

1906

Multimeter

Service Manual

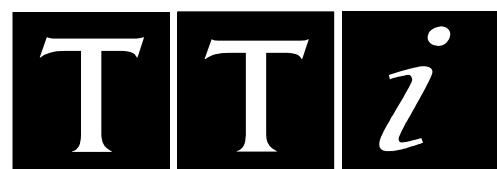


Table of Contents

Specification	2
Safety	5
General Overview & Principles Operation	6
Detailed Circuit Operation	7
Calibration	19
Parts List	24
Circuit Diagrams	33

Specification

Accuracy

Accuracies apply for 1 year 18°C to 26°C. Temperature coefficient outside these limits is <0.1x quoted range accuracy per °C. Warm-up time to rated accuracy is 1 hour.

DC VOLTS

Range	Accuracy	Input Impedance	Max Input
200mV	0.017% + 3D	10MΩ or >1GΩ	1kV DC or AC Peak, any range
2V	0.012% + 3D		
20V	0.019% + 3D		
200V	0.019% + 3D		
1000V	0.019% + 3D		

RESISTANCE (OHMS)

Range	Accuracy	Max. Measuring Current	Max Input
200	0.025% + 4D	1.5mA 1.5mA 0.4mA 40uA 4uA 400nA	300V DC or RMS continuous, any Ohms input, any range
2k	0.019% + 3D		
20k	0.019% + 3D		
200k	0.019% + 3D		
2M	0.022% + 3D		
20M	0.07% + 3D		

Max open circuit voltage 3.5V.

Audible continuity check available on all ranges.

TRMS AC VOLTS

Range Accuracy

Range	Accuracy				
	45Hz - 5kHz	5kHz - 10kHz	10kHz - 20kHz	20kHz - 50kHz	
200mV	0.2% + 150D	0.2% + 250D	3% + 500D	-	
2V	0.2% + 150D	0.2% + 250D	0.5% + 300D	3% + 1500D	
20V	0.2% + 150D	0.2% + 250D	0.5% + 300D	2% + 1000D	
200V	0.2% + 150D	0.2% + 250D	0.5% + 500D	-	
750V	0.2% + 150D	-	-	-	

Additional error at crest factor=3 typically 0.7%

Input impedance 1MOhm//<100pF any range.

Max input 750V rms, 1kV peak, any range.

AMPS

Range	Accuracy	Voltage Burden	Max Input
200uA	0.08% + 12D	1A,300V 300mV max	fuse protected
2mA	0.08% + 12D		
20mA	0.08% + 12D		
200mA	0.08% + 12D		
10A	up to 2000mA 0.06% + 10D above 2000mA 0.12% + 10	650mV max	10A, 300V fuse protected

TRMS AC AMPS

Range	Accuracy	45Hz - 1kHz	Voltage Burden	Max Input
200uA	0.37% + 100D	300mV max	1A,300V fuse protected	
2mA	0.37% + 100D			
20mA	0.37% + 100D			
200mA	0.37% + 100D			
10A	up to 2000mA 0.34% + 100D above 2000mA 0.4 % + 100D	650mV max	10A, 300V fuse protected	

Additional error at crest factor=3 typically 0.7%.

DISPLAY

Display Type: 13mm LED, 8 digit.

Scale Length: Selectable 5½ digit or 4½ digit.

Reading Rate: 3 readings/sec (5½ digit).
10 readings/sec (4½ digit).

Overrange Indication: Displays -OL- if input too great for range.

Overflow Indication: Displays OFLO if calculated result too large for display.

Annunciators: LED annunciators for range, function and program modes.

Input Characteristics

Input Current: <100pA.

DC NMR: >60dB at 50/60Hz.

1k Unbalanced CMR: >120dB at DC/50Hz/60Hz, DC ranges;
>60dB at DC/50Hz/60Hz, AC ranges;

Hi Z: Switchable high impedance (>1GOhm) on 200mV and 2V DC ranges.

COMPUTING FUNCTIONS

Null: Operates over full range; values can be stored for every function.

Digital Filter: 10 options, including optimised default values for each range and function.

T/HOLD
(Touch & Hold): Reading is held when stable.

% DEV: Displays % deviation from entered reference value.

dB:	Displays measurement in dB relative to 1V, 1mA, 1kOhm or user entered value, or in dBm.
Ax+B:	Linear scaling of results, with offset.
Limits:	Reading displayed with 'H','L',or'P' (pass) with respect to user-defined high and low limits.
Min/Max:	Minimum and maximum reading stored.
Data Logger:	Manual or automatic storage of 100 measurements.

INTERFACES

RS232:	Complies fully with the ARC (Addressable RS232 Chain) interface standard. Address selectable from the front panel. Baud rates 9600, 1200 and 300
GPIB (Optional):	Fully complies with IEEE-488.2

POWER REQUIREMENTS

AC Input:	110/120 Volts AC nominal 50/60Hz or 220/240 Volts AC nominal 50/60Hz by rear panel adjustment. The instrument will operate safely and meet specification within normal AC supply variations, viz. 99-132 Volts AC and 198-264 Volts AC respectively.
Power Consumption:	25VA max.

Safety

This multimeter DMM is a Safety Class I instrument by IEC classification; it has been designed to meet the requirements of both IEC348 and IEC1010-1.

This multimeter has been designed for use in a Pollution Degree 1 environment in the temperature range 5°C to 40°C, 20% - 80% RH (non-condensing). It has been designed for Installation Category II measurement use to 600VDC/rms and Installation Category I measurement use to 1000V DC/rms.

General

Environmental Operating Range:	+5°C to +40°C, 20% to 80% RH
Environmental Storage Range:	-40°C to +60°C
Size:	260(W) x 88(H) x 235(D)mm, excluding handle and feet
Weight:	2.2kg.

Safety

When operating the instrument with the covers off the users attention is drawn to the fact that the measurement circuit analogue common is capable of being driven up to 1kV above earth ground. All measurement circuits are therefore potentially hazardous, including the CPU section of the main board and the display/keyboard mounted behind the front panel. Instrument safety in normal use with the cover on is dependent on the safety earth connections to the front and rear panels and to the remote interface section of the main board.

It is therefore essential that these connections are only disturbed when absolutely necessary and are then replaced correctly. In this case the safety tests at the end of this manual should be carried out to ensure that the meter still meets the specified safety standard.

Mains Fuse

The mains input is protected by a fuse located in a drawer beneath the mains input socket. This fuse should only be replaced with one of the type specified on the rear panel label. Note that the fuse drawer orientation selects the mains voltage required to power the instrument.

Current Range Protection Fuses

The mA ranges, measuring currents up to 200mA, are protected by a 1A, 20mm HRC fuse mounted on the rear panel.

The 10A, range is protected by a 10A, 20mm HRC fuse mounted on the main board. To change this fuse first remove the top cover of the instrument. The 10A fuse is designated FS2 and is located near the input sockets.

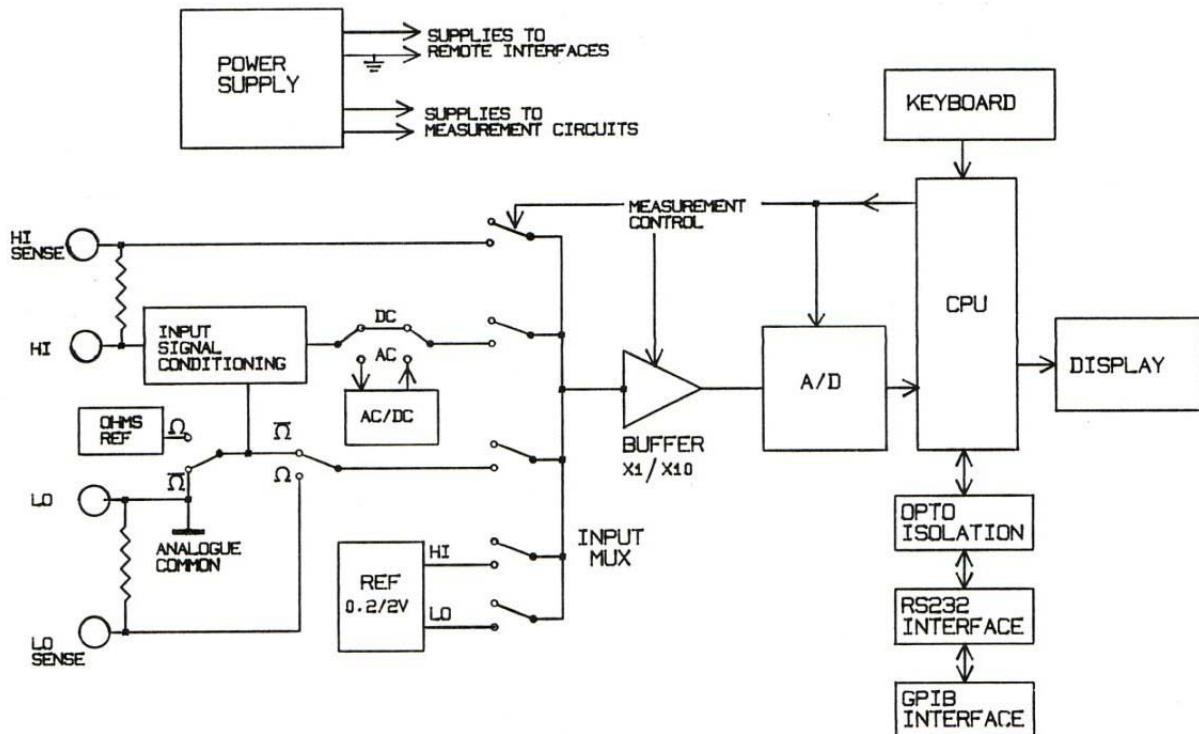


Fig. 1 – Block Diagram

General Overview & Principles Operation

(refer to the block diagram fig.1)

The input signal conditioning includes the input attenuator, current shunts, and analogue switches required for range switching. All analogue switches are either CMOS gates or MOSFETs. By software calibrating every meter range high precision components are avoided, the only requirement is stability.

The reference for voltage and current measurements consists of a reference diode with dividers connected to analogue ground. Resistance measurements use a separate Ohms reference voltage and are made using a ratiometric method so that the reference actually becomes the voltage across the reference resistor.

The input multiplexer consists of analogue gates which feed the A/D converter with the signals necessary to perform a complete meter reading. Each complete meter reading requires up to four 'sub-readings', each with a different signal fed to the A/D converter for the duration of one 20ms or 100ms conversion period. The complete reading is calculated from the sub-readings using the following generalised formula:-

$$\text{reading} = (\text{input signal hi} - \text{input signal lo}) / (\text{ref hi} - \text{ref lo})$$

DC voltage readings require two sub-readings, one where the input attenuator's output is fed to the A/D converter and one where the bottom of the attenuator is fed to the converter. As in all voltage and current measurements reference hi and reference lo sub-readings are performed at timed intervals once the meter function has been established.

The AC voltage and all current functions require only one sub-reading per displayed reading, the reference lo sub-reading also being used as the signal lo sub-reading. This has the advantage of speeding up the reading rate. For AC voltage and current measurements the signal hi sub-reading is taken from the AC/DC converter output. For DC current measurements the signal HI sub-reading is taken directly from the input current shunt. Resistance measurements require four sub-readings. The details of the signal paths used for the sub-readings of each meter function are given in the sections describing detailed circuit operation.

The buffer amplifier, IC40, which drives the A/D converter is switched between gains of x1 and x10 according to the meter function and range.

The A/D converter is of the charge balance type controlled directly by the CPU. The counters for the A/D converter reside within the CPU. The dividing line between A/D and CPU sections is therefore more blurred than the diagram suggests.

The basic remote interface is an opto-isolated RS232, which is incorporated in each instrument. The optional GPIB interface works via the RS232.

The display consists of multiplexed 7-segment LEDs. The front panel LEDs are also driven via the main display multiplexing and the keyboard is scanned by the CPU using the display multiplexing signals.

Detailed Circuit Operation

The following sections describe the detailed operation of the circuit blocks outlined in the general overview. Refer to the main circuit diagrams where information is not presented on simplified schematics.

Measurement Control Signals and Signal Drivers

The CPU is responsible for setting up all the measurement signal paths implemented using CMOS analogue gates and MOSFETS. In addition the CPU controls the A/D conversion process in real time.

The CPU controls all instrument functions using signals at two different levels. All control signal names start with 'CTRL' followed by the signal number and if the signal swings nominally between +5V and -10V it is suffixed with 'A'. 5V logic signals have no suffix. All +5/-10V level control lines are translated from their logic level equivalents by the amplifiers in IC21, IC22, IC23 and IC24.

