DIGITAL VOLTMETER
DVM5

Instruction Manual

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Introduction

Section 1

The Advance digital voltmeter DVM5 is a multi-function, multi-range instrument for measuring d.c. and a.c. volts and resistance with a resolution of 1 part in 20,000. The instrument will autorange over the 5 d.c. and a.c. voltage ranges and 5 resistance ranges. Manual ranging is also provided. Maximum resolution on all voltage ranges is 10μV.

Careful guarding and the use of a 40 ms integration period gives high rejection to the supply frequency. The guard is brought separately to a terminal on the front panel.

The printer B.C.D. output option is fully floating maintaining the high noise rejection even when used with grounded print out systems.

Specification

Display

Maximum reading of 20000 with 5 neon indicators.
Automatic display of range, polarity, over-range and decimal point.
Stored display.
Illuminated push buttons for function and range.

Input

Three terminal floating HIGH, LOW and GUARD.
Maximum voltage ratings:–

D.C. and a.c. voltage ranges.	1kV between High and Low terminals.
Resistance ranges.	100V continuous between High and Low terminals. Protected above 100V by 60mA fuses.
Guard.	200V between Low and Guard terminal. 500V between guard and supply ground.

Reading Rate

5 reading/sec. (approximately).
Front panel hold facility.

Integration Period

40ms. Crystal controlled for 50Hz operation.
33⅓ms. Crystal controlled for 60Hz operation (optional).

Operating Temperature Range

0° – 50°C.

D.C. Volts

Ranges
± 200mV, ± 20V, ± 200V and ± 1000V. Selected automatically or manually.

Resolution
0.005% of range. Maximum resolution 10μV.

Accuracy

30 days 23°C ± 1°C.	90 days 23°C ± 5°C.
± 0.01% rdg. ± 0.01% f.s.	± 0.03% rdg. ± 0.01% f.s.

Temperature Coefficient

10°C to 40°C.

Zero.	± 15 p.p.m. of f.s./°C.
Accuracy. 200mV and 2V ranges.	± 15 p.p.m. of f.s./°C.
Accuracy. 20V, 200V and 1000V ranges.	± 35 p.p.m. of f.s./°C.

Input Impedance
200mV, 2V ranges >1000MΩ
20V, 200V, 1000V ranges 10MΩ

Input Current
30pA max. at 23°C.

Interference
Common Mode rejection of 50Hz, with 1kΩ unbalance, >130dB.
Normal Mode rejection of 50Hz >60dB.

Settling Time
Input filter to 0.1% of final reading, 600ms.

A.C. Volts

Ranges
200mV, 2V, 20V, 200V and 1000V.

Resolution
0.005% of range, maximum resolution 10μV.

Bandwidth
40Hz – 20kHz (40Hz – 2kHz on 1000V range).

Accuracy

	30 days 23°C ± 1°C.	90 days 23°C ± 5°C.
50Hz–10kHz	± 0.1% rdg. ± 0.05% f.s.	± 0.2% rdg. ± 0.05% f.s.
40Hz–20kHz	± 0.1% rdg. ± 0.1% f.s.	± 0.2% rdg. ± 0.1% f.s.

Temperature Coefficient

10°C – 40°C.

Zero.	± 50 p.p.m. of f.s./°C.
Accuracy.	± 65 p.p.m. of f.s./°C.

Input Impedance

200mV and 2V ranges.	2MΩ and 50pF.
20V, 200V and 1000V ranges.	1MΩ and 50pF.

Interference
Common Mode rejection of 50Hz with 1kΩ unbalance >60dB.

Settling Time
A.C. to d.c. converter to 0.1% of final reading 3 secs.

Resistance

Ranges	2kΩ, 20kΩ, 200kΩ, 2000kΩ and 20,000kΩ.		
Resolution	0.005% of range. Maximum resolution 0.1Ω.		
Accuracy		30 days 23°C ± 1°C.	90 days 23°C ± 5°C.
	2kΩ, 20kΩ, 200kΩ ranges.	± 0.02% rdg. ± 0.02% f.s.	± 0.04% rdg. ± 0.02% f.s.
	2,000kΩ range.	± 0.05% rdg. ± 0.02% f.s.	± 0.1% rdg. ± 0.02% f.s.
	20,000kΩ range.	± 0.2% rdg. ± 0.02% f.s.	± 0.4% rdg. ± 0.02% f.s.

