

**Thurlby** SINCLAIR

**1905 intelligent multimeter  
SERVICE MANUAL**

FOR SERVICE MANUALS  
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### 1. INTRODUCTION

This manual is intended to assist skilled personnel, in the maintenance and repair of the type 1905a multimeter.

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

The meter should only be dismantled if absolutely necessary. Repair or maintenance work inexpertly carried out will void the guarantee.

### 2. OPERATING INSTRUCTIONS

Refer to Operating Manual.

### 3. SPECIFICATIONS

Refer to Operating Manual.

#### 4. GENERAL DESCRIPTION

The 1905a is a microprocessor based instrument. It is constructed on two printed circuit boards mounted one above the other separated by an aluminium electrostatic screen.

The lower PCB carries the power supply, the analogue to digital converter (ADC) and the input conditioning circuitry.

The upper PCB carries the microprocessor components and the LED displays. Connection is made to the lower PCB via a 16 way ribbon cable plus 2 wires which carry the power rails. The membrane type keyboard is also connected to the upper PCB via a flexible tail.

#### 5. DISMANTLING THE INSTRUMENT

The meter is removed from its case by removing the four bolts through the feet, then lifting up the top cover followed by the sidepiece and handle assembly. The meter can then be lifted out of the bottom cover.

When re-assembling the instrument great care must be taken to avoid damaging the edges of the front panel membrane when inserting it into the slots of the top and bottom covers.

In order to remove the upper PCB the keyboard flexible tail must be disconnected. (When re-connecting it ensure that the nuts are not overtightened - the rubber pad should be compressed to about two thirds of its normal thickness.) The upper PCB is retained by four nuts, with these removed the PCB can be lifted at its rear and by pulling the front panel forward can be taken off its studs.

With the upper PCB removed, the top aluminium screen can be taken off allowing access to the component side of the lower PCB. Access to the foil side is achieved by removing the lower aluminium screen.

## 6. CIRCUIT DESCRIPTIONS

### a) The Power Supply (see Fig 1 )

The 1905a power supply provides three rails, -5V, +15V and -15V. The mains transformer has primary taps for 220V and 240V. A 115V version is also available.

The -5V supply (typical current drain 750mA) is regulated by an NPN pass transistor Q17 mounted on the back panel, controlled by transistors Q18 and Q19 and zener diode D11. Preset potentiometer PR14 is used to set the supply to exactly five volts.

The +15V supply (typical current drain 65mA) is regulated by a 3 terminal regulator IC18.

The -15V supply (typical current drain 22mA) is regulated by a 3 terminal regulator IC19.

Two further rails of +6V and -8.5V are generated from the +15V and -15V rails by emitter followers Q7 and Q9 respectively. (see Fig 5 )

### b) The Microprocessor PCB (see Fig 2 )

All the circuitry on the microprocessor PCB operates between 0V and -5V.

A 6502 microprocessor IC205 communicates with a 6522 versatile interface adaptor IC203, two 4Kx8 EPROMS IC208 and IC213, and two 1Kx4 static RAMS IC206 and IC207, via an 8 bit data bus.

The 16 bit address bus is used in conjunction with the address decoder IC204 which provides 8 chip select lines. IC203 provides two 8 bit input/output ports, whilst an additional 8 bit latch IC209 provides 8 additional output lines, and 8 additional input lines are provided by IC210 and IC211.

Transistor Q217 operates as a 4MHz crystal controlled oscillator which is divided by IC212 to provide a 1MHz clock signal for the microprocessor, and a 250kHz signal for the analogue to digital converter.

...continued

Transistor Q218 is used to disable the astable, formed by the schmitt trigger inverter 1/6 IC201, whilst the interrupt request line is regularly pulsed. If interrupt request pulses cease, as happens at switch-on or in the event of a program corruption, the astable pulses the microprocessor reset line in order to correctly restart the program.

The eight digit common cathode LED display is fully multiplexed. The digit lines are driven by inverting NPN saturating transistors controlled by the 8 bit latch IC209. The segment lines are driven by NPN emitter followers controlled from port A of IC203 with the segment current being defined by resistors in series with the collector of each transistor. (Resistor pack RP201).

The keyboard is arranged as an 8 x 3 matrix of which only 20 positions are used. The three keyboard scan lines are connected to port B of IC203 whilst the eight drive lines are commoned with the eight display digit drive lines.

Seven lines from IC203 form the logic interface between the microprocessor system and the analogue to digital converter, whilst the eight input lines to IC210 and IC211 accept information from the switchbank as to the function and range to which the meter is set.

c) The ADC logic interface (see Fig 3 )

This block of circuitry forms the interface between the microprocessor PCB and the CMOS transmission gates which control the analogue to digital converter (ADC).

Because the microprocessor PCB operates between 0V and -5V, whilst the ADC transmission gates operate between +6V and -8.5V, level shifting is needed, and this is performed by IC11 and IC13 which also invert the signals.

The dual D type flip-flop IC14 is used to define the length of the integrate and de-integrate periods of the ADC. IC15 and IC17 drive the transmission gates of the ADC whilst IC12 and IC16 provide information from the ADC to the microprocessor PCB.

d) The analogue to digital converter (ADC) (see Fig 4 )

The ADC operates on a modified form of the dual-slope principle, whereby the input signal to be measured is integrated for a fixed period of time resulting in a voltage at the output of the integrator given by  $V = K \times V_{in} \times T_{int}$ . A known reference voltage of opposing polarity is then applied to the integrator to return its output to zero in some unknown time period  $t$ . Hence  $V = K \times V_{ref} \times t$

$$\begin{aligned} \text{Thus } K \times V_{ref} \times t &= K \times V_{in} \times T_{int} \\ \text{or } \frac{t \times V_{ref}}{T_{int}} &= V_{in} \end{aligned}$$

So by defining  $T_{int}$  as 0.1 seconds (say) and  $V_{ref}$  as 1 volt, the value of  $V_{in}$  has been converted to a time period  $t$  secs =  $V_{in}(\text{volts}) \times 0.1$ . The microprocessor can then measure the length of  $t$  via a precision clock. Since the same clock is used to define  $T_{int}$ , any drift in the clock rate does not affect the result.

There are three major elements to the ADC. These are the Buffer which provides a low impedance output voltage from high impedance input and reference, voltage sources, the integrator, and the zero crossing comparator.