Note that the signals CTRL1A, CTRL2A and CTRL10A are used to switch relays RL1,RL2 and RL3. All three relays are bistable latching types which require pulses of positive polarity to switch one way and negative polarity to switch the other way. This is achieved by ac coupling the control lines via C35, C36 and C37. No dc current flows through the relay coils so little power is dissipated in them.

The supply to IC22 is raised a Vbe by D22. This is to guarantee that **CTRL4A** swings positive enough to turn on MOSFET F3 which switches in the 200mA current shunt.

Fig.6 presents a complete list of control signals and their states for each meter function and range.

Input Signal Conditioning, - Guard Tracks

All input sense paths which would be susceptible to board leakage are protected by a guard track driven by IC20-D. The guard track is driven with a voltage which approximates to the mean buffer input. The guard track can be identified on the PCB by the absence of solder resist over it.

Input Signal Conditioning, - DC Volts

(refer to the main circuit diagram sheet 1)

Each complete measurement requires two sub-readings representing the incoming signal HI, either direct or attenuated, and the incoming signal LO connected to AG (Analogue Ground). The displayed measurement is calculated from these two sub-readings and the regularly updated reference sub-readings.

On the 200mV and 2V DC ranges the input voltage is passed to the buffer unattenuated via R93, R1, RL1, R44 and IC4-D. RL1 is switched to pin 4 by a low going **CTRL1A** signal. Input protection on this sense line is provided by Q5 and Q6 which limit the voltage to approximately $\pm 3.6V$. The input multiplexer switches between IC4-D and IC4-B, the analogue common being sensed, as for all DC Volts ranges, via IC4-B, IC7-B, IC6-C and F5. F7 is turned off by a low **CTRL12f** or all DC Voltage measurements.

The input impedance on the 200mV and 2V ranges is determined by R78 and RP1-B. When LOZ is selected these resistors are connected in parallel by IC8-B and IC1-A and the combination is connected to the HI input terminal via RP1-A, RL3 and R11, giving an input impedance of $11\text{ M}\Omega$. All other gates which could contribute to this impedance are turned off. When HIZ is selected IC8-B and IC1-A are turned off so that the input impedance effectively becomes infinite.

On 20V DC ranges and above RL1 is switched to pin 5 to isolate this sense line from incoming high voltages and the input multiplexing takes place between IC4-A and IC4-B. IC4-A senses the output from the input attenuator via R46, R45 and IC5-A. IC5-B and IC5-D are turned off for all DC voltage measurements. The two element DC input attenuator is formed by RP1-A in series with RP1-C, RP1-D or RP1-E in the 20V, 200V and 1kV ranges respectively. The measurement

current is fed to the bottom element of the attenuator via IC1-A in the 20V range and via IC1-D plus the appropriate gate in IC2 in the 200V and 1kV ranges. The voltage across the bottom of the attenuator is sensed via IC1-C or IC1-B and IC2.

The gate selection in IC2 is controlled by **CTRL6** and **CTRL7**, which select the gates according to a binary code with CTRL6 the LSB.

	CTRL7	CTRL6	IC2 gate
	0	0	0
i.e.	0	1	1
	1	0	2
	1	1	3

The bottom of the attenuator is connected to AG by F5. The LO voltage is sensed at the drain of F5 via IC6-C, IC7-B and IC4-B.

IC11-B and associated components form an active filter which is switched in on critical ranges via IC5-E. The ranges where the filter is switched in are indicated in fig.□6 where □CTRL11A□ is shown to be high.

Input Signal Conditioning - DC Current

(refer to main circuit diagram sheet 1)

DC current readings require only one sub-reading per complete reading. This is the sense reading from the hi end of the current shunt. The lo end of the current shunts is connected to and sensed via AG. This sub-reading is made when the reference readings are made at regular intervals of a few seconds.

The DC current shunt sense voltage is connected to the A/D converter buffer input via IC4-D, RL1, IC8-A and IC6-B, pin 2 of IC6 selecting the sense voltage up to 200mA and pin 1 selecting the 10A sense.

The 200uA to 200mA current shunts are contained in RP2 and R74 is the 10A shunt. The current is switched into the appropriate shunt in RP2 by MOSFETs F6, F1, F2 or F3. The 10A shunt is fed from a separate input socket and so is not switched. The MOSFETs are turned on by high going signals on their gates. The 10A input is fuse protected by FS2 and lower current ranges are protected by FS1. V4 and V5 prevent high voltage transients from occurring if the current is fed from an inductive source when the fuse blows; these could otherwise prevent the arc from extinguishing within the fuse body which could therefore result in instrument damage. D1 to D5 prevent overvoltage from damaging the current switches and shunts and result in FS1 blowing if sufficient current is drawn.

Input Signal Conditioning - AC/DC Converter

(refer to main circuit diagram sheet 1)

The AC/DC conversion is performed by true RMS converter IC15. The signal to be measured is input to pin 2 and negative DC appears at pin 6. The input signal is AC coupled via C19 with bootstrapped DC bias supplied by IC11-C and R32 for good LF performance. The source of the signal is selected by

IC6-A, pin 13 of IC6 being the AC Volts input and pin 12 being the AC current input.

C12 is the converter's averaging capacitor which averages a logarithmic voltage at pin 5. R106 is switched across the averaging capacitor by IC4-C for inputs below 1/200th of full scale to allow the reading to reach zero for zero input.

The converter's output is switched into the A/D buffer via IC5-D and IC4-A with post filtering of the converter's output performed by IC11-B and associated components.

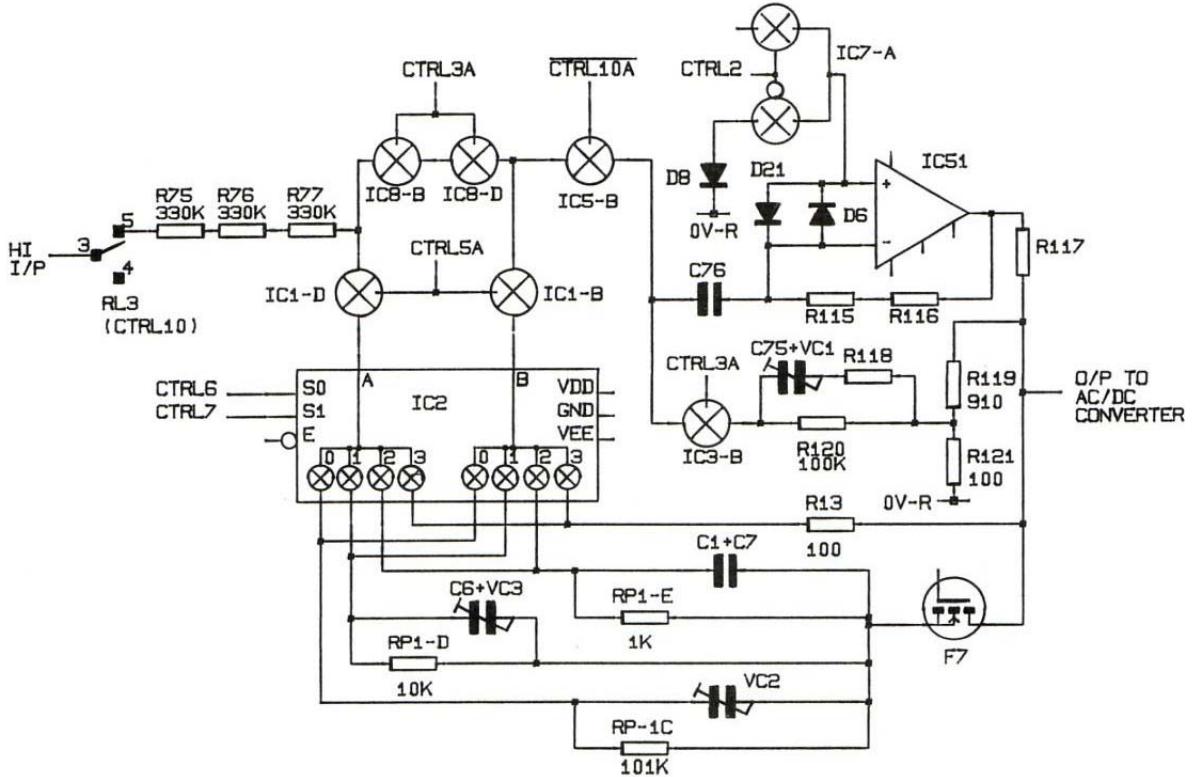


Fig. 2 - AC Volts I/P - Simplified Schematic

Input Signal Conditioning, - AC Volts Attenuation,

(refer to simplified schematic fig. 2)

The AC voltage readings require one sub-reading. The **LO** terminal is sensed via **AG** and is measured during the regular reference updates. IC4-A is therefore switched on permanently except during the reference sub-readings. The AC/DC converter works in the range 0-200mV RMS input signal, so all AC inputs are first converted to this level. For AC Volts measurements the multimeter uses an active attenuator centred around the amplifier IC51, configured as an inverting amplifier with the virtual earth node, pin 3, biased via IC7-A at one Vbe above analogue common. The signal is AC coupled into the amplifier's inverting input by C76 with DC stabilisation provided by feedback resistors R115 and R116. D21 and D6 prevent large transients on the input causing latch up.

The AC attenuator presents a constant input impedance on all ranges of nominally 990kOhms, consisting of R75, R76 and R77. In the 200mV range the input resistors are connected to the amplifier inverting input by IC8-B, IC8-D and IC5-B. IC1-D and IC1-B are turned off. R120 is the 200mV feedback resistor around IC51. The output from IC51 is divided by about ten at the junction of R119 and R121 and the feedback is taken from this point. This gives a nominal overall gain of one whilst maintaining a relatively low feedback resistance for better HF performance. It is essential for HF performance also that F7 is turned off in the 200mV range as this isolates spurious capacitive feedback through RP1 and associated gates. R117 provides current limiting for IC6-A's input protection diodes if the output of IC51 goes more positive than +5V.

In the ranges 2V, 20V and 200V F7 is turned on and IC2 selects the feedback for IC51. As for the DC attenuator the measurement signal is gated via IC1-D and the sense is routed via IC1-B to the amplifier input. IC8-B and IC-D are turned off so that R78 is not in circuit. IC3-B is turned off so that R120 is not in circuit. RP1-C gives the amplifier a gain of approximately 1/10 for the 2V range with VC2 allowing frequency trimming. Similarly RP1-D and RP1-E are used in the 20V and 200V ranges respectively. In the 750V range F7 is again switched off and IC2 selects R13 to give a gain of approximately 1/10,000.

Input Signal Conditioning, - AC Current

(refer to main circuit diagram sheet 1)

The AC current shunt operation is the same as for DC current. The AC current sense signal is routed from IC6-B to the RMS converter via IC6-A. IC8-A isolates the AC current sense line from the filter R44 and C8, which would otherwise represent an unacceptably low impedance when connected in parallel with the higher value current shunts.