Temperature Coefficient	10°C to 40°C.	
	Zero.	± 20 p.p.m. of f.s./°C.
	Accuracy. 2kΩ, 20kΩ, 200kΩ ranges.	± 30 p.p.m. of f.s./°C.
	Accuracy. 2000kΩ range.	± 65 p.p.m. of f.s./°C.
	Accuracy. 20000kΩ range.	± 120 p.p.m. of f.s./°C.

Measuring Current
1mA on 2kΩ range.
100μA on 20kΩ range.
10μA on 200kΩ range.
1μA on 2000kΩ range.
100nA on 20000kΩ range.

Open Circuit Volts
20V Max.

Settling Time

2kΩ, 20kΩ, 200kΩ ranges.	700ms.
2000kΩ range.	1.5s.
20,000kΩ range.	3.0s.

Auto Ranging Delay
Range transition for d.c. and resistance 500ms.
Range transition for a.c. 1.5 seconds.

Supply
200V – 250V a.c. 45Hz – 60Hz 25VA.
100V – 130V a.c. 45Hz – 60Hz 25VA.

Dimensions
20.5cm wide, 9cm high, 30cm deep (8" x 3.5" x 12").

Weight
3.85kg. 8.5 lbs.

Accessories Supplied
Service Adaptor.
Input Leads

B.C.D. Printer Output (optional)
The printer output provides positive-logic buffered B.C.D. 1248 outputs at a rear socket for all digits, ranges, polarity and over-range. Print command and hold or digitise command facilities are provided. All outputs are T.T.L. levels fully isolated from the measurement terminals. (See table 2).

Current Measurement (optional)
Use of the current shunt pack S.P2 will enable currents in the range 200μA full scale to 2A full scale to be manually selected and measured with the following accuracies:–

d.c. ± 0.1% of reading.
a.c. ± 0.3% of reading 40Hz to 10kHz.

3.1 PRELIMINARY

The instrument is despatched from the factory with the supply voltage selector switch, S2, set for 200V–250V a.c. supply voltages. To operate from 100V–125V a.c. supply voltages, set switch S2, which is recessed at the rear of the instrument, to the indicated position with a screwdriver in the slot provided. The supply fuse, FS1, located at the rear of the instrument, is a 20 mm 0.25A SLO-BLO fuse for 200V–250V operation and must be changed to a 0.5A SLO-BLO fuse for 100V–125V operation.

The a.c. supply voltage is connected via the PL71 lead (live-brown; neutral-blue; ground-yellow/green) to the three pin socket at the rear of the instrument marked 'SUPPLY'. The instrument may now be switched on with the front panel switch marked 'SUPPLY'.

3.2 DISPLAY

The display has a maximum reading of 19999. If the reading exceeds 19999 the most significant '2' digit flashes as an indication of overload. On d.c. ranges the input polarity is indicated by plus and minus symbols. The selected function (d.c., a.c. or kΩ) is indicated by illuminating the appropriate push button. The range is indicated by automatically selected decimal points and illuminated range push buttons. When automatically ranging, both the 'AUTO' push button and the selected range push button will be illuminated.

3.3 ZERO

Select the function labelled 'D.C.' and the '0.2V' range push button. Short circuit the 'HIGH', 'LOW' and 'GUARD' terminals. With an instrument screwdriver adjust the zero potentiometer located between the function and range push buttons until the display reads + or – zero. Ensure switch S3, labelled 'MEASURE and HOLD', is in the 'MEASURE' position when the instrument is required to make repetitive readings.

3.4 D.C. VOLTAGE MEASUREMENT

Select the function switch labelled 'D.C.' Now select the range required from one of the five range push buttons. Connect the input voltage to the terminals labelled 'HIGH' and 'LOW' leaving the 'LOW AND GUARD' terminals linked. With the positive of the input voltage applied to the 'HIGH' terminal the instrument indicates a positive reading. Care must be taken not to exceed maximum ratings (see specification).