- (i) The Buffer:- The buffer amplifier IC8 is controlled by a large number of CMOS transmission gates IC4, IC5, IC6, IC7. IC5a and IC5b define the buffer gain as  $\times 1$  or  $\times 10$  respectively. Capacitors C26 and C27 store the system error voltages set up during the auto-zero (AZ) phase of the conversion which follows each measurement. During AZ the buffer input is grounded via IC4b and IC4c, and IC6d is closed to form a negative feedback loop around the whole system causing C26 and C27 to charge to the system offsets thus removing offset errors during the integrate and de-integrate phases of the measurement.

The input signal to be measured, which is in the range  $-2.1V$  to  $+2.1V$ , is applied through protection component R47 (in conjunction with Q11 and Q12) via IC4d to the buffer input. C21 forms an analogue filter with R47.

During the integrate phase, IC4d is turned on, and the buffer gain is set at  $\times 1$  or  $\times 10$ , depending on whether a full scale of  $\pm 2.1V$  or  $\pm 210mV$  is required ( $200mV$ ,  $200\Omega$  and current ranges).

During this time, the reference voltage (exactly 1 volt) is stored on capacitor C25 via IC6a and IC6b.

During the de-integrate phase IC4d is turned off, and the buffer input is grounded via IC4b, IC5d, and IC4a. At the same time IC7 places C25 in series with the buffer feedback path, thus generating a voltage at the buffer output of either  $+1V$  or  $-1V$  depending on which pair of gates within IC7 are operated.

When  $\Omega$  is selected the buffer input is not grounded during de-integrate, but is instead taken to a voltage point in the  $\Omega$ s current source generator. Similarly C25 is also charged to a voltage point within the  $\Omega$ s current source.

Op-amp IC9 is used in conjunction with Q13 and Q14 to provide boot-strapped supply rails to the buffer amplifier. This ensures a high level of linearity for the buffer input stage.

- (ii) The Integrator:- IC10 forms an integrator whose time constant is defined by R59 and C33. Q15 is used to buffer the output of IC10. IC5c is normally closed, but is opened for a short period of the de-integrate phase resulting in the integrator time constant increasing by the ratio of R60 to R59 in parallel with R60. C34 is used to compensate for charge injection at the integrator.
- (iii) The Comparator:- IC11d forms the zero-crossing comparator. Q16 is used to shift the zero crossing voltage during the integrate phase of the conversion in order to allow the microprocessor to interrogate the size of the input signal.

#### e) Input Conditioning Circuitry (see Fig 5)

The input conditioning circuitry converts current, resistance AC voltage and higher DC voltages to a DC voltage of a suitable level to be measured by the ADC.

Voltages are divided by either 1, 10, 100 or 1000 via the 10M $\Omega$  voltage attenuator pack RP2. In the case of AC voltage the output of the attenuator is applied to the AC to DC convertor formed by IC2.

The resistors of RP2 are also used as reference resistors for measuring resistance. IC1 generates a voltage of 1 volt across a proportion of RP2 resulting in a current of 1mA, 100 $\mu$ A, 10 $\mu$ A, 1 $\mu$ A or 100nA flowing into the unknown resistor dependant on range. The voltage across the unknown resistor is then measured by the ADC. In order to eliminate inaccuracy caused by drift in the voltage across RP2, this voltage is also used as the reference voltage for the ADC.

Current measurement is achieved using current shunt resistors RP1 and R5, at a full scale sensitivity of 210mV except for the 5A range.

IC2 forms an average sensing AC to DC converter which is used on both AC voltage and AC current ranges.

IC3 is an ovened reference zener diode which is divided down to provide a precise 1 volt reference voltage on the slider of PR7.