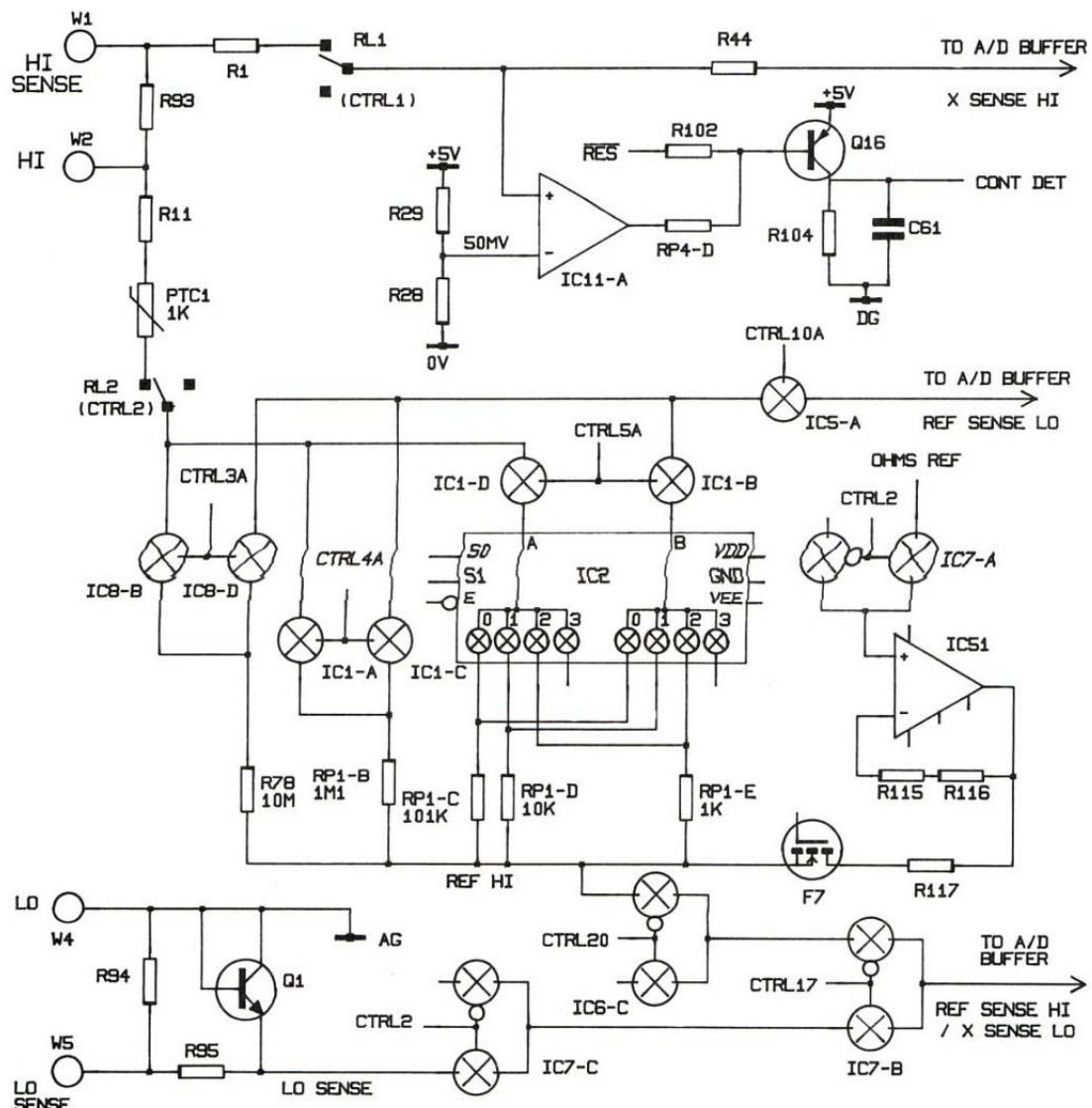


Fig. 3 - Resistance Measurements - Simplified Schematic

Input Signal Conditioning, - Resistance Measurement and Continuity Check

(refer to simplified schematic fig. 3)

Resistance measurements are made using a ratiometric method. The same measurement current is passed through a reference resistor and the resistance to be measured (X). For each complete reading a sub-reading is made of the voltage at each end of the reference resistor (REF HI and REF LO) and at each end of the unknown resistance (X HI and X LO). The complete reading is calculated from these four sub-readings:

$$X \text{ resistance} = (\text{REF resistor}) (X \text{ HI} - X \text{ LO}) / (\text{REF HI} - \text{REF LO})$$

The measurement current is generated by biasing the HI end of the reference resistor with the Ohms reference voltage (**OHMS REF**) of approximately +4V. **OHMS REF** is generated in resistive attenuator R35 and R23. IC7-A selects the **OHMS REF** as the bias for IC51 which forms a unity gain buffer to drive the reference resistor via R117 and F7. The REF HI voltage is passed to the A/D buffer via IC6-C and IC7-B. Because R117 has significant resistance the actual bias on the reference resistor varies with selected reference resistor and the unknown resistance.

In the 200Ohms and 2kOhms ranges RP1-D (1kOhm) is selected by IC2, IC1-D and IC1-B to form the reference resistor. Measurement current flows from RP1-D to the unknown resistor via IC1-D and RL2 and the REF LO voltage is sensed via IC1-B and IC5-A. Similarly in the 20kOhm and 200kOhm ranges RP1-D and RP1-C are selected and sensed. RP1-C forms the 2MOhm range reference resistor.

Measurement current flows via IC1-A and the REF LO voltage is sensed via IC1-C. Similarly R78 forms the reference resistor for the 20MOhm range in conjunction with IC8-B and IC8-D.

The measurement current passes through the positive temperature coefficient resistor PTC1 and R11. These provide protection against overvoltage on the HI input in conjunction with Q2 and Q3 (not shown on simplified schematic). A high voltage on the HI input will cause either Q2 or Q3 to clamp the REF LO sense line at $\pm 3.5V$. The initial surge current into these transistors is limited by the 1KOhm cold resistance of PTC1 and R11. However very quickly PTC1 heats up to reduce the current to a safe low level.

Resistance measurements may be made in two terminal or four terminal mode. Four terminal mode requires that the **HI** and **LO SENSE** terminals are connected externally to the resistance being measured. In this way the voltage across the unknown resistance can be sensed without the measurement leads' resistance causing inaccuracies. The instrument defaults to two terminal measurements if the **HI** and **LO SENSE** terminal are left unconnected, the sensing being performed internally at the **HI** and **LO** measurement terminals.

The HI voltage on the unknown resistance is sensed via R1, RL1, R44 and via R93 in two terminal mode or via the **HI SENSE** terminal in four terminal mode.

The LO voltage on the unknown is sensed via IC7-B, IC7-C, R95 and via R94 in two terminal mode or via the **LO SENSE** terminal in four terminal mode. R95 and Q1 provide protection from overvoltage on the **LO SENSE** terminal.

In the 200Ohms range the reference resistor used is 1k contained in RP1. To scale the measured resistance correctly the gain of the A/D buffer, IC40, is switched between x1 and x10 during the four sub-readings which comprise the complete resistance measurement. IC40 has a gain of ten when measuring **HI SENSE** and **LO SENSE** across the unknown and a gain of one when measuring REF HI

and REF LO. Accuracy in this range is therefore dependent on the ratio stability of R30 and R31. For all other resistance ranges the gain of IC40 remains fixed at one.

Continuity detection is performed by IC11-A and associated components. IC11-A compares the incoming unknown HI sense line with the 50mV reference voltage generated by R29 and R28. If the HI sense voltage is less than 50mV IC11-A turns on Q16 via RP4-D, which raises the **CONT DET** line. The **CONT DET** line is polled by the CPU under interrupt and the buzzer is sounded if the instrument is in the Ohms function and the continuity buzzer is programmed as active.

Because the CPU input pin used by **CONT DET** can also be used as the processor **HALT bar** input it is necessary to ensure at power up that the **CONT DET** signal is held high until the power up routine has time to change the function from **HALT bar** to input port. For this reason **RES bar** hold Q16 turned on at power up via R102 and C61 ensures that **CONT DET** does not fall before the software has had time to set up the input port.

Reference Generator

(refer to main circuit diagram sheet 1)

The meter uses a temperature stabilised Zener, IC16, as the central reference generator. Note that IC16 maintains a junction temperature of 85°C so it can be expected to be hot! IC16 regulates at 6.95V. The 6.95V from IC16 is divided down by R15, R22 and R107 to produce 2V and 200mV references, which are selected by IC9-B according to the meter function and range. The signal **CTRL18** controls IC9-B such that 200mV is selected when **CTRL18** is high and 2V is selected when it's low. The table in fig.□6 shows which reference voltage each meter function and range uses.

The selected reference voltage is further selected in IC7-C. During resistance measurements IC7-C is switched to **LO SENSE** and in all other functions it's switched to the reference voltage.

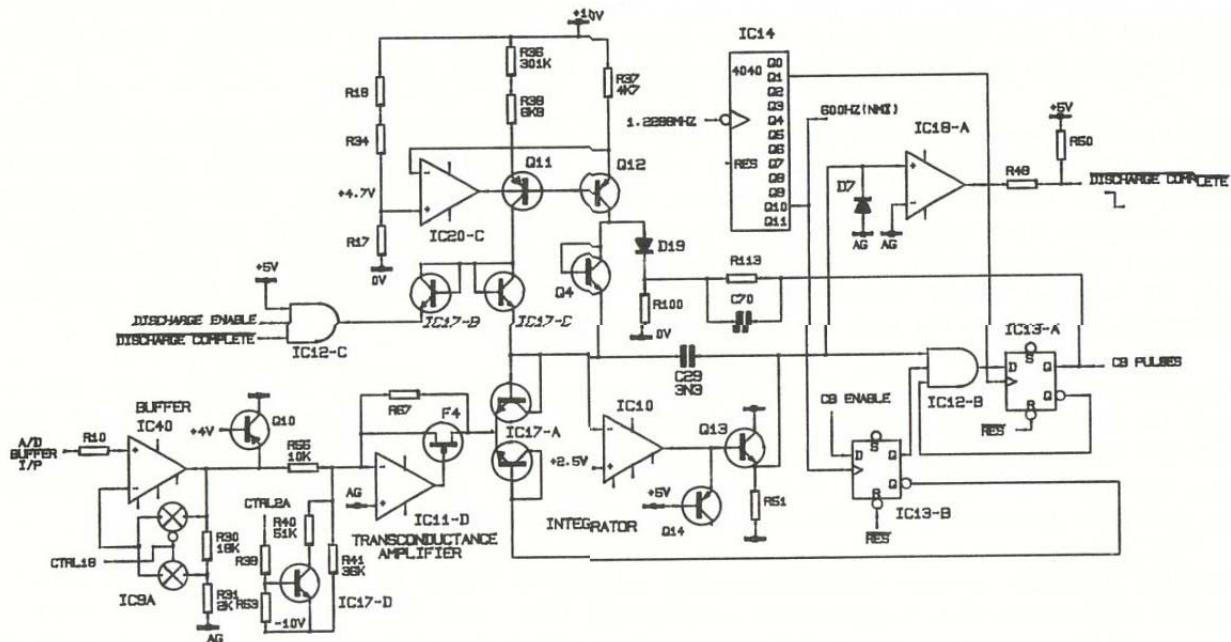


Fig. 4 - Simplified Schematic of A/D Converter□

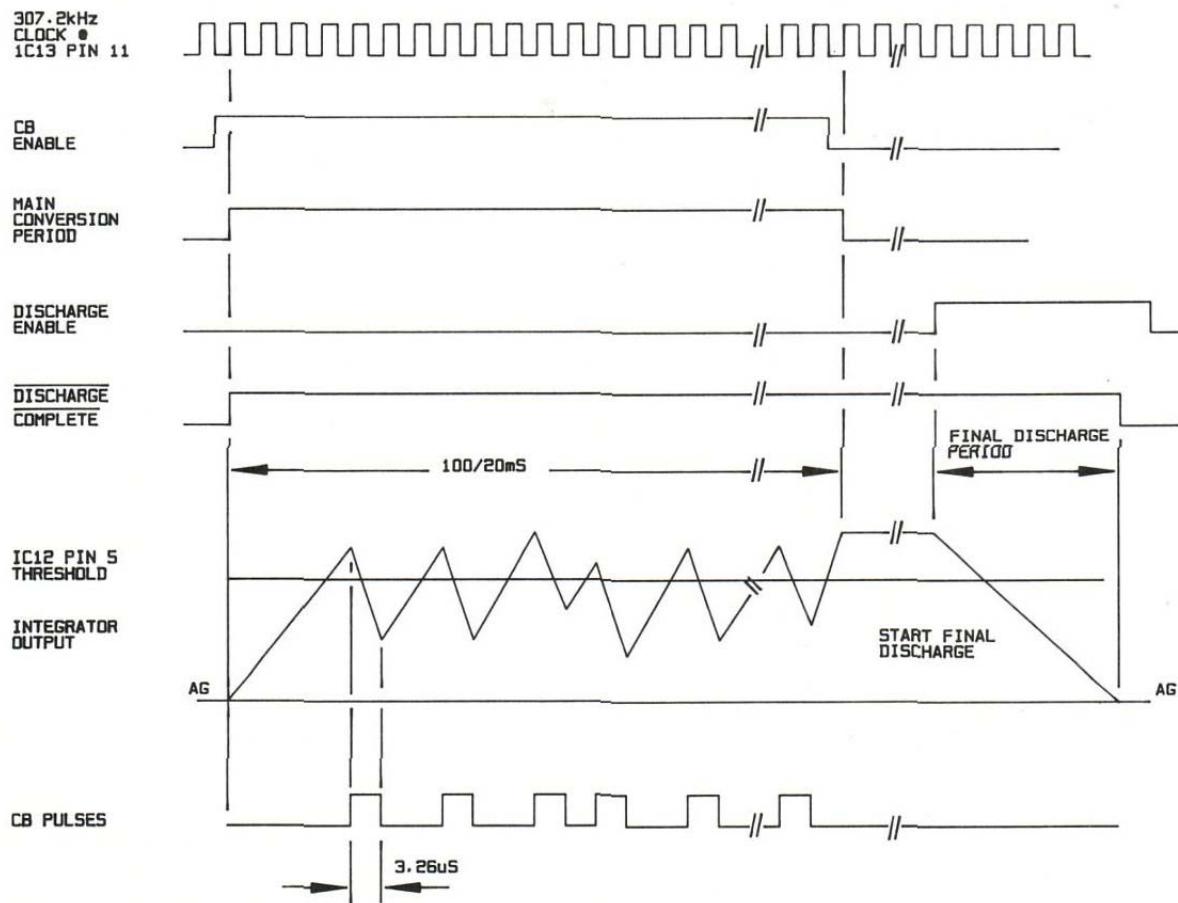


Fig. 5 - A/D Converter Waveforms (not to scale)

The A/D Converter

(refer to simplified schematic fig. 4 and waveform diagram fig.5)

IC40 provides a x1 or x10 input buffer to the converter. R10 filters out HF noise picked up on the extremely high impedance node feeding IC40. Analogue multiplexer IC9-A switches the feedback to change the gain under control of signal **CTRL18**. IC40 is switched to x10 for all AC functions, 200mV DC and for all current measurements. It is switched to x1 for Volts DC, ranges 2V and above and all Ohms ranges except the 200Ohm range where it is switched between x1 and x10 depending upon the sub-measurement under way.