3.5 A.C. VOLTAGE MEASUREMENT

Select the function switch labelled 'A.C.' Now select the range required from one of the five range push buttons. Connect the input voltage to the terminals labelled 'HIGH' and 'LOW' leaving the 'LOW' and 'GUARD' terminals linked. Connect the 'LOW' terminal to the input point having minimum impedance to ground. Care must be taken not to exceed maximum ratings (see specification).

3.6 RESISTANCE MEASUREMENT

Select the function switch labelled 'kΩ'. Now select the range required from one of the five range push buttons. Connect the resistance to be measured to the terminals labelled 'HIGH' and 'LOW' leaving the 'LOW' and 'GUARD' terminals linked. Care should be taken not to apply excessive voltages to the resistance ranges (see specification).

3.7 AUTOMATIC RANGING

Automatic ranging can be used for any of the three functions. When the push button labelled 'AUTO' is selected, it is illuminated and one range push button is also illuminated, indicating the range selected by the instrument. The range is stepped up (reducing the sensitivity to the input) at any reading greater than full scale reading (19999). The range is stepped down (increasing the sensitivity) at any reading less than 1800. An internal delay is introduced between readings when a range change occurs, allowing time for the input circuits to settle.

3.8 GUARD TERMINAL

The 'GUARD' terminal is connected to the screen surrounding the instrument but insulated from the external case. Normally the 'GUARD' is connected to the 'LOW' input terminal but can be used separately where interference causes an erroneous reading. The 'GUARD' extends the instrument screen to the input source as shown in Fig. 1. For the optimum use of the guard screen it should be connected with minimum impedance to the Low input and as near to the input source as possible. This will intercept common mode noise interference, reducing errors in the reading due to the noise current flowing to ground through impedances in the 'HIGH' and 'LOW' inputs. Care must be taken not to exceed the voltage ratings between 'GROUND' and 'GUARD' (500V) or 'GUARD' and 'LOW' (200V).

3.9 HOLD FACILITY

The front panel slider switch has two positions, 'Measure' and 'Hold'. In the 'Measure' position, the instrument continuously makes measurements at a rate of approximately 5 per second. In the 'Hold' position, the instrument retains the last reading. If applying a step input of >500V d.c. from a low impedance source, connect a 330Ω resistor in series with the high terminal, otherwise an unwanted reading may occur.

3.10 PRINTER OUTPUT OPTION

The printer output unit provides isolated data at a 36 way socket mounted on the rear panel. The data outputs are reading, polarity, overrange and range in B.C.D. code. The numerical data is in parallel positive logic. (See table 2).

The instrument may be held from making measurements by holding the digitise input low. There are two methods of commanding a measurement. With the front panel slider switch in the 'Measure' position the instrument will measure at approximately 5 times a second while the digitise input is high (+ ve). With the front panel slider switch in the 'Hold' position, the instrument will start a measurement cycle the instant a + ve edge is applied to the digitise input. Care should be taken to ensure a clean + ve edge.

A print command signal is generated at the end of a measurement. When auto-ranging the print command is inhibited until the instrument is on the correct range.