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Fig. 1 1905 Power Supply

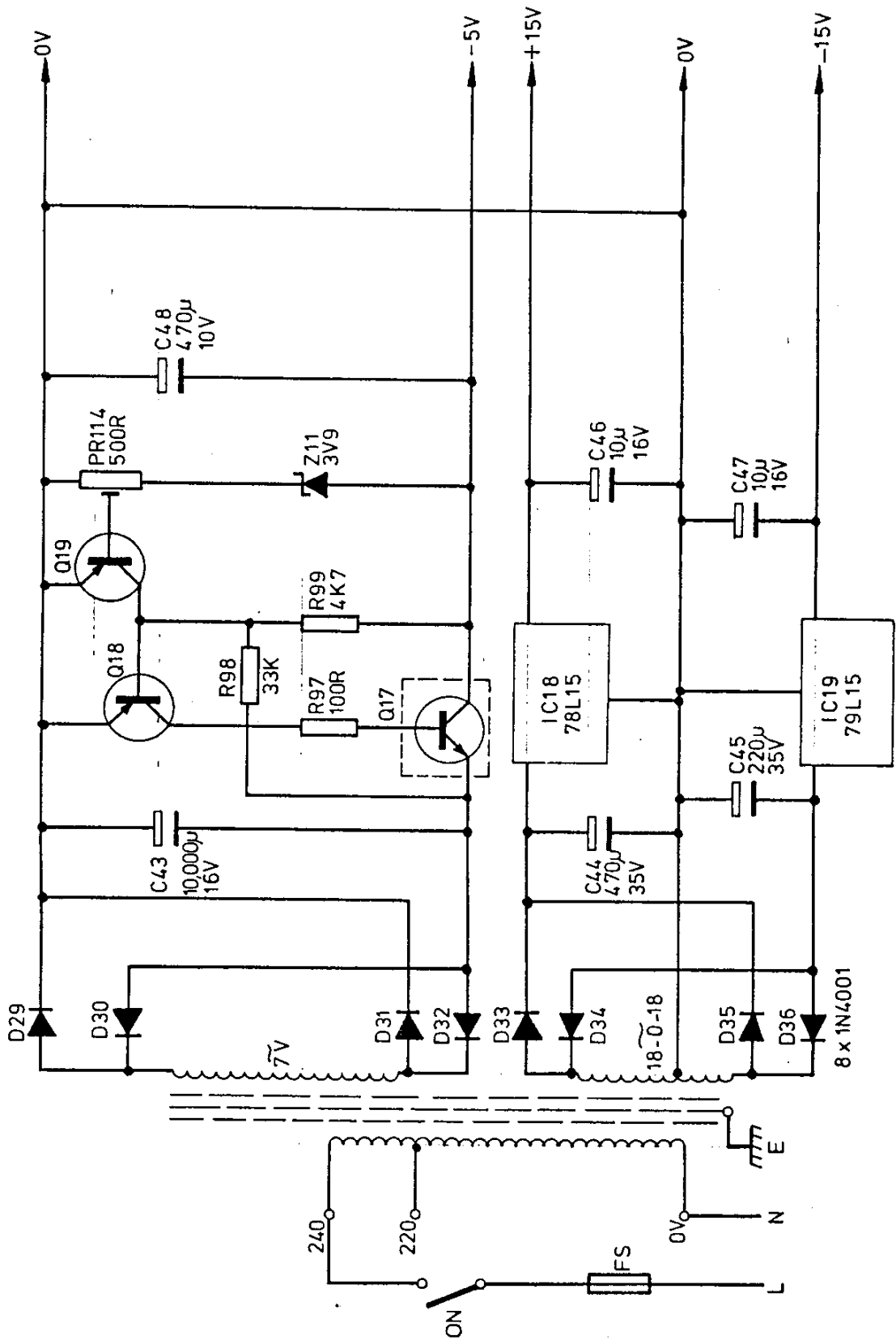


Fig. 2 1905 Microprocessor PCB