The output from IC40 is bipolar, ranging between 0 and +4V for the Ohms measurements and between $\pm 2.1V$ for all other functions.

R55, IC11-D and F4 form a transconductance amplifier with output current proportional to the output voltage of IC40. The magnitude of the measurement current is determined by R55. R40 and R41 represent constant current sources which are added to the measurement current. This offsets the measurement current so that the current out of F4 is unipolar for all measurement inputs.

R40 is switched in by IC17-D under control of signal **CTRL2A** for Ohms measurements only.

Q10 limits the output of IC40 for open circuit Ohms measurements. R67 is necessary to ensure that under that same condition, even if F4 turns off completely, there is always current to keep IC17-A biased correctly. Without this precaution the converter would lock up.

IC10, Q13 and C29 form the converter's integrator. The measurement current is gated into the integrator for the duration of the main conversion period by pulling IC17 pin 2 low. IC17 is a

transistor array and IC17-A is a common emitter pair wired to form a diode switch. At the end of the conversion period pin 2 is pulled high to divert the measurement current from the integrator.

The main conversion period is determined by the CPU control signal **CB ENABLE**, whose state is changed within the CPU's NMI routine, which is initiated by the low going edge of the 600Hz signal generated in IC14. **CB ENABLE**, is accurately timed at IC13-B by the rising edge of the 600Hz clock. **CB ENABLE** is held high for the duration of the main conversion period. For 5½ digit operation the conversion period is 100ms and for 4½ digit operation it is 20ms.

IC20-C, Q11 and Q12 form two constant current sources in the ratio of 1:64, determined by R36, R37 and R38. IC20-C is biased at about 5V below the +10V rail by R18, R34 and R17. Note that this resistor chain also provides the feedback for the +10V regulator compromised of IC46-A and Q7. During the main conversion period Q11 current is diverted away from the integrator by holding IC17-B on and IC17-C off. This is achieved by a low \square DISCHARGE ENABLE, signal from the CPU forcing gate IC12-C output low.

At the start of the main conversion period D19 is turned on by the output of IC13-A. This ensures that Q4 is turned off so that the only current into the integrator at the start of the main conversion period is the measurement current. C29 is therefore charged by the measurement current and the emitter of Q13 rises. When the integrator output reaches the input threshold of IC12-B the output of IC12-B is allowed to go high. The high is gated through IC13-A on its next clock which turns off D19 and allows Q12 current to flow into the integrator. The integrator is now charged by the measurement current minus the

Q12 current. The value of Q12 current is designed to be just greater than twice the largest measurement current so the integrator output is always forced down at a rate which guarantees it will reach the input threshold of IC12-B within one clock period.

When the integrator output reaches the input threshold of IC12-B again the output of IC12-B is forced low which is gated through IC13-A at the next clock and so turns on D19 to divert the Q12 current from the integrator once more. Because the Q12 current has flowed into the integrator for exactly one clock period a known amount of charge has been removed from the integrator capacitor. With the Q12 current switched out the integrator is again charged positively by the measurement current only, thus forming a relaxation oscillator. The cycle repeats for the duration of the main integrate period.

The **CB PULSES**, out of IC13-A are counted by a hardware counter within the CPU. At the end of the main conversion period this count represents the amount of charge which had to be removed from the integrator capacitor in order to balance the charge delivered by the measurement current and maintain the output of the integrator close to the threshold of IC12-B. It is therefore a coarse measure of the measurement current itself.

At the end of the main conversion period there remains an unknown amount of charge in the integrator capacitor. To determine how much charge is left the integrator output is discharged down to AG by the Q11 current source and the time taken for the discharge is measured using a timer within the CPU.

The timer is started when the CPU drives **DISCHARGE ENABLE**, high. **DISCHARGE COMPLETE bar**, is already held high by the high output of IC18-A so IC17-C is turned on and Q11 current flows into the integrator. When the integrator output reaches \square AG \square the comparator, IC18-A, switches **DISCHARGE COMPLETE bar**, low to stop the Q11 current and thus hold the integrator output at AG ready for the next conversion cycle.

DISCHARGE COMPLETE bar, also stops the timer in the CPU. The timer is clocked by the 1.2288MHz E clock generated within the CPU, which is 4x the frequency of the clock used for the main conversion period. Thus because the Q11 current is 1/64th the Q12 current it is known that the charge removed from the integrator capacitor during each of the timer clock periods is 1/256th of that removed during each clock period during the main conversion period. It is therefore possible to multiply the \square CB PULSES, count by 256 and add it to the timer count from the second conversion phase to obtain a number accurately representing the measurement current.

Buzzer

The programmable buzzer is driven by a square wave from IC14, buffered by Q17. The buzzer is turned on by a high **CTRL19**, signal.

Power Supply

The power supply consists of two sets of linear regulators driven from the mains transformer. One set of regulators, IC41, IC42, IC43 and IC50, supplies the measuring circuitry which requires to be completely floating relative to earth ground. The measuring circuitry includes the CPU, keyboard and display components. The other set of regulators, IC44 and IC45, supplies the remote interfaces via supply signals designated **SER +5V**, **SER 0V** and **SER -5V**. **SER 0V**, is connected to earth ground. The transformer provides the necessary isolation between the supply groups. Signal isolation is provided by opto-couplers (see remote interface section).

Note that care must be taken with the insulator between the three terminal regulators and the rear panel as this insulator must withstand flash testing to 3kV AC. It is possible to puncture the insulator with sharp device corners. In addition it must be positioned so that there is maximum possible material surrounding all sides of the regulator tabs. This means positioning it hard against the clamp screws and centralising the regulators across its width.

CPU, Keyboard and Display

(refer to main circuit diagram sheet 2)

The CPU section features a 6303 processor with battery backed RAM to store instrument set-ups and the current hardware configuration when the instrument is switched off. In addition an EEPROM retains calibration constants which are stored during the calibration procedure. Default calibration constants are stored in the main EPROM and may be recalled at any time (overwriting any existing calibration constants in the EEPROM).

The CPU, IC25, controls all the input signal conditioning circuitry, the A/D circuitry, the keyboard and the display. The CPU contains a timer/counter which is used to count **CB PULSES**, from the A/D hardware and another timer which is used to time the final discharge of the integrator capacitor at the end of each conversion period (see A/D section). This represents the time difference between **DISCHARGE ENABLE**, going high and **DISCHARGE COMPLETE bar**, going low. In addition the CPU contains an integral serial port which is used for the remote control serial interface.

Most hardware control lines, the 7-segment display, the front panel LED indicators and the keyboard scan are driven through a single external port, **PORT 1**. Six hardware control lines, CTRL14, CTRL21, CTRL15, CTRL16, CTRL17 and CTRL18, are driven directly from output ports within the processor chip. **PORT 1**, is memory mapped at address 0400H and consists of latches IC47 and IC35. Four bytes of information are stored in Port 1. Three bytes of information are stored in secondary latches IC36, IC37 and IC38 and the fourth byte, which drives the display segments, is retained in IC47 and IC35. □PORT 1, is updated regularly in the NMI routine at 600Hz.

The **PORT 1** writing process is as follows. Data is first written into IC47 and IC35 and then latched from their outputs into one of the secondary latches by **LATCH ENABLE 1**, **LATCH ENABLE 2**, or, **LATCH ENABLE 3**, which are themselves output port data lines driven from within the CPU under software control. The third byte is latched by **LATCH ENABLE 1**, into IC38, which is on the display PCB and drives the display digits. The fourth byte is then written into IC47 and IC35 to turn on the segments. The output enable of IC38 is driven by **LATCH ENABLE 1**, delayed by R16. This ensures that each digit is not driven until the correct segment information is latched into IC47 and IC35, which thus avoids spurious segments appearing on the display. C66 is present to remove glitches injected by cross-talk in display cable. D14, D11, R21 and C4 delay turn on of the display at instrument switch on until after the software has started the display multiplex.

IC36 and IC37 store the current hardware control lines **CTRL1 - CTRL13**. In addition the front panel LED indicators are driven from IC37. The LEDs and the main display are multiplex driven.

The main display is driven one digit at a time by open collector driver IC39 under control of latch IC38. The LEDs are arranged in a row and column matrix with the three rows anode driven from IC37 and the columns driven by the digit driver, IC39.

The keyboard is scanned using the digit multiplex drive signals from IC38. The keyboard columns are read into the CPU via input port lines **COL0**, **COL1**, **COL2** and **COL3**.

Memory and port decoding are provided by IC32, IC19 and IC29. D20 isolates IC32-B pin 6 from IC29-B so that current does not flow from \square VBAT, out of IC32 into the main +5V, supply via the input protection diodes of IC29 when the instrument is switched off.

IC49 is the EEPROM used for storing calibration constants. It is controlled and accessed via IC48 which is decoded as **PORT 2**, at address 0401H. The EPROM is written to serially via D0 of IC48 and read from via the CPU input port line P52. Note that because P52 doubles as the processor's 'Memory Ready' input is necessary to ensure that this line is held high at power up. To this end the output enable of IC48 is held high by the **RES**, signal, which tri-states the latch output allowing R97 to pull the chip select pin of the EEPROM low.

The deselected EEPROM has tri-stated outputs which allows R98 to hold the 'Memory Ready' input high.

The EEPROM contents are protected from accidental overwriting by two methods. The main overwrite protection is the **CAL ENABLE**, signal driven directly from the recessed **CAL**, switch on the front panel. This signal has to be high to allow the EEPROM to be programmed. Similarly pin 7 of the EEPROM, the 'PRE' input, must be high to enable writing. This input is driven by the software.

The battery backup supply, **VBAT**, is generated by the lithium battery, **BATT**. When the instrument is switched on Q18 and Q9 are turned on and **VBAT**, is pulled to within 200mV of the +5V, rail. As the +5V, rail falls at power off Q18 and Q9 turn off and D14 holds **VBAT**, up until D12 starts to conduct and the battery takes over at about 3.3V.

The CPU reset circuitry uses three of the comparators in IC18. The reset period (**RES bar low**) is determined by the charge time of C41 via RP3-A. At power on the open collector output of IC18-B is turned off, C41 has no charge so **RES bar**, is driven low by IC18-C. C41 charges up via RP3-A until it reaches the 2.5V threshold of IC18-C, set by RP3-B and RP3-C, and **RES bar**, is driven high. C40 starts with no charge at switch on and then charges down to 25mV, as defined by R68 and R69. The output of IC18-C is therefore held open circuit until the +5V, rail starts to drop at switch off. The rail drop is AC coupled to the input of IC18-B by C40 and the reset capacitor is immediately discharged , driving the processor into reset. D13 allows fast discharge of C40 when the instrument is switched off, ready for immediate switch on again.

Serial Interface

The CPU contains an SIO port which provides the RS232 communication via the serial remote interface. The serial interface is opto-isolated from the processor and measuring circuitry by IC28 and IC30. Q15 supplies the drive current for the transmit LED in IC28. Incoming serial data is received by IC27-D and passed to the SIO via IC30. The serial interface conforms to the ARC standard. IC26-C thus relays incoming RS232 signals on to other instruments further down the RS232 chain. IC27-C receives RS232 data from devices further down the chain and relays them back to the RS232 controller via IC26-A.

