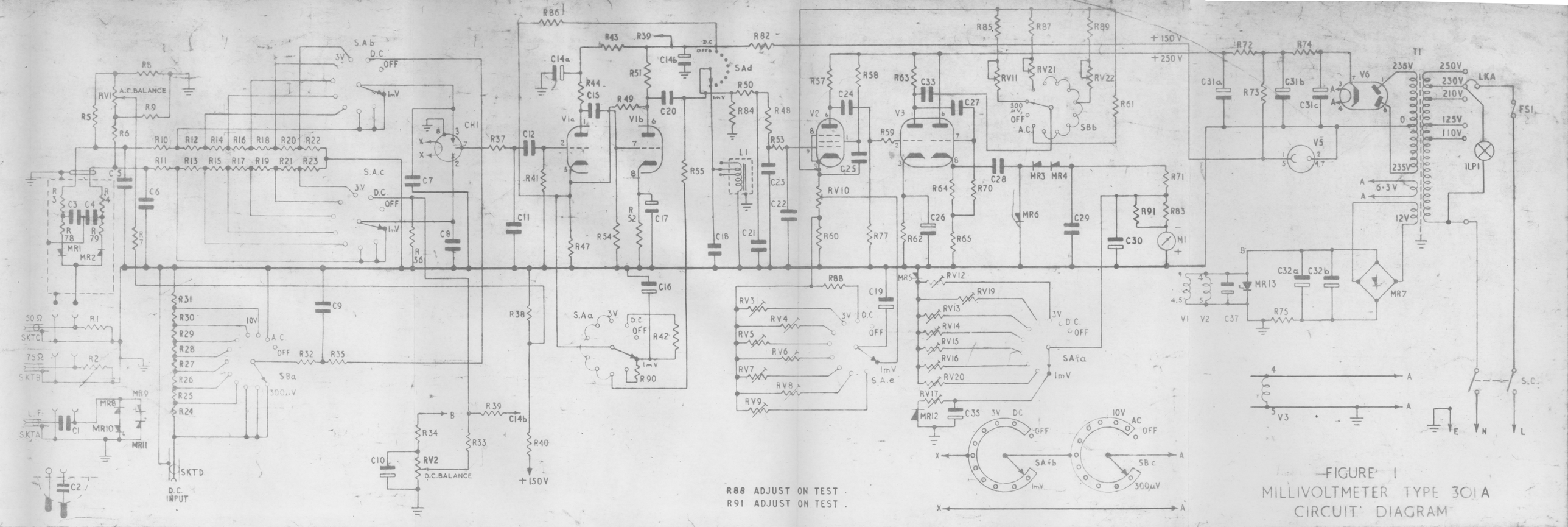


FIG.3. LEFT HAND VIEW - COMPONENT LOCATION



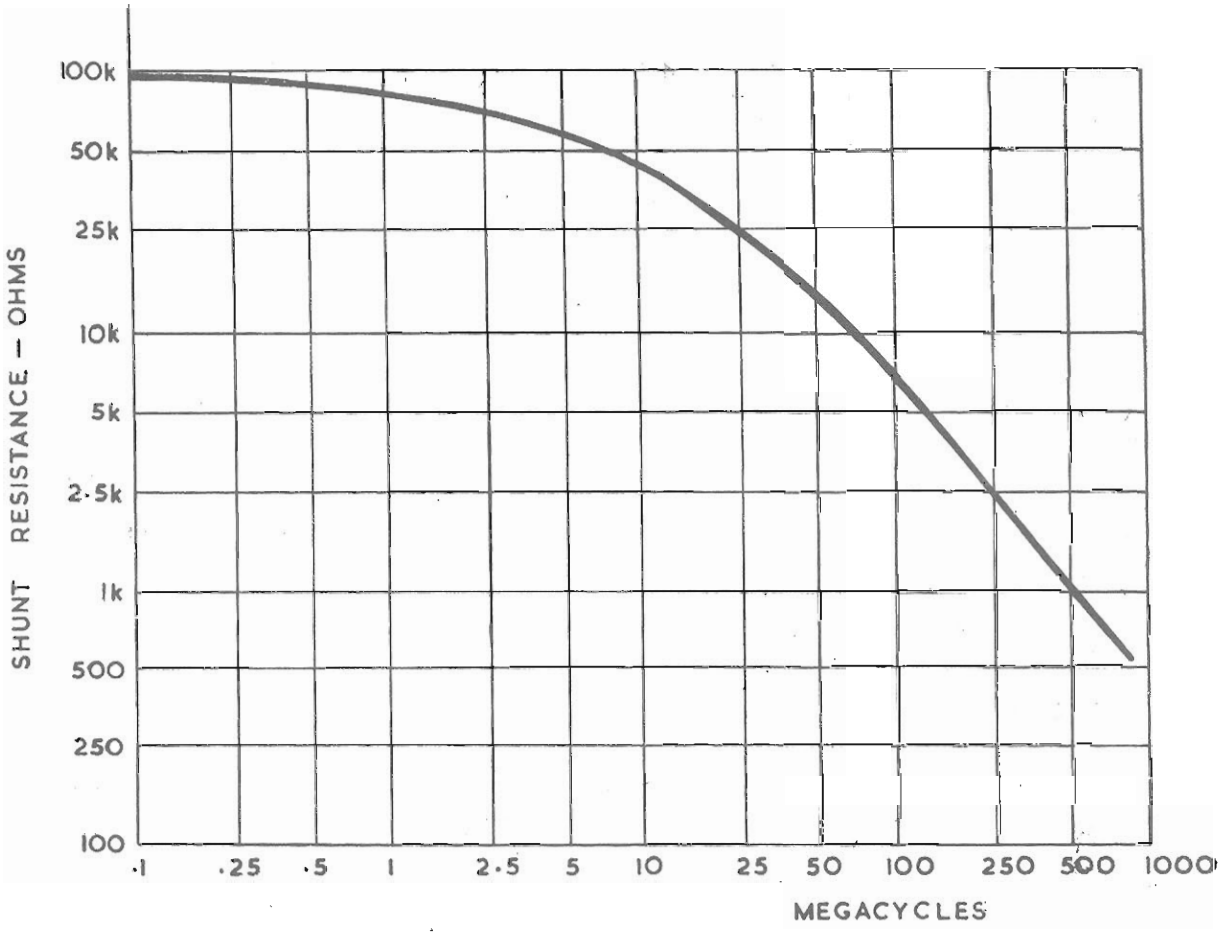
R88 ADJUST ON TEST .
R91 ADJUST ON TEST .

FIGURE 1
MILLIVOLTMETER TYPE 301A
CIRCUIT DIAGRAM

DRN. JAB	TRD EJA	CHD R.C.	APPD	DRAWING NUMBER	
AIRMEC LTD HIGH WYCOMBE BUCKS				6658 101	

ISSUE
C.N. 2862 15.7.65
C.N. 0436 20.5.64
10. 9.9.64
C.N. 2508
11. C.N. 2557 22.9.66
12. 24.10.66 c/n 2879
13. 24.10.67 C.N. 3110

FOR USE ON MO 2076 AND SUBSEQUENT



APPROXIMATE IMPEDANCE/FREQUENCY CHARACTERISTICS
HIGH IMPEDANCE PROBE
INPUT CAPACITANCE – 3pF
INPUT LEVEL 0·1 VOLT.

FIGURE 4
MILLIVOLTMETER TYPE 301A.

DRG. No.
6658-901