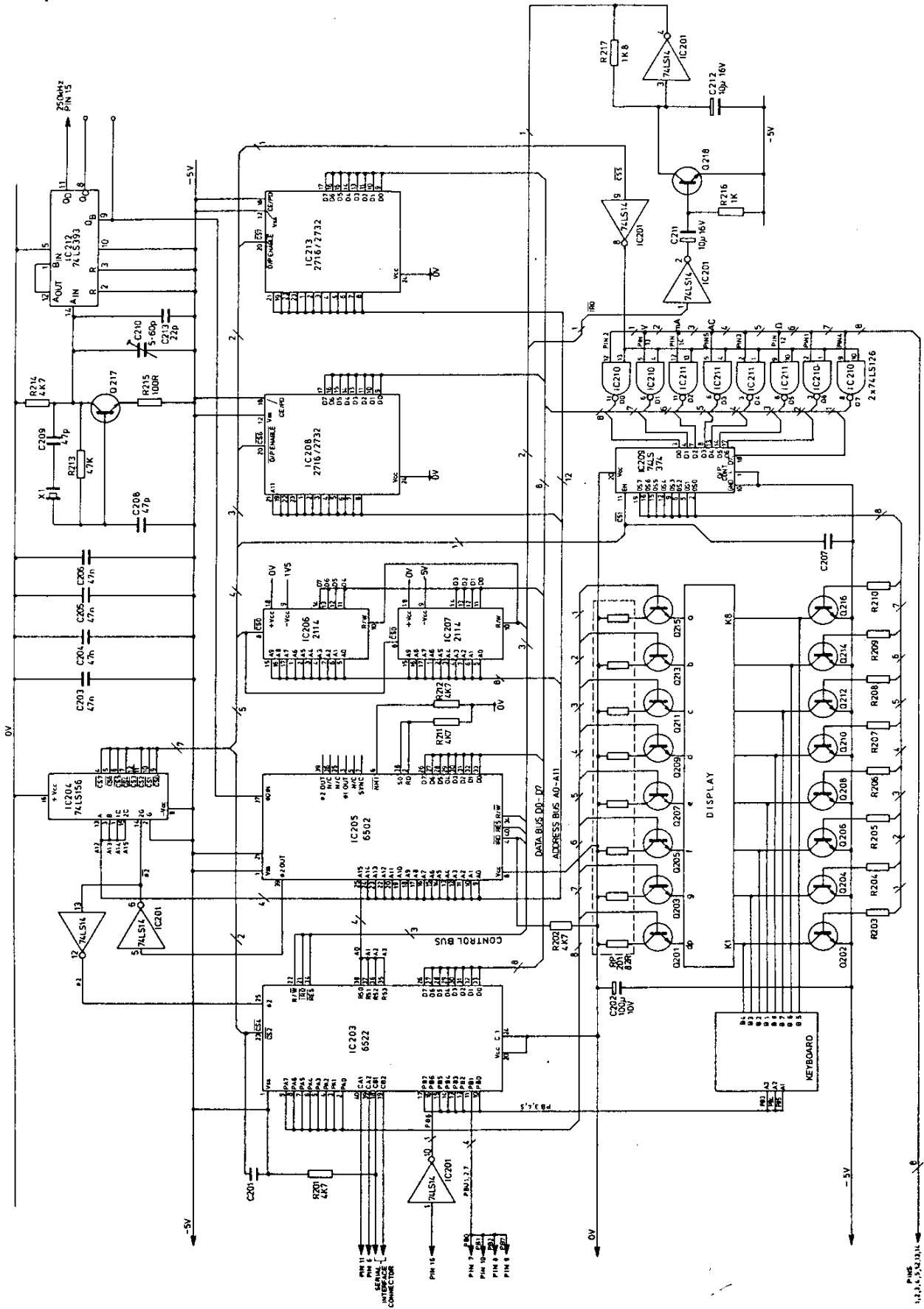


Fig. 3 1905 ADC Logic Interface

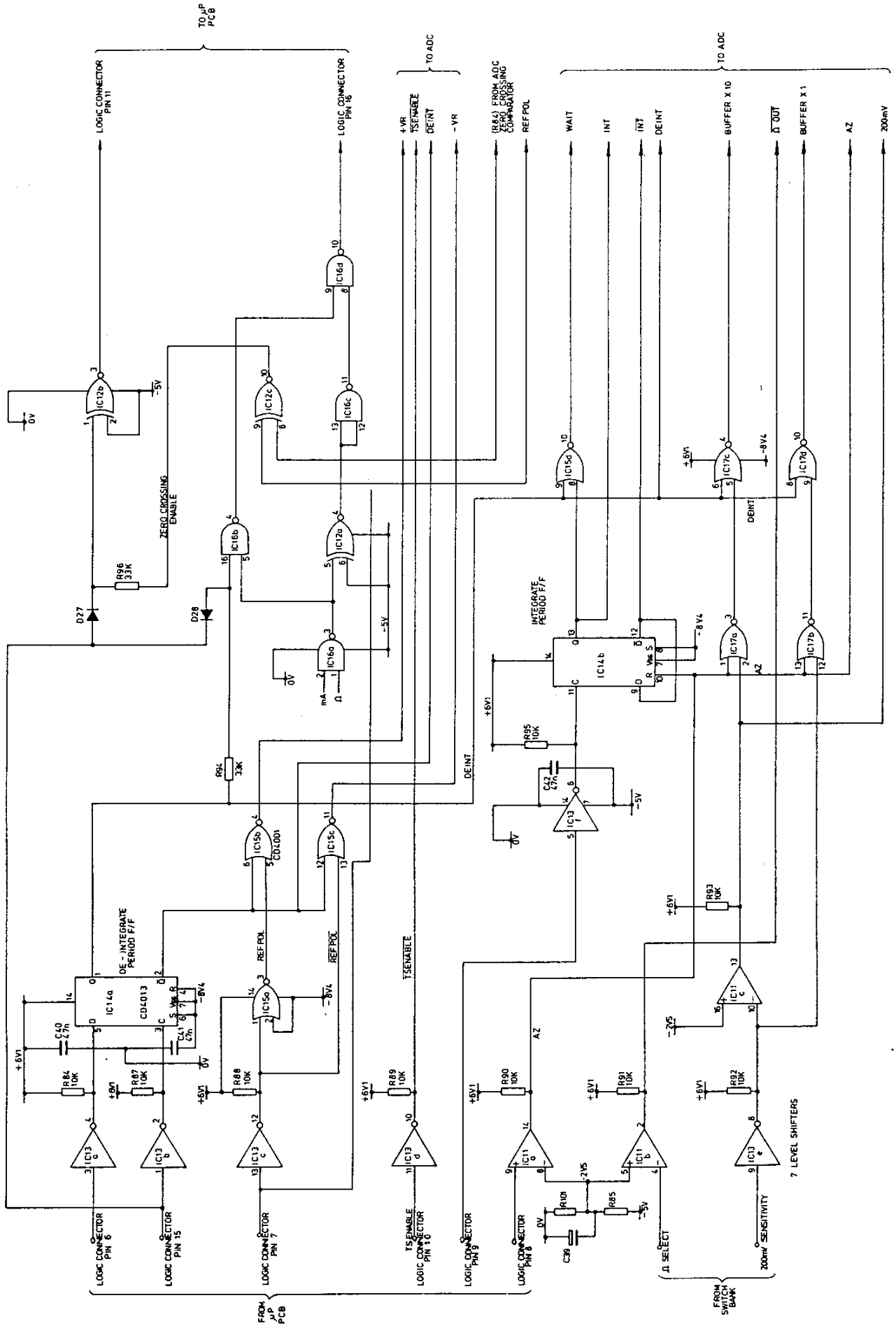


Fig. 4 1905 Analogue to Digital Converter

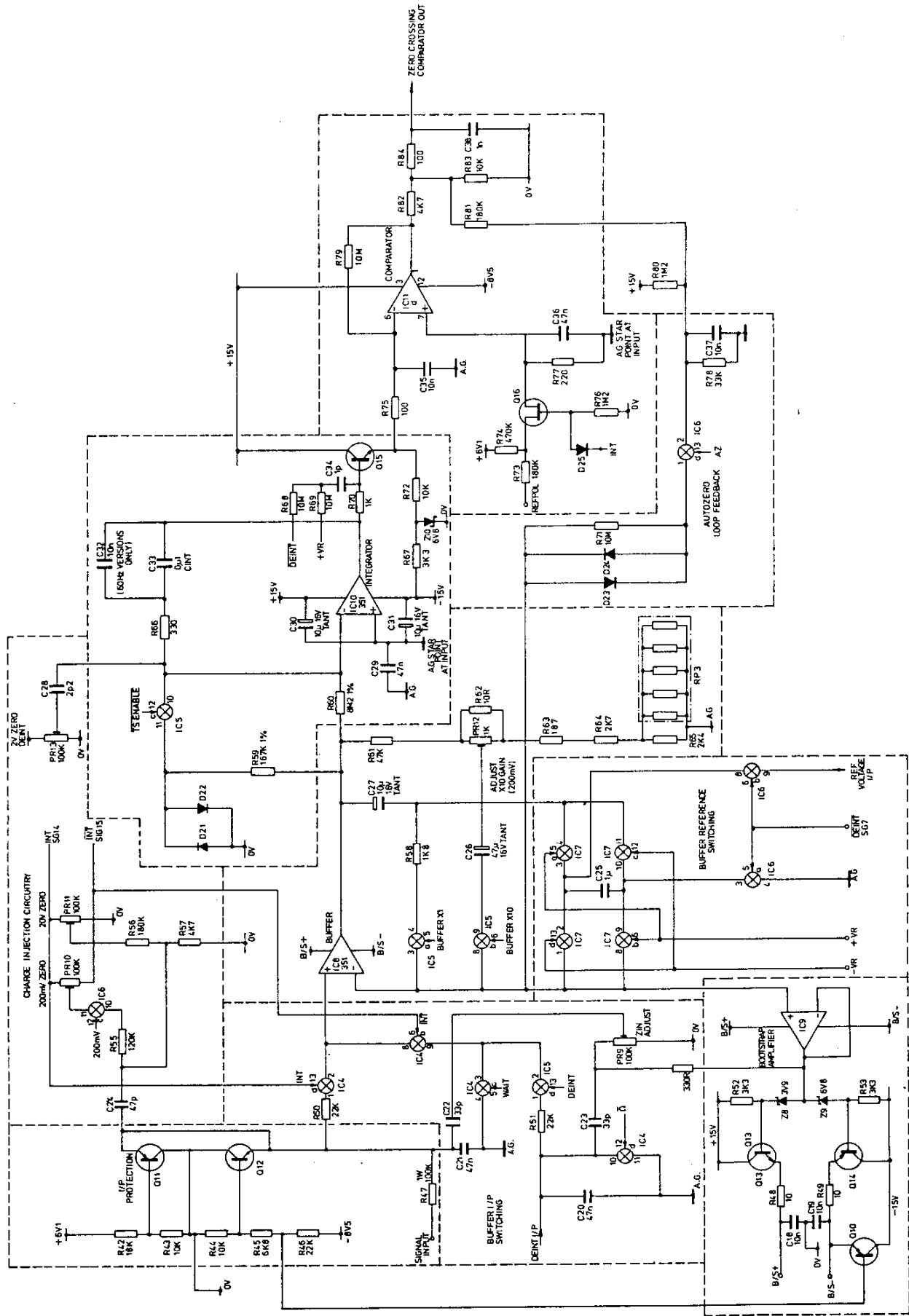