GPIB Interface

(refer to both the main CPU/Keyboard/Display and GPIB circuit diagrams)

The GPIB interface operates via the RS232 interface. The source and destination of the RS232 signals are selected on the main board as follows. IC26-B is used as a logic gate to inhibit RS232 data reaching the GPIB board when RS232 is selected. Similarly IC26-A inhibits output to the RS232 connector when GPIB is selected. The RS232 receivers, IC27-B and IC27-D, are DC controlled via pins 12 and 5, respectively, so that the source of incoming RS232 data may be switched between the RS232 connector and the GPIB board. A low level on these pins turns the receiver off and drives its output to a high impedance which allows the two output to be wire ANDed. IC26-B, IC26-A, IC27-B and IC27-D are controlled by DC signals generated by IC4 on the GPIB board according to the state of the RS232/GPIB selection switch.

The GPIB interface proper is held on the GPIB board and consists of a remote processor, IC6, which communicates with the GPIB via the GPIB controller IC18 and with the processor on the main board via its own inbuilt serial SIO port. Serial communication between the two processors is asynchronous. The GPIB CPU uses internal RAM and the external ROM IC7. IC1 and IC2 are GPIB buffers.

The remote processor's power on reset signal is generated by IC5-A and IC4-B. The reset period is determined by the time constant of C9 and R2. Note that this time constant is required to be less than that of the main board's reset time for correct operation at power up.

The state of the RS232/GPIB switch is read by the main CPU at power up (only). The interface between the switch and the main CPU is optically isolated by IC8 on the GPIB board.

CTRL No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
VOLTS DC																			
200mV LOZ	1	0	1	1	0	0	0	1	x	1	0	0	0	x	A	A	0	1	0
200mV HIZ	1	0	0	0	0	0	0	1	x	1	0	0	0	x	A	A	0	1	0
2V LOZ	1	0	1	1	0	0	0	1	x	1	0	0	0	x	A	A	0	0	0
2v HIZ	1	0	0	0	0	0	0	1	x	1	0	0	0	x	A	A	0	0	0
20V	0	0	0	1	0	0	0	1	x	1	0	0	0	x	0	A	0	0	A
200V	0	0	0	0	1	0	0	1	x	1	1	0	0	x	0	A	0	0	A
1kV	0	0	0	0	1	1	0	1	x	1	1	0	0	x	0	A	0	0	A
VOLTS AC																			
200mV	0	0	1	0	0	0	0	1	x	0	1	0	0	x	0	A	0	1	A
2V	0	0	0	1	1	0	0	0	x	0	1	1	0	x	0	A	0	1	A
20V	0	0	0	0	1	1	0	0	x	0	1	1	0	x	0	A	0	1	A
200V	0	0	0	0	1	0	1	0	x	0	1	1	0	x	0	A	0	1	A
750V	0	0	0	0	1	1	1	0	x	0	1	1	0	x	0	A	0	1	A
AMPS DC																			
200uA	0	0	1	0	0	0	0	0	x	1	0	1	0	x	A	A	0	1	0
2mA	0	0	0	0	0	1	0	0	x	1	0	1	0	x	A	A	0	1	0
20mA	0	0	0	0	1	0	0	0	x	1	0	1	0	x	A	A	0	1	0
200mA	0	0	0	1	0	0	0	0	x	1	0	1	0	x	A	A	0	1	0
10A	0	0	0	0	0	0	0	0	x	1	0	1	1	x	A	A	0	1	0
AMPS AC																			
200uA	0	0	1	0	0	0	0	0	x	0	1	1	0	x	0	A	0	1	A
2mA	0	0	0	0	0	1	0	0	x	0	1	1	0	x	0	A	0	1	A
20mA	0	0	0	0	1	0	0	0	x	0	1	1	0	x	0	A	0	1	A
200mA	0	0	0	1	0	0	0	0	x	0	1	1	0	x	0	A	0	1	A
10A	0	0	0	0	0	0	0	0	x	0	1	1	1	x	0	A	0	1	A
OHMS																			
200	1	1	0	0	1	0	1	0	x	1	1	1	0	x	A	A	1	A	A
2k	1	1	0	0	1	0	1	0	x	1	1	1	0	x	A	A	1	0	A
20k	1	1	0	0	1	1	0	0	x	1	1	1	0	x	A	A	1	0	A
200k	1	1	0	0	1	0	0	0	x	1	1	1	0	x	A	A	1	0	A
2M	1	1	0	1	0	0	0	0	x	1	0	1	0	x	A	A	1	0	A
20M	1	1	1	0	0	0	0	0	x	1	0	1	0	x	A	A	1	0	A

1/0 = high/low state

A = active, toggling according to measurement sub-reading

x = not set according to function/range

Fig. 6 Table of Control Signals vs. Function/Range

Calibration

The instrument is software calibrated and retains its calibration constants in EEPROM. The calibration procedure is programmed into the ROM and simply has to be stepped through by front panel key presses or by remote interface commands.

The magnitude of the required calibration signal for each range and function is also programmed into the ROM and is displayed as a calibration prompt at each step. The calibration point can however be changed by remote command.

There is no facility for changing the calibration point from the front panel. Each meter function can be calibrated separately, however certain calibration constants are calculated during the DC Volts calibration procedure and used by other functions. It is therefore necessary to know that the DC Volts function is calibrated before any other functions may be calibrated.

The calibration status of each function is recorded in a series of flags, one for each meter function (see table below). The flags can be displayed when in calibrate mode (CAL, switch latched in, CAL, LED on) by pressing the LOG, key. The flags are shown as a series of 1's and 0's across the main display. All flags are set to 0 when a default calibration is performed and the appropriate flag is set to 1 when true calibration constants are stored for each function.

DIGIT 7	DIGIT 6	DIGIT 5	DIGIT 4	DIGIT 3	DIGIT 2	DIGIT 1	DIGIT 0
	OHMS	10A AC	10A DC	mA AC	mA DC	V AC	V DC

0 = DEFAULT CALIBRATION
1 = TRUE CALIBRATION

Fig. 7 - Calibration Flags

Calibration Equipment

It is recommended that calibration equipment with accuracy five times that of the instrument is used for DC Volts and Ohms and four times the specification for all other functions.

AC Voltage and current calibrations are performed at 500Hz. In addition frequency trimming of the AC input attenuator is necessary at 200mV/20kHz, 2V/10kHz and 20V/50kHz.

Ohms calibration is performed in four-terminal mode, so the calibration equipment must provide a remote sense facility.

Two low thermal EMF, zero Ohm links are necessary to short across the meter's input terminals for certain calibration steps.

Default Calibration

For non-calibrated operation it is possible to load default calibration constants into the EEPROM from the ROM. This is necessary when the instrument is switched on for the very first time and if an error is detected in the EEPROM at power up.

To perform a default calibration the instrument must first be put into calibrate mode with the instrument switched off. This is done by depressing the recessed CAL, switch located at the top

left hand corner of the front panel using a suitable narrow tool. The switch should be made to latch in.

The instrument is then switched on and the display shows 'DeF cAL'. Pressing the STORE, key stores the default calibration constants in EEPROM, overwriting any that may already have been there. Depress the CAL, switch to unlatch it and release the instrument from calibrate mode.

Manual Calibration

Switch on the instrument and enter calibrate mode by depressing and latching in the CAL, switch. The CAL, LED will light.

Start the calibration of the required function by pressing the appropriate function key. Except for Ohms, pressing the AC or DC key will change the selected function and/or start the calibration too. Calibration of a function can be restarted at any time by pressing the same function key again. Calibration of a function will be aborted at any time by pressing any function key. When calibration of a function is started the meter is automatically switched to the range for the first calibration step and the user is prompted for the first input required. A 'c' is displayed in the right most character which indicates calibration mode. The calibration prompt can be replaced at each step by default calculated readings by pressing the AUTO, key.

When the meter reading is stable the 'c' flashes. The pre-programmed stability criteria are different for each function and range. When the 'c' is flashing pressing the RANGE UP, key causes the meter to automatically calculate the step's calibration constant. If the calculated constant is within about 5% of the expected value it is accepted and the meter moves onto the next step.

If the calculated value is unacceptable then 'F' is displayed in the right most character, the meter bleeps and the input reading, calculated using default calibration values, is displayed. One more press of RANGE UP, is required to step onto the next calibration step. The step will also fail to calibrate if the RANGE UP, key is pressed when 'c' is not flashing. A failure at any calibration step will make the calibration for this function unsuccessful and inhibit storage of calibration constants for this function until it is successfully calibrated.

When the last step in the function has been successfully calibrated the 'c' changes to 'P. At this point the STORE, key may be pressed to store the new constants for this function. New calibration constants are stored and old constants over written only when the STORE, key is pressed following a successful calibration.

Calibration constants are stored for all functions that have been successfully calibrated since calibrate mode was entered and the STORE, key was last pressed. If calibration of a function is unsuccessful then no new constants can be stored for that function. If pressing the STORE, key results in new constants being stored then 'CAL donE' is displayed. If no new constants are stored then 'no CAL' is displayed.

When all required functions have been calibrated exit calibrate mode by releasing the CAL switch, the CAL, LED will turn off. If the CAL, switch is released before the new constants have been stored using the STORE, key they will be lost.

Remote Calibration

The user is referred to the instrument operating manual for instructions on how to use the remote interfaces. There are some commands which are only used for calibration while other commands are common to normal operation. Note that the READ? command is common but it operates differently in calibrate mode and normal mode.

It is possible to perform the calibration procedure over either of the remote interfaces. The procedure is essentially the same as described above for manual calibration. The instrument must first be put into calibration mode manually after which the required function can be selected remotely to initiate calibration. See the list of remote calibration commands.

Stepping through the calibration is achieved using the STEPCAL command, which is equivalent to pressing the RANGE UP, key in manual mode. The STEPCAL, command generates a

response which is 'P' if the step calibration was successful and 'F' if it failed. Note that in GPIB or addressed RS232 operation the meter is held up until the response is taken by the controller. If the response is 'F' it is necessary to send another STEPCAL, in order to move to the next calibration step. There is no response to be taken from the second STEPCAL.

After successful calibration of a function the calibration constants may be stored using the STORECAL, command, which is equivalent to pressing the STORE, key.

A facility only available via the remote interface is to set the point at which the calibration of individual steps is performed. This is achieved using the SETCAL, command. The syntax of the SETCAL, command is SETCAL followed by the value of the required calibration input, which is rounded to form an integer corresponding to display reading ignoring the decimal point. For instance if the new calibration point for the 20V DC range is to be 18.0000V then the value sent should be 180000 in any nrf format. The calibration value can only be sent once the meter has been stepped into the range concerned. If the SETCAL, command is not sent then the inbuilt calibration value will be used.

To allow a remote controller to know when the reading is stable the READ?, command may be used. When in calibrate mode the response to this command is inhibited until the meter reading is stable and the 'c' is flashing.

AC Voltage Input Attenuator Frequency Checks and Adjustment

After calibration of the AC Volts function the following checks should be carried out and if necessary adjustments made. VC1, VC2 and VC3 are accessed through holes in the upper aluminium screen. VC1 is adjusted through the rear most hole and VC3 through the hole closest to the front of the meter.

200mV AC

Switch the meter to 200mV AC and check that with an input signal of 200mV at 20kHz the meter reads 195.000 ± 50 digits. If necessary adjust VC1.

2V AC

Switch the meter to 2V AC and check that with an input signal of 2.00000V at 10kHz the meter reads 2.00000 ± 50 digits. If necessary adjust VC2.

20V AC

Switch the meter to 20V AC and check that with an input signal of 20.0000V at 50kHz the meter reads 20.4000 ± 50 digits. If necessary adjust VC3.

DC Volts Calibration

Step No.	Input Value	Comments
1	000.000mV	s/coni/p
2	0.00000V	ditto
3	00.0000V	ditto
4	+200.000mV	
5	+2.00000V	
6	-2.00000V	
7	+20.0000V	
8	+200.000V	
9	+1000.00V	

AC Volts Calibration

Step No.	Input Value	Comments
1	200.000mV500Hz	
2	40.000mV500Hz	
3	2.00000V500Hz	
4	0.40000V500Hz	
5	20.0000V500Hz	
6	200.000V500Hz	
7	750.00V500Hz	

DC Amps Calibration

Step No.	Input Value	Comments
1	000.000mA	o/cinput
2	+200.000uA	
3	+2.00000mA	
4	+20.0000mA	
5	+200.000mA	

AC Amps Calibration

Step No.	Input Value	Comments
1	200.000uA500Hz	
2	2.00000mA500Hz	
3	20.0000mA500Hz	
4	200.000mA500Hz	

Ohms Calibration

Step no	Input value	Comments
1	000.000Ohms	s/c HI to LO on signal and SENSE i/ps
2	0.00000kOhms	ditto
3	100.000Ohms	4-terminal mode
4	1.00000kOhms	4-terminal mode
5	10.0000kOhms	4-terminal mode
6	100.000kOhms	4-terminal mode
7	1.00000MOhms	
8	10.0000MOhms	

Fig. 8 Table of Standard Calibration Values

Remote Calibration Commands

VDC	-	start calibration of DC Volts function
ADC	-	start calibration of DC Amps function
A10DC	-	start calibration of DC 10Amps function
VAC	-	start calibration of AC Volts function
AAC	-	start calibration of AC Amps function
A10AC	-	start calibration of AC 10Amps function
OHMS	-	start calibration of Ohms function
STEPCAL	-	calculate the calibration constant for this step and move on to the next step; invokes response of 'P' or 'F' if first attempt to step calibration, no response if step has already failed.
READ?	-	return the next reading once the reading is stable (operation mode specific to calibration routine but returned value is as described in the operating manual)
SETCAL <nrf>	-	set the calibration prompt to the value <nrf>, value rounded to an integer representing the display value.
STORECAL	-	store calibration constants of any successfully calibrated functions.
AUTO	-	remove the calibration prompt from the display and show the current reading using default calibration constants.

Safety Tests

The following tests will be necessary to ensure that the instrument meets the specified safety standard if the instrument has been damaged or repairs have been carried out.

Equipment required :-

high voltage generator providing 1k5V and 3kV 50Hz.

earth continuity tester operating at 25A

Test 1 - Earth Continuity

Check that the resistance between the earth pin of the mains input socket and any exposed metal part is less than 0.5 Ohm, corresponding to 12.5V at 25A.

Test 2 - Breakdown Between Mains Live/Neutral and Safety Earth

Remove all connections from the measuring inputs. Using a special mains input lead with the live and neutral connections joined together check that there is no breakdown at 1k5V between the live/neutral wires of the power cord (joined together) and the earth wire in the cord.

Test 3 - Breakdown Between The Measurement Inputs and Safety Earth

This test is particularly necessary if the mains transformer or opto isolators have been replaced or the insulator between the rear panel and the IC regulators has been disturbed. This test should be carried out after Tests 1 and 2 if they are also required.

Remove the mains cord from the instrument. Connect the 3kV source between the LO, input terminal and the head of the earth bonding screw on the rear panel. Ensure that there is no breakdown between the two points. Note that there may be AC leakage current up to 100uA, which is permissible.

Parts List

PCB ASSY MAIN - (44812-0540)

Part Number	Description	Position
20030-0263	WASHER M3 ZPST	SCREEN LOWER/SCREEN SPACERS
20037-0301	WASHER M3 SHK/PROOF ZPST	SCREEN LOWER/SCREEN SPACERS
20210-0101	NUT M3 ZPST	SCREEN LOWER/SCREEN SPACERS
20234-0027	SCREW M3 X 6 PNHDPZ ZPST	SCREEN SPACERS, PJ3
22010-0610	BATTERY 3V LITH 20MM BUTTON	BATT
22247-9604	RELAY 1P C/O MIN. LATCHING	RL1,2,3
22312-0242	FUSE CLIPS PCB MOUNTING	FOR FS2
22315-0242	FUSE 10A F HBC 20 x 5mm	FS2
22454-0010	RECEPTACLE RED 187-5	
22573-0041	HEADER2 WAY STRAIGHT	LK2,3
22573-0203	HEADER3 WAY STRAIGHT .156P	PJ5
22573-0205	HEADER5 WAY STRAIGHT .156P	PJ2
22574-0400	SKT9W R/A D-TYPE (RS232)	PJ3
22575-0065	HEADER 20 WAY (2X10) STR SKELN	PJ1
22575-0103	HEADER 16 WAY (2X8) STR SKELN	PJ4
23185-0047	RES4 R7J W25CF RD25S	B/RR19,20
23185-1100	RES 100RJ W25CF RD25S B/R	R9,65,105,110
23185-1220	RES 220RJ W25CF RD25S B/R	R28
23185-1390	RES 390RJ W25CF RD25S B/R	R117
23185-1560	RES 560RJ W25CF RD25S B/R	R56,62
23185-2100	RES 1K0J W25CF RD25S B/R	R2
23185-2150	RES 1K5J W25CF RD25S B/R	R49,64
23185-2180	RES 1K8J W25CF RD25S B/R	R59
23185-2220	RES 2K2J W25CF RD25S B/R	R5,6,27,58
23185-2270	RES 2K7J W25CF RD25S B/R	R14
23185-2330	RES 3K3J W25CF RD25S B/R	R123
23185-2390	RES 3 K9J W25CF RD25S B/R	R3,51
23185-2470	RES 4K7J W25CF RD25S B/R	R70,102,111,114
23185-2560	RES 5K6J W25CF RD25S B/R	R12,100
23185-3100	RES 10KJ W25CF RD25S B/R	R33,50,57,66,99,101
23185-3220	RES22KJ W25CF RD25S B/R	R29
23185-3470	RES47KJ W25CF RD25S B/R	R39,53,118
23185-4100	RES 100KJ W25CF RD25S B/R	R46,69,97,98,104,112
23185-4330	RES 330KJ W25CF RD25S B/R	R45
23185-4470	RES 470KJ W25CF RD25S B/R	R44

PCB ASSY MAIN - (44812-0540) continued/...

Part Number	Description	Position
23185-4560	RES 560KJ W25CF RD25S B/R	R47
23185-5100	RES1M0J W25CF RD25S B/R	R10,48,67,96,106
23185-5220	RES2M2J W25CF RD25S B/R	R68
23185-6100	RES10MJ W25CF RD25S B/R	R32,115,116
23187-1300	RES 300RJ W25CF RD25S B/R	R52
23187-1620	RES 620RJ W25CF RD25S B/R	R8
23187-2510	RES5K1J W25CF RD25S B/R	R4,7
23202-2200	RES 2K00F W25 MF 50PPM	R113
23202-2240	RES 2K40F W25 MF 50PPM	R43
23202-2390	RES 3K90F W25 MF 50PPM	R35
23202-2470	RES 4K70F W25 MF 50PPM	R34,37
23202-2620	RES 6K20F W25 MF 50PPM	R23
23202-2680	RES 6K80F W25 MF 50ppm	R18,38,103
23202-2750	RES 7K50F W25 MF 50PPM	R42
23202-3100	RES 10K0F W25 MF 50PPM	R17,55,63,109
23202-3140	RES 14K0F W25 MF 50PPM	R108
23202-3150	RES 15K0F W25 MF 50PPM	R24
23202-3360	RES 36K0F W25 MF 50PPM	R41
23202-3510	RES 51K0F W25 MF 50PPM	R40
23202-6100	RES 10M0F W25 MF 50PPM	R78
23203-1100	RES 100RF W25 MF 25PPM	R13,121
23203-1910	RES 910RF W25 MF 25PPM	R119
23203-9608	RES 100K 1% 25ppm MF	R120
23204-2470	RES4K7C W25 MF 50PPM	R37
23204-4301	RES 301KC W25 MF 50PPM	R36
23206-4330	RES 330KF W60 MF 50PPM	R75,76,77
23208-2200	RES 2K00F W125 MF 10PPM	R31
23208-3180	RES 18K0F W125 MF 10PPM	R30
23225-2100	RES 1K0J FUSIBLE	R11
23225-4100	RES 100K FUSIBLE	R94,95
23225-4220	RES 220K FUSIBLE	R93
23225-4470	RES 470K FUSIBLE	R1
23296-0030	RES 0R01G 4 TERM 30PPM PBV	R74
23301-0416	RES NETWK SIL 10K X 4S	RP3,4
23310-0010	PREC VOLT DIV NETWK 1776-C4	RP1
23310-0510	PREC CURRENT NETWK 1787-41	RP2
23339-0203	RES MATCHED SET	R15,22,107

PCB ASSY MAIN - (44812-0540) continued/...

Part Number	Description	Position
23386-9201	VARISTOR	V1,2,3,4
23388-9103	THERMISTOR	PTC1
23427-0254	CAP1N0K 100V CER MED K P2.5	C61
23427-0268	CAP22PG 100V CER NPO P2.5	C70
23427-0328	CAP10PC63V CER RD870-6NPO1	C75
23427-0357	CAP33PG63V CER N150 P2.5	C81
23427-9206	CAP15PG 100V CER NPO P2.5	C38,39
23557-0647	CAP 10U 35V ELEC RE2 P2	C14,31,32,33,34,40,41,58,67
23557-0655	CAP 470U 35V ELEC RE2 P5	C43,44,47
23557-0657	CAP 100U 10V ELEC RE2 P2	C12,69,71,80
23557-0658	CAP 100U 25V ELEC RE2 P2.5	C13,49-53,66,68
23557-0659	CAP 47U 25V ELEC RE2 P2	C21,22,35,36,37,56,57
23557-0677	CAP 4700U 25V ELEC RAD P7.5	C45,46
23620-0236	CAP 1N0K 100V P/E 435/1 P5	C72
23620-0246	CAP 100NK 63V P/E P5	C2,10,11,15,16,19,20,24-28,30,42,48,54,55,62,63,65,73,74,76-79
23620-0255	CAP 3N3K 63V P/E P5	C9
23620-9007	CAP 10NK 100V P/EP5	C8
23647-0527	CAP68PF 630V P/S	C6
23648-0002	CAP 330PF 630V P/S	C1
23649-0001	CAP1N0F 63V P/S RADIAL	C7
23685-0006	CAP 3N3J 63V P/P FKP2 P5	C29
23984-0005	TRIMCAP 2-22P P/P 107-2831-022	VC1,2,3
25021-0901	DIO 1N4148 B/R	D6,7,8,9,10,12,14,19,20,21,22
25115-0907	DIO 1N4002 B/R	D1-5,13
25211-9302	RECTIFIER BRIDGE W02G	BR1,2,3
25341-0214	TRAN PNP ZTX214L/BC559	Q2,5,9,10,11,12,14,15,16,17
25341-0215	TRAN PNP ZTX550-L/BC327	Q8
25380-0229	TRAN NPN BC549	Q1,3,4,6,13,18
25383-0506	TRAN NPN BC337	Q7
25386-9901	TRANMOUNTING CLAMP	HEATSINK
25601-0001	TRAN FET (DNJ) BF245A	F4
25601-0400	TRAN MOSFET N CHAN ZVN3306A	F1,6
25601-0410	TRAN MOSFET N CHAN ZVN2106A	F2,5,7
25601-0420	TRAN MOSFET N CHAN BUZ71A	F3
27001-0020	OPTO-COUPLER CNY17-3	IC28,30
27103-0020	IC LM339	IC18

PCB ASSY MAIN - (44812-0540) continued/...