Fig. 5 1905 Input Conditioning Circuitry

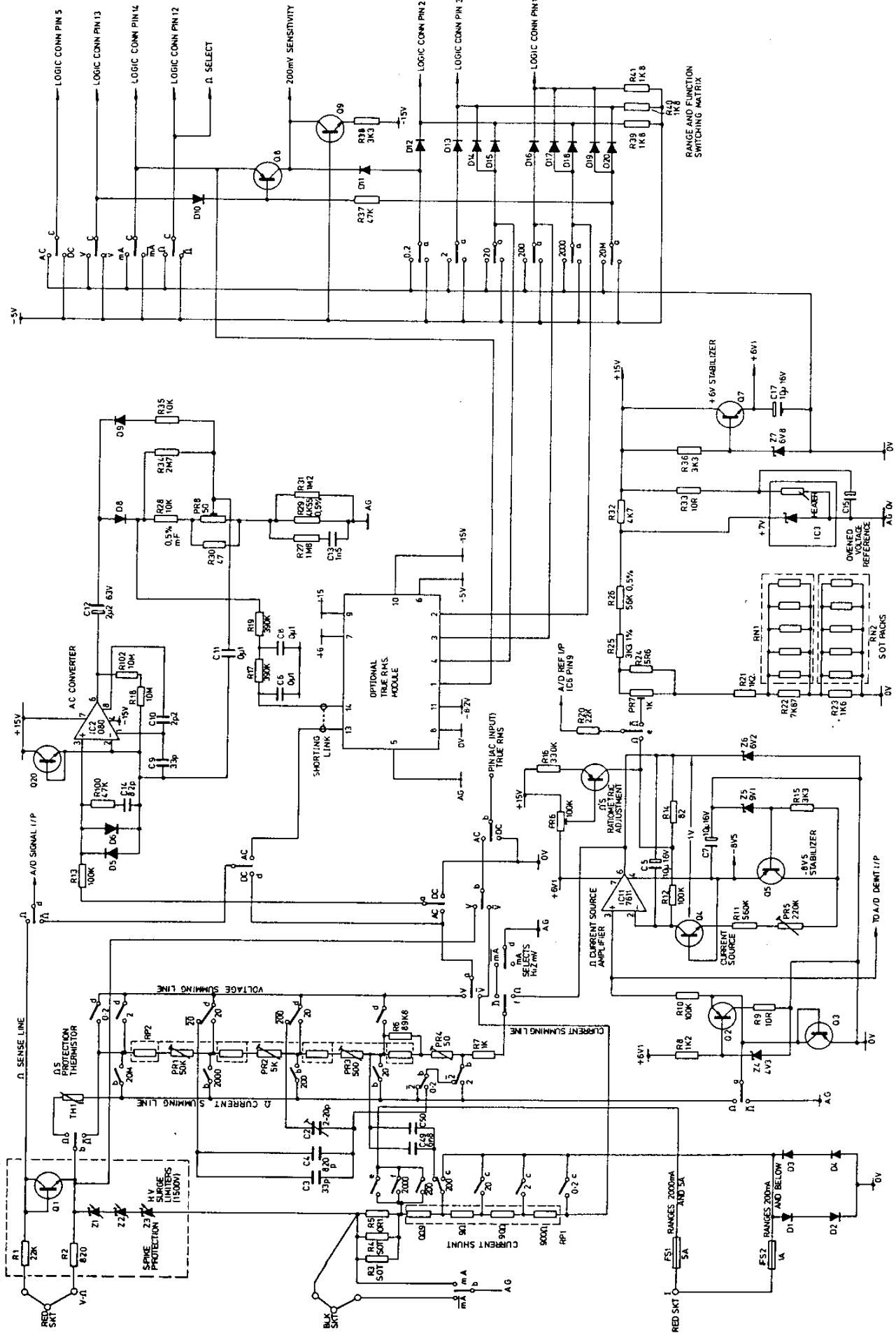
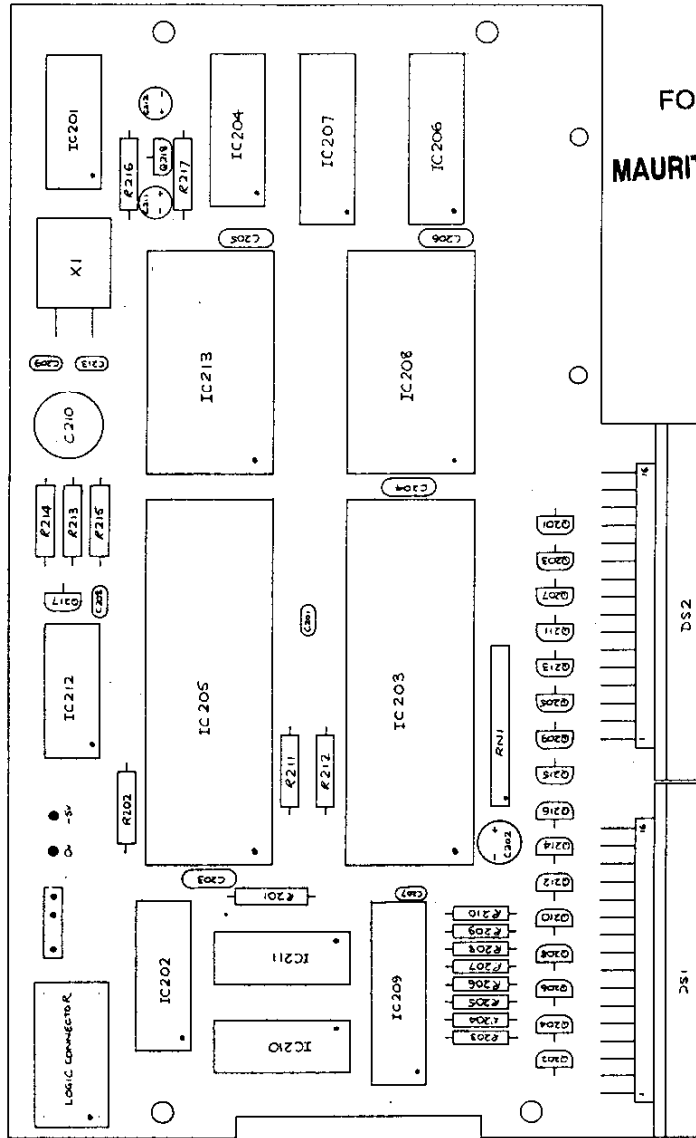
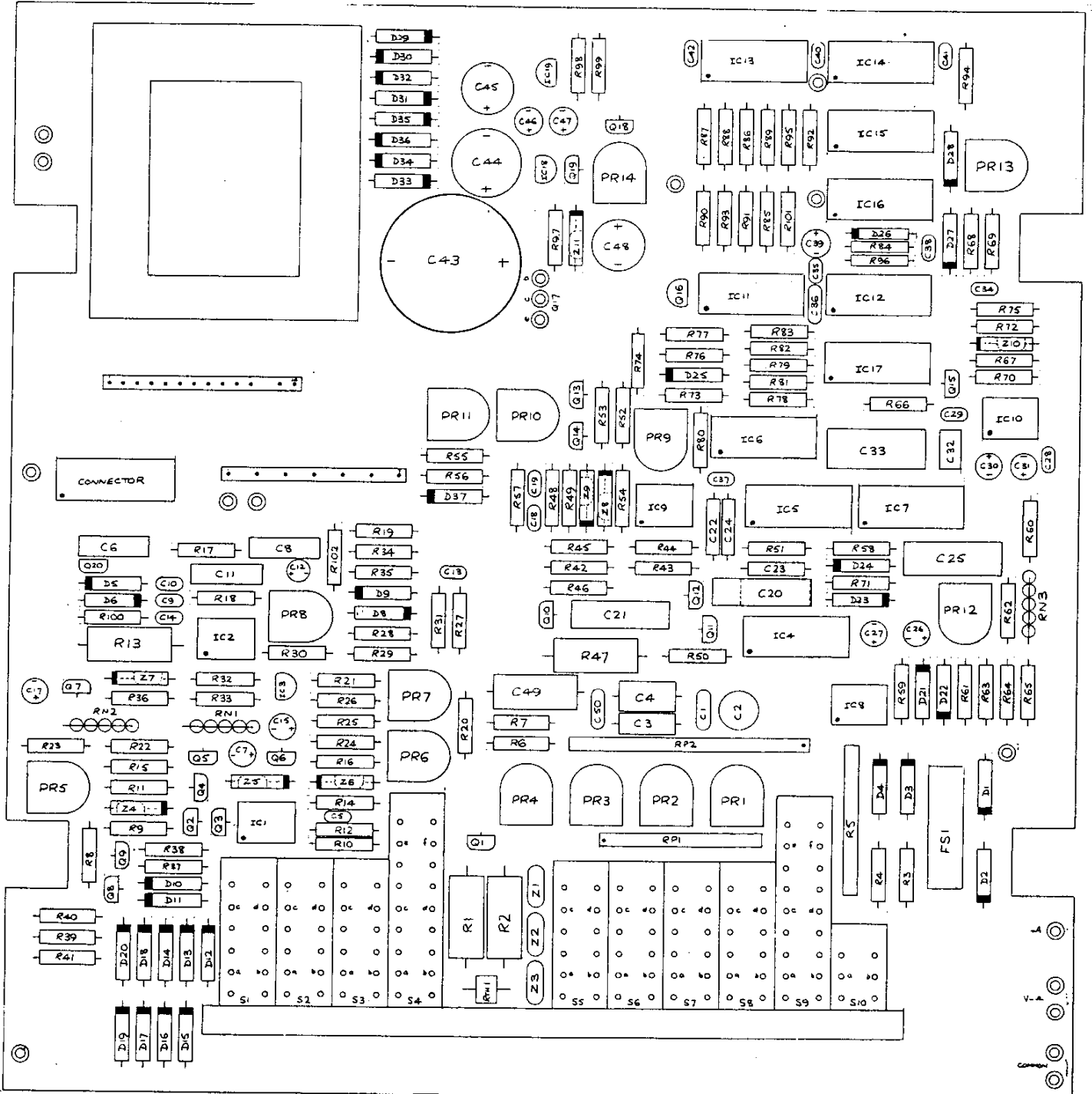