Part Number	Description	Position
27106-0506	IC LM324N	IC20-24, 46
27106-0624	IC AD711JN	IC10,51
27106-0626	IC AD548JN	IC40
27106-0704	IC MC34184P	IC11
27160-0009	IC V/REG 7805 TO220	IC43,44
27160-0011	IC V/REG 78L05 TO92	IC50
27160-0012	IC V/REG 79L05 TO92	IC45
27160-0013	IC V/REG 7815 TO220	IC41
27160-0020	IC V/REG 7915 T0220	IC42
27161-0040	IC LM3999Z	IC16
27164-0502	IC CA3086	IC17
27165-0400	IC AD737JN	IC15
27226-0161	IC CD4016	IC1,3,4,5,8
27226-0400	IC 4040B	IC14
27226-0520	IC 4052B	IC2
27226-0530	IC 4053B	IC6,7,9
27231-0000	IC 74HC00	IC32
27231-0110	IC 74HC11	IC12,29
27231-0270	IC 74HC27	IC19
27231-0740	IC 74HC74	IC13
27231-5730	IC 74HC573	IC36,37
27231-5740	IC 74HC574	IC48
27234-5730	IC 74AC573	IC35,47
27240-9404	IC HD6303XP	IC25
27250-0050	IC 14C88	IC26
27250-0160	IC MC1489P	IC27
27400-0100	IC 27C512 64Kx8 EPR0M 200ns	IC34
27401-0020	IC 93CS56 2K(128x16)SER EEPROM	IC49
27410-0420	IC 32Kx8 CMOS RAM 120ns	IC33
28151-0010	BUZZER C & D TRANSDUCER 40TGPC	BUZZ
28500-0800	XTAL - 4.9152MHZ - MICROPROCSR	XTL1
35555-1750	PCB - MAIN	

PCB ASSY KEYBOARD ASSEMBLY (44812-0550)

Part Number	Description	Position
20105-0510	INSERT THREADEDKF2-M3-ET	
22225-0220	SWITCH PUSH/PUSH	SW1
22226-0140	KEYSWITCH DARK GREY	SW2-16
22573-0056	HEADER 16 WAY STR SIL	FOR DISP1,2
23185-0000	RES ZERO OHM	LINKS
23185-0330	RES33RJ W25CF RD25S B/R	R81-88
23185-0820	RES82RJ W25CF RD25S B/R	R25,26,27
23185-3100	RES10KJ W25CF RD25S B/R	R89-92
23185-3470	RES47KJ W25CF RD25S B/R	R16
23185-4100	RES 100KJ W25CF RD25S B/R	R21
23427-0324	CAP56PG 100V CER N150 P5T	C66
23557-0647	CAP 10U 35V ELEC RE2 P2	C4
23557-0657	CAP 100U 10V ELEC RE2 P2	C60
23620-0246	CAP 100NK 63V P/E P5	C59
25021-0901	DIO 1N4148 B/R	D11,14-18
25061-0200	LED - T1 ROUND (3mm) - RED	LED1-21
25061-9503	DISPLAY - 4 DIGIT LED	DISP1,2
27164-0506	IC ULN-2803A	IC39
27231-5730	IC 74HC573	IC38
35515-1140	PCB - KEYBOARD	
43171-0070	CONN ASSY KEYBOARD/MAIN	

REAR PANEL ASSY - (46812-0500)

Part Number	Description	Position
20030-0263	WASHER M3 ZPST	AC RECEPTACLE
20030-0266	WASHER M4 ZPST	EARTH
20037-0301	WASHER M3 SHK/PROOF I/T ZPST	AC RECEPTACLE, TRANSFORMER
20037-0304	WASHER M4 SHK/PROOF I/T ZPST	BLANKING PLATE/BRACKET OUTER
20037-0401	SOLDER TAG SHAKEPROOF - 4BA	EARTH
20038-9501	WASHER M3 Spring	AC RECEPTACLE, TRANSFORMER
20038-9502	WASHER M4 Spring	BLANKING PLATE, BRACKET
20210-0101	NUT M3 ZPST	MAINS RECEPTACLE
20210-0102	NUT M4 ZPST	BLANKING PLATE, BRACKET
20234-0011	SCREW M3 X 10 PNHDPZ NPST	MAINS RECEPTACLE
20234-0012	SCREW M3 X 8 PNHDPZ ZPST	REAR PANEL/TRANSFORMER SPACERS
20234-0028	SCREW M4 X 10 PNHDPZ ZPST	BLANKING PIECE
20234-0029	SCREW M4 X 12 PNHDPZ ZPST	BRACKET, EARTH

REAR PANEL ASSY - (46812-0500) continued/...

Part Number	Description	Position
20661-0221	SPACER Hex M3 x 20NPBR	REAR PANEL/TRANSFORMER
22115-0240	TRANSFORMER	
22300-9301	FUSEHOLDER Panel Mounting	FOR FS1
22315-9401	FUSE 1A Fast Blow HBC	FS1
22520-0140	AC RECEP FUSED C19271 MS3-DPS	
22520-0500	FUSE DRAWER 230/115 CL19274	
22538-9404	BOOT INS FOR FUSED IEC SKT	
22575-0203	SKT3W .156 20AWG (Yellow) IDT	
22575-0205	SKT5W .156 20AWG (Yellow) IDT	
23386-9201	VARISTOR	FOR FS1
31334-0120	BLANKING PIECE 24W IEEE + SW	
31342-0140	INSULATOR REAR PANEL	
33111-9030	BRACKET MOUNTINGS	
33331-1950	REAR PANEL	
37541-0860	LABEL EARTH BOND POINT	

FRONT PANEL ASSY - (46812-0510)

Part Number	Description	Position
10233-0102	TUBING H/S 4.8MM ID 08886F	
20030-0263	WASHER M3 ZPST	KEYBOARD/SWITCH
20037-0401	SOLDER TAG SHAKEPROOF - 4BA	FRONT PANEL STUD
20038-9501	WASHER M3 Spring	KEYBOARD/FRONT PANEL/SWITCH
20038-9502	WASHER M4 Spring	FRONT PANEL STUD
20210-0102	NUT M4 ZPST	FRONT PANEL STUD
20234-0012	SCREW M3 X 8 PNHDPZ ZPST	KEYBOARD/SWITCH
20234-0027	SCREW M3 X 6 PNHDPZ ZPST	KEYBOARD/FRONT PANEL
20612-0011	WASHER FIBRE M3	KEYBOARD
22225-0221	PUSHBUTTON PB09/50/000 GREY/6	ON/OFF SWITCH
22225-0400	SWITCH PUSH-PUSH PBMS 6018	
22571-0800	SKT 4MM SAFETY BLACK	
22571-0810	SKT 4MM SAFETY RED	
22571-0820	SKT 4MM SAFETY WHITE	
33331-1890	FRONT PANEL	
33331-1900	OVERLAY FRONT PANEL	

CASE PARTS

Part Number	Description	Postion
10220-0100	GROMMET STRIP HEAT RECOVERABLE	SCREEN UPPER, SCREEN LOWER
10232-0305	SLEEVE H20 X 20MML BLACK	
20010-0253	RIVET SNAP-LOCK PLSTC 8x2.5MM	FEET
20030-0263	WASHER M3 ZPST	REGULATORS, SCREEN LOWER, PCB/SCREEN SPACERS
20030-0264	WASHER M2.5 ZPST	FEET
20037-0301	WASHER M3 SHK/PROOF I/T ZPST	
20038-9501	WASHER M3 SPRING	REGULATORS, PCB, SCREEN UPPER, SCREEN LOWER
20062-9303	SCREW NO 6 X 0.5" PNHDPZ ST/AB	IEEE PCB PILLAR
20065-0030	SCREW N0 4 X 3/8"PLASTT PNHDPZ	PCB
20210-0101	NUT M3 ZPST	IC'S/PCB/SCREEN
20234-0011	SCREW M3 X 10 PNHDPZ NPST	FOR IC44
20234-0025	SCREW M3 X 12 PNHDPZ ZPST	FOR IC41,42,43
20234-0027	SCREW M3 X 6 PNHDPZ ZPST	SCREEN UPPER
20234-0038	SCREW M3 X 40 PNHDPZ ZPST	CASE UPPER/LOWER
20234-0042	SCREW M3 X 30 PNHDPZ ZPST	TRANSFORMER
20612-0011	WASHER FIBRE M3	PCB
20661-9301	SPACER HEX STUD M3 x 25ZPST	MAIN SCREEN/PCB
20661-9402	SPACER RND/HEX/ST 1.5"LP	IEEE PCB MTG
20662-0540	FOOT MOULDED GREY 543-248	
22315-0239	FUSE 125MA TL HRC	
22491-0010	MAINS LEAD 2M RA IEC SKT/STRPENDFOR 240V WORKING	OR
22491-0020	MAINS LEAD 2M RA IEC SKT/EURO	FOR 220V WORKINGOR
22491-0010	MAINS LEAD 2/2.5 IEC SKT/USA	FOR 120V WORKING
25386-9901	TRANMOUNTING CLAMP	FOR IC41,42,43
31336-0250	HANDLE BENCH INST CASE (STD)	
31346-0160	SCREEN - PCB LOWER	
31547-0320	SCREEN UPPER	
33536-0810	CASE UPPER BENCH INST (STD)	
33536-0820	CASE LOWER BENCH INST (STD)	
37511-0480	LABEL - GPIB	
37511-0490	LABEL - RS232	
37511-0510	LABEL - RS232/GPIB SELECTOR	
37523-0170	LABEL HANDLE LOGO BENCH INSTR	
37541-0830	LABEL REAR PANEL 1 AMP FUSE	

CASED PARTS continued/...

Part Number	Description	Position
37541-0840	LABEL REAR PANEL MAINS FUSE	
48581-1070	INSTRUCTION BOOK	
48581-1071	ADDENDUM TO INSINS BOOK	
58231-0050	TEST LEAD SET - DMM SAFETY	

PCB ASSY GPIB INTERFACE (44812-0560)

Part Number	Description	Position
20030-0263	WASHER M3 ZPST	INSULATOR/PCB
20038-9501	WASHER M3 SPRING	INSULATOR/PCB
20234-0011	SCREW M3 X 10 PNHDPZ NPST	INSULATOR/PCB
22218-0212	SWITCH SLIDE RA PCB MTG DPDT	SW1
22573-0041	HEADER2 WAY STRAIGHT	LK1
22574-0430	SKT 24W RA IEEE RC10-24R-LNA	PJ1
23185-1100	RES 100RJ W25CF RD25S B/R	R6
23185-2100	RES1K0J W25CF RD25S B/R	R9
23185-3100	RES10KJ W25CF RD25S B/R	R1,2,3,5,10
23185-4100	RES 100KJ W25CF RD25S B/R	R4,7,8
23427-9206	CAP15PG 100V CER NPO P2.5	C7,8
23557-0612	CAP 1U0 50V ELEC RE2 P2	C9
23620-0246	CAP 100NK 63V P/E P5	C1,2,3,4,5,6
25021-0901	DIO 1N4148 B/R	D1,2
27001-0020	OPTO-COUPLER CNY17-3	IC8
27163-1600	IC 75160	IC2
27163-1610	IC 75161	IC1
27231-0050	IC 74HC05	IC4
27231-0100	IC 74HC10	IC5
27240-9403	IC HD6303RP	IC6
27250-0410	IC UPD7210C GPIB	IC3
27400-0080	IC 27C256 32Kx8 EPRM 200ns	IC7
28500-0800	XTAL - 4.9152MHZ - MICROPROCSR	XTL1
31343-0020	INSULATOR - IEEE INTRFC	
35555-1890	PCB - IEEE INTERFACE	
43172-1060	CONN ASSY - IEEE/MAIN	

Manufacturing Changes

From December 1995 a number of changes were made to improve performance, particularly the settling time on AC measurements, and to ensure full compliance with EMC and LVD Directives. The main pcb became Issue 4, the IEEE interface assembly used the same pcb but without IC8 and with a different cable assembly, and the transformer was changed. These parts are not interchangeable with earlier versions. At the same time the software was revised to V1.18; the easiest way to identify instruments built in this way is to check that the software revision (shown briefly at power-up) is V1.18 or later.

Main Pcb: Refer to schematics "Issue 4 onwards". The true RMS converter IC15 was changed from an AD737 to an AD636 which has a faster conversion rate and wider bandwidth; some associated components changed, see below. Analogue gate IC9-C was added to switch the guard track driver, IC20-D; this allows the guard track which surrounds the input signal conditioning tracks to follow the DC input signals more closely by switching in the RC filter for AC function only. Input protection resistors R1 and R93 were changed to a different type with improved thermal EMF characteristics; this required the addition of R122 in series with R1 to maintain the protection.

The opto-coupler providing isolation between the main board and the RS232/IEEE interface was moved from the interface board (was IC8 on that board) to the main board (now IC31); this simplifies the isolation requirements of the connecting flat cable which also changed. A link must be fitted between pins 6 & 7 of PJ4 on the main board when no interface board is fitted. Pcb mounted fuses FS3, 4, 5, 6, 7 were fitted to ensure that the instrument fully complied with the LVD directive by remaining safe under any 'Single Fault' condition.