Fig. 6 1905 Microprocessor PCB Component Layout



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Fig. 7 1905 Main PCB Component Layout



## Section 7

1905 MAIN P.C.B.Electrical Parts List

All resistors 5% carbon film 1/4W unless otherwise marked.

R1	22K 1W iw 5% carbon comp.	R55	120K
R2	820R iw 5% carbon comp.	R56	180K
R3	Select-on-test	R57	4K7
R4	Select-on-test	R58	1K8
R5	0R1 laminated	R59	167K 1% 50ppm metal film
R6	89K8 1% 25ppm metal film	R60	8M2 1% 50ppm metal film
R7	1K 0.01% wirewound	R61	47K 0.5% 25ppm metal film
R8	1K	R62	10R
R9	10R	R63	187R 1% 50ppm metal film
R10	100K	R64	2K7 1% 25ppm metal film
R11	510K	R65	2K4 1% 25ppm metal film
R12	100K	R66	330R
R13	100K iw 5% carbon comp.	R67	3K3
R14	82R	R68	10M
R15	3K3	R69	10M
R16	560K	R70	1K
R17	680K	R71	10M
R18	10M	R72	10K
R19	680K	R73	180K
R20	22K	R74	470K
R21	1K2 1% 25ppm metal film	R75	100R
R22	7K87 0.5% 10ppm metal film	R76	1M2
R23	1K6 1% 25ppm metal film	R77	220R
R24	8R2	R78	33K
R25	3K3 1% 50ppm metal film	R79	10M
R26	56K 0.5% 10ppm metal film	R80	1M2
R27	3M3	R81	180K
R28	10K 50ppm metal film	R82	4K7
R29	4K55 0.5% 50ppm metal film	R83	10K
R30	47R	R84	100R
R31	1M2	R85	10K
R32	4K7	R86	10K
R33	10R	R87	10K
R34	2M7	R88	10K
R35	10K 0.5% 50ppm metal film	R89	10K
R36	4K7	R90	10K
R37	47K	R91	10K
R38	3K3	R92	10K
R39	1K8	R93	10K
R40	1K8	R94	33K
R41	1K8	R95	10K
R42	18K 1% 50ppm metal film	R96	33K
R43	10K 1% 50ppm metal film	R97	100R $\frac{1}{2}$ W
R44	10K 1% 50ppm metal film	R98	33K
R45	6K8 1% 50ppm metal film	R99	4K7
R46	22K 1% 50ppm metal film	R100	22K
R47	100K iw 5% carbon comp.	R101	10K
R48	10R	R102	10M
R49	10R		
R50	22K	RTH1	Thermistor
R51	22K		
R52	3K3		
R53	3K3		
R54	330R		

/contd...



1905 MAIN P.C.B.

C1	Not fitted	PR1	47K cermet
C2	2-10pf trimmer	PR2	4K7 cermet
C3	Not fitted	PR3	470R cermet
C4	820pf polystyrene	PR4	47R cermet
C5	1µf 50v. low leakage electrolytic	PR5	220K carbon
C6	0.1µf polyester	PR6	100K carbon
C7	10µf 16v electrolytic	PR7	1K cermet
C8	0.1µf polyester	PR8	47R cermet
C9	33pf ceramic	PR9	100K carbon
C10	2p2 ceramic	PR10	100K carbon
C11	0.1µf polyester	PR11	100K carbon
C12	2µ2 63v electrolytic	PR12	1K cermet
C13	Inf ceramic	PR13	100K carbon
C14	100pf ceramic	PR14	500R carbon
C15	2µ2 63v electrolytic		
C16	Not fitted	Z1	Varistor 2322-593-62712
C17	10µf 16v electrolytic	Z2	Varistor 2322-593-62712
C18	10nf ceramic	Z3	Varistor 2322-593-62712
C19	10nf ceramic	Z4	4V3 zener
C20	0.1µf polycarbonate	Z5	9V1 zener
C21	0.047 polycarbonate	Z6	6V2 zener
C22	33pf polystyrene	Z7	6V8 zener
C23	47pf polystyrene	Z8	3V9 zener
C24	47pf polystyrene	Z9	6V8 zener
C25	1µf polyester	Z10	8V2 zener
C26	47µf 6.3v tantalum	Z11	3V9 zener
C27	10µf 10v tantalum		
C28	2p2 ceramic	Q1	ZTX 239
C29	22nf ceramic	Q2	ZTX 214 low leakage
C30	10µf 16v tantalum	Q3	ZTX 214 low leakage
C31	10µf 16v tantalum	Q4	ZTX 239
C32	Not fitted	Q5	ZTX 214
C33	0.1µf polypropylene	Q6	ZTX 214
C34	1pf ceramic	Q7	ZTX 239
C35	10nf ceramic	Q8	ZTX 214
C36	47nf ceramic	Q9	ZTX 239
C37	10nf ceramic	Q10	ZTX 214
C38	Inf ceramic	Q11	ZTX 214 low leakage
C39	10µf 16v electrolytic	Q12	ZTX 239 low leakage
C40	22nf ceramic	Q13	ZTX 239
C41	22nf ceramic	Q14	ZTX 214
C42	22nf ceramic	Q15	ZTX 239
C43	10000µf 16v electrolytic	Q16	BF 245A
C44	470µf 40v electrolytic	Q17	T1P 31A
C45	220µf 35v electrolytic	Q18	ZTX 214
C46	10µf 16v electrolytic	Q19	ZTX 214
C47	10µf 16v electrolytic	Q20	ZTX 239
C48	470µf 16v electrolytic		
C49	6800pf polystyrene		
C50	Not fitted		

/ contd....

1905 MAIN P.C.B.

IC1 ICL 7611  
IC2 TL080  
IC3 LM3999Z  
IC4 CD4016 selected  
IC5 CD4016 selected  
IC6 CD4016 selected  
IC7 CD4016 selected  
IC8 LF351 grade 1  
IC9 LF351  
IC10 LF351 grade 2  
IC11 LM339  
IC12 CD4077  
IC13 DS7406  
IC14 CD4013  
IC15 CD4001  
IC16 CD4011  
IC17 CD4001  
IC18 78L15  
IC19 79L15

D33 In 4003  
D34 In 4003  
D35 In 4003  
D36 In 4003  
D37 In 4148  
  
RP1 1776-10  
RP2 1787-312  
  
RN1 SOT  
RN2 SOT  
RN3 SOT

D1 In 4003  
D2 In 4003  
D3 In 4003  
D4 In 4003  
D5 In 4148  
D6 In 4148  
D7  
D8 In 4148  
D9 In 4148  
D10 In 4148  
D11 In 4148  
D12 In 4148  
D13 In 4148  
D14 In 4148  
D15 In 4148  
D16 In 4148  
D17 In 4148  
D18 In 4148  
D19 In 4148  
D20 In 4148  
D21 In 4148  
D22 In 4148  
D23 In 4148  
D24 In 4148  
D25 In 4148  
D26 Not fitted  
D27 In 4148  
D28 In 4148  
D29 In 4003  
D30 In 4003  
D31 In 4003  
D32 In 4003

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1905 Microprocessor P.C.B.Electrical Parts List

R201	4K7	IC201	74LS14
R202	4K7	IC202	Not fitted
R203	470R	IC203	6522 - socket mounted
R204	470R	IC204	74LS155
R205	470R	IC205	6502 - socket mounted
R206	470R	IC206	2114
R207	470R	IC207	2114
R208	470R	IC208	2732 - Program E
R209	470R	IC209	74LS374
R210	470R	IC210	74LS126
R211	4K7	IC211	74LS126
R212	4K7	IC212	74LS93
R213	47K	IC213	2732 - Program F
R214	4K7		
R215	100R	DS1	MMN59440
R216	1K	DS2	MMN59440
R217	1K8		
RN1	8 X 82R	X1	4.00000 MHz crystal
C201	Not fitted		
C202	100 $\mu$ f 10v electrolytic		
C203	47nf ceramic		
C204	47nf ceramic		
C205	47nf ceramic		
C206	47nf ceramic		
C207	Not fitted		
C208	47pf ceramic		
C209	47pf ceramic		
C210	Not Fitted		
C211	10 $\mu$ f 16v electrolytic		
C212	10 $\mu$ f 16v electrolytic		
C213	47pf ceramic		
Q201	ZTX 450		
Q202	ZTX 450		
Q203	ZTX 450		
Q204	ZTX 450		
Q205	ZTX 450		
Q206	ZTX 450		
Q207	ZTX 450		
Q208	ZTX 450		
Q209	ZTX 450		
Q210	ZTX 450		
Q211	ZTX 450		
Q212	ZTX 450		
Q213	ZTX 450		
Q214	ZTX 450		
Q215	ZTX 450		
Q216	ZTX 450		
Q217	ZTX 313		
Q218	ZTX 239		

## 8. Calibration Check

The Thurlby 1905a 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 1905a in applications where maintenance of specified accuracy is of critical importance should arrange to have the calibration checked. The calibration should also be checked following any serious abnormality in operating conditions e.g. impact, prolonged vibration, extremes of temperature, or electrical overloads in excess of those given in section 3.2 of the operating manual.

The following section lists procedures for verifying the conformance to specification of a 1905a multimeter by applying accurately known values of voltage, current and resistance, and observing the display to within specific limits. The limits quoted apply only where the value of the source is known to within  $\pm 1$  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 an ambient temperature of  $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$  in dry conditions.

Switch on the instrument and leave for 1 hour before commencing the check.

### DC Voltage

<u>Range</u>	<u>DC Input</u>	<u>Display Limits</u>	
200mV	Short Circuit	-00.010 to 00.010	Note 1
200mV	+100.000mV	99.968 to 100.032	
2000mV	+1000.00mV	999.79 to 1000.21	
2000mV	-1000.00mV	-999.79 to -1000.21	
20V	+10.0000V	9.9969 to 10.0031	
200V	+100.000V	99.969 to 100.031	
1100V	+1000.00V	999.69 to 1000.31	

Note 1:- Following this test, null display with null key before checking 100mV accuracy. Cancel before checking 1000mV accuracy.