Main component changes were as follows:

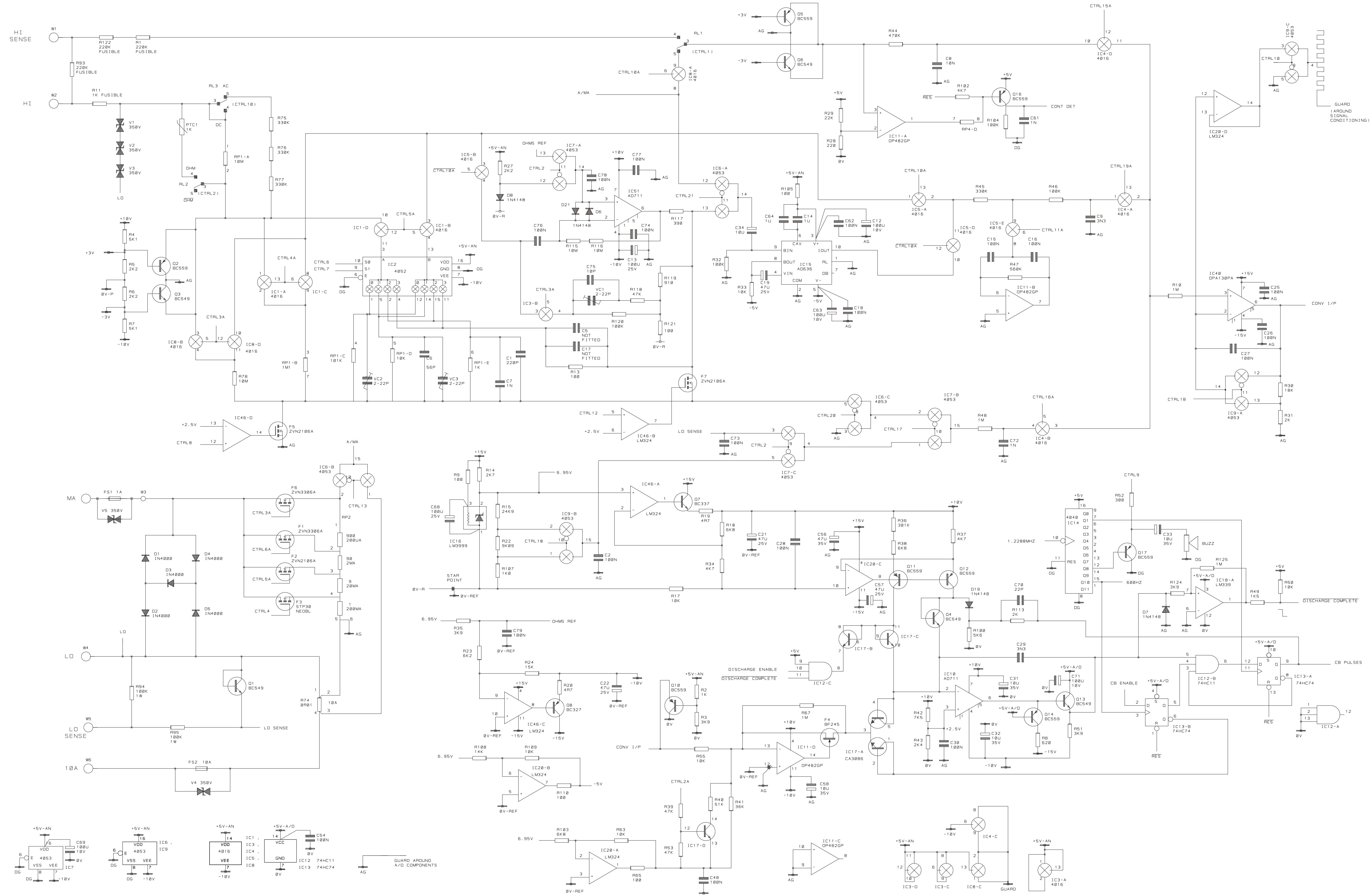
IC15	AD737JN (27165-0400)	AD636KH	(27165-0411)
IC31	-	CNY17-3	(27001-0020)
C14	Cap 10u 35V (23557-0647)	Cap 1u 63V	(23620-0256)
C18	Cap 100N 63V Cer (23438-0007)	Cap 100N 63V P/E	(23620-0246)
C19	Cap 100N 63V P/E (23620-0246)	Cap 47U 25V	(23557-0659)
C63	Cap 100U 16V (23557-0530)	Cap 100U 10V	(23557-0657)
C64	-	Cap 1U 63V P/E	(23620-0256)
R1	Res 470k Fusible (23225-4470)	Res 220k W75	(23209-4220)
R93	Res 220k Fusible (23225-4220)	Res 220k W75	(23209-4220)
R122	-	Res 220k W75	(23209-4220)
R127	-	Res 1k00F	(23202-2100)
R32	Res 10M0F (23202-6100)	Res 100kF	(23202-4100)
FS3,4,7	-	Pcb Fuse 375mAT	(22315-0440)
FS5,6	-	Pcb Fuse 750mAT	(22315-0451)
PJ4	16-way header (22575-0103)	10-way header	(22575-0062)

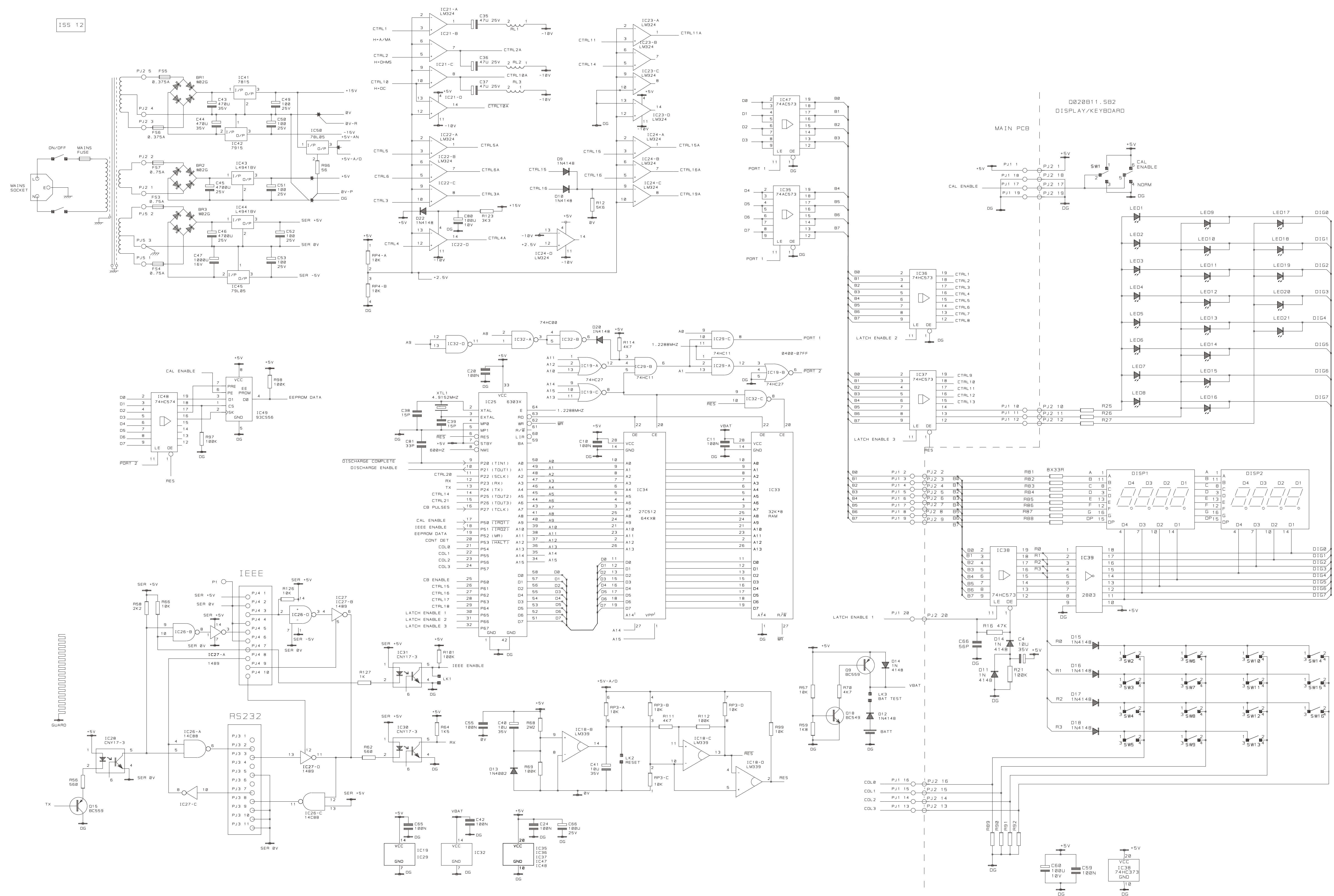
RS232/IEEE Pcb: IC8, R6 and R9 are no longer fitted. The connector assembly changes from 16-way (43172-1060) to 10-way (43171-1460). The part number of the new complete assembly is 44812-0580 (was 44812-0560).

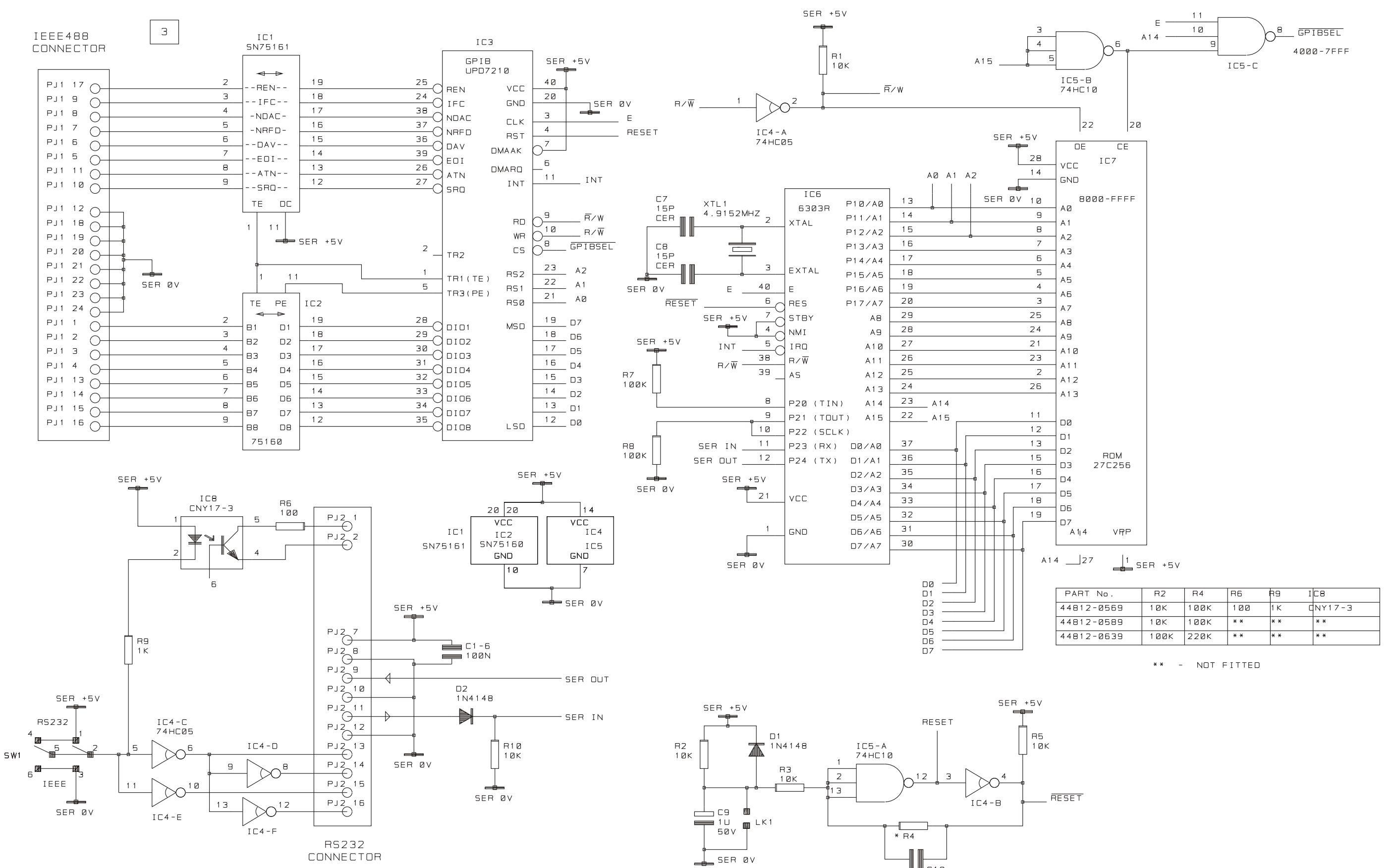
Mechanical: The transformer changes from 20661-0240 to 20661-0241; the electrical specification is the same as before but the new transformer is wound differently to simplify manufacture and has a different pin out. The rear panel also changes to accommodate the revised transformer and is now printed (instead of using labels); the new part number is 33331-2010 (was 33331-1950). Ferrite sleeves 22040-0030 (quantity 2, used on mains wiring and safety earth) and 20040-0040 (used on input socket leads) were added to improve conducted emissions and RF immunity/emissions respectively.

Circuit Diagrams

1. Circuit Diagram – Main Board – Input Signal Conditioning and A/D Converter.
2. Circuit Diagram – Main Board – CPU Section, Keyboard and Display.
3. Circuit Diagram – GPIB Interface Board.









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