AC Voltage      Note 2

<u>Range</u>	<u>AC Input</u>	<u>Frequency</u>	<u>Display Limits</u>
200mV	100.00mV	50/60Hz	99.50 to 100.50
2000mV	1000.0mV	50/60Hz	997.2 to 1002.8
2000mV	1000.0mV	20kHz	991.0 to 1009.0
20V	10.000V	50/60Hz	9.972 to 10.028
20V	10.000V	20kHz	9.472 to 10.528
200V	100.00V	50/60Hz	99.62 to 100.38
200V	100.00V	5kHz	94.62 to 105.38
750V	750.0V	50/60Hz	746.9 to 753.1
750V	750.0V	400Hz	731.9 to 768.1

Note 2:- AC signal must be sinusoidal with less than 0.05% distortion.

DC Current

<u>Range</u>	<u>Input</u>	<u>Display Limits</u>	
200μA	Open Circuit	-00.010 to 00.010	Note 3
200μA	100.000μA	99.894 to 100.106	
2000μA	1000.00μA	998.94 to 1001.06	
20mA	10.0000mA	9.9894 to 10.0106	
200mA	100.000mA	99.844 to 100.156	
2000mA	1000.00mA	997.44 to 1002.56	

Note 3:- Following this check, null display with null key

Resistance

<u>Range</u>	<u>Input</u>	<u>Display Limits</u>	
200Ω	100.000Ω	99.942 to 100.058	Note 4
2000Ω	1000.00Ω	999.44 to 1000.56	
20kΩ	10.0000kΩ	9.9954 to 10.0046	
200kΩ	100.000kΩ	99.954 to 100.046	
2000kΩ	1000.00kΩ	999.14 to 1000.86	
20MΩ	10.0000MΩ	9.9744 to 10.0256	

Note 4:- Resistance of connecting leads must be taken into account when checking 200Ω and 2000Ω ranges.

## 9. Re-calibration Procedure

Where an instrument is outside its specification, or where a user wishes to improve the accuracy of the instrument, re-calibration can be carried out as per the following procedure.

It must be stressed that re-calibration is a delicate procedure requiring high performance equipment, and should only be attempted by skilled personnel who are certain of their competence to do so.

Because the 1905 generates considerable heat, it is necessary to calibrate it warmed up with the covers in place and consequently a calibration cover, available from Thurlby Electronics or their agents overseas, is needed to perform re-calibration. This cover replaces the bottom cover of the instrument and allows access to the various preset adjustments.

Calibration must be carried out using precision sources whose value is known to an accuracy at least 5 times better than the 1905 accuracy for that range.

Calibration temperature should be  $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$

Before commencing calibration the instrument must be dismantled (see Section 5) and re-assembled using the calibration cover in place of the normal bottom cover. The meter must then be switched on and left to warm up for 1 hour. The stand should then be set to angle the meter upwards at  $75^{\circ}$  to the horizontal thus allowing access to the preset adjustments using a trimmer tool with a non-metallic shaft. Before commencing select filter program 0.

The 1905 has eleven preset adjustments accessible through the calibration cover. The function of each adjustment is described below:-

- PR13/A1 - 2000mV zero : adjusts short circuit reading for 2000mV Dc range.
- PR11/A2 - 20V zero : adjusts short circuit reading for 20V DC range
- PR10/A3 - 200mV zero : adjusts short circuit reading for 200mV DC range.

- PR7/A4 - 2000mV scale set : adjusts scale accuracy for 2000mV DC range and all other voltage and current ranges.
- PR12/A5 - 200mV scale set : adjusts scale accuracy of 200mV DC range and 200 $\Omega$  range and current ranges.
- PR6/A6 - 2000 $\Omega$  scale set : adjusts scale accuracy for 2000 $\Omega$  range and all other resistance ranges.
- PR4/A7 - 20k $\Omega$  scale set : adjusts scale accuracy for 20k $\Omega$  range and for 1100V range.
- PR3/A8 - 200k $\Omega$  scale set : adjusts scale accuracy for 200k $\Omega$  range and for 200V range.
- PR2/A9 - 2000k $\Omega$  scale set : adjusts scale accuracy for 2000k $\Omega$  range.
- PR1/A10 - 20V scale set : adjusts scale accuracy for 20V DC range.
- PR8/A11 - AC scale set : adjusts scale accuracy for 2000mV AC range and all other AC ranges.

The following calibration procedure must be followed in exactly the order stated. In particular it is not possible to repeat stages 7 to 9 once stage 11 has been reached.

	<u>Select Function/Range</u>	<u>Apply</u>	<u>Adjust</u>	<u>For display reading</u>	<u>Tolerance</u>
1.	DCV 2000mV	Short Circuit	A1	000.00	just +ve of -000.00
2.	DCV 20V	" "	A2	0.0000	just +ve of -0.000
3.	DCV 200mV	" "	A3	00.000	$\pm 1$ digit
4.	DCV 2000mV	+1000.00mV	A4	1000.00	Exact
5.	DCV 200mV	+100.000mV	A5	100.000	$\pm 2$ dgts
6.	$\Omega$ 2000 $\Omega$	1000.00 $\Omega$	A6	1000.00 $\Omega$ (note 1)	$\pm 5$ dgts
7.	$\Omega$ 20k $\Omega$	10.0000k $\Omega$	A7	10.0000	$\pm 3$ dgts
8.	$\Omega$ 200k $\Omega$	100.000k $\Omega$	A8	100.000	$\pm 3$ dgts
9.	$\Omega$ 2000k $\Omega$	1000.00k $\Omega$	A9	999.90	$\pm 5$ dgts
10.	DCV 20V	10.0000V	A10	10.0000	$\pm 2$ dgts
11.	DCV 200V	100.000V	A8	100.000	$\pm 2$ dgts

	<u>Select Function/Range</u>	<u>Apply</u>	<u>Adjust</u>	<u>For display reading</u>	<u>Tolerance</u>
12.	DCV 1100V	1000.00V	A7	1000.00	± 2 dgts
13.	ACV 2000mV	1000.0mV 50/60Hz	A11	1000.0	± 2 dgts

Note 1:- In setting up the 1000 $\Omega$  and 10k $\Omega$  ranges, the resistance of connecting leads must be taken into account.