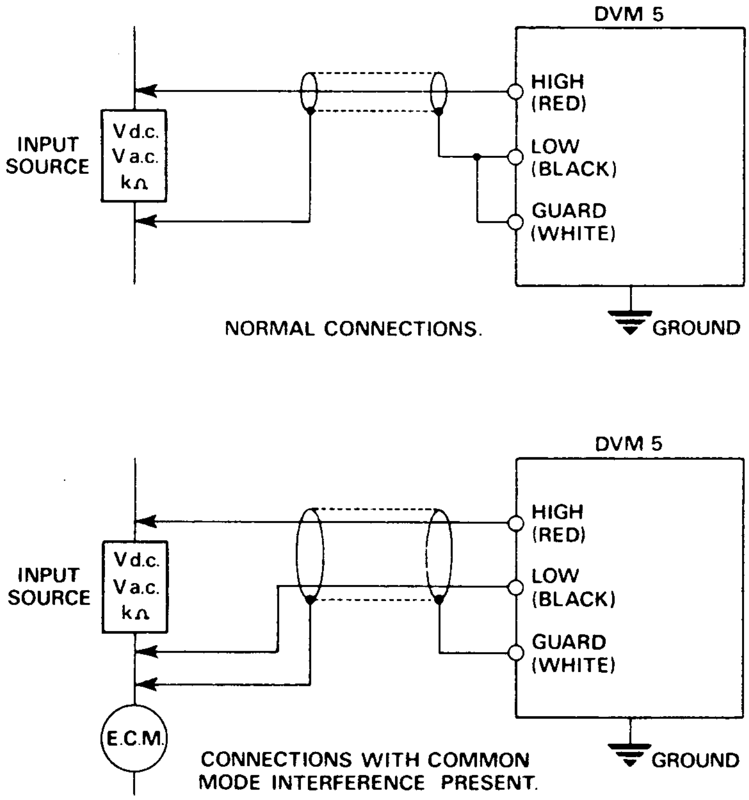


Fig. 1 Use of the Guard Terminal

4.1 POWER SUPPLY (Figs. 9, 10)

The instrument has four stabilized supplies and one voltage doubled half wave rectified supply. The a.c. supply is connected to the primary of T1 via the on-off switch, S1; the protection fuse, FS1; the input filter, L1, C1, C2 and the voltage selector switch, S2. The primary winding is enclosed by screens, 1 and 2, which are connected to the input supply ground. Screen 3 and the frame of the transformer are connected to the guard screen. Screen 4 is connected to the 0V rail of the instrument. The +24V relay supply is obtained via the bridge rectifier, MR201, stabilized by TR230 and TR231, and protected by the fuse, FS201. The +5V digital logic supply is obtained via the bridge rectifier, MR202, stabilized by TR232, TR233 and TR234, and protected by the fuse, FS202. The +5V line is dependent upon the +24V line since the +5V reference Zener, D207, is supplied from the +24V line. The +190V numeric indicators anode supply is voltage doubled and half wave rectified with C215 and D204. The +15V and −15V analogue circuitry supplies are obtained from a bi-phase winding and bridge rectifier, MR301. The +15V line is stabilized by IC307 and TR331 and protected by the limiting resistor, R388. The −15V line is stabilized by IC308 and TR332, and protected by the fuse, FS301.

4.2 PRINCIPLE OF OPERATION (Fig. 2)

The analogue to digital conversion is basically of the dual slope type. The dual slope integration method is to convert a d.c. input voltage to an accurately proportioned time interval displayed by a digital readout. This is achieved by an integrator Fig. 2.

where $$Vo = -\frac{1}{RC} \, Vin \, dt$$

Assume that the output of the integrator is zero. Switch Vin (constant d.c.) to the integrator for time, T2.

then $$Vo_1 = -\frac{Vin\,T2}{RC}$$

After T2 switch to Vref (opposite polarity to Vin) the integrator will return to zero in unknown time, T5.

Similarly: $$Vo_2 = \frac{Vref\,T5}{RC}$$

$$Vo_1 = -Vo_2$$

or $$-\frac{Vin\,T2}{RC} = \frac{Vref\,T5}{RC}$$

$$\therefore T5 = \frac{Vin\,T2}{Vref}$$

$\frac{T2}{Vref}$ is constant $\therefore$ $\underline{\underline{T5 = kVin}}$

Note that the reading is independent of the values of R and C, and also of the oscillator frequency.

In DVM5 the dual slope integration method is applied in the following manner. A d.c. voltage from the input signal conditioning circuits is applied to the integrator via switch, S1, (Fig. 5) for a period of 40ms (T2, The fixed period of 40ms is defined by counting down the 500kHz crystal oscillator. After 40ms (T2), the output of the integrator amplifier will attain a voltage proportional to the input voltage (Fig. 6). At this point, the polarity of the input is determined by the comparator amplifier and S1 is switched off. An internal reference voltage of the same polarity as the input voltage, is now applied to the integrator via switch, S2 (+ve ref.) or S3 (−ve ref.), for 20μS (T3). The integrator amplifier ramps further away from zero at a constant rate for this period. Immediately, the opposite reference voltage is applied and the integrator output ramps at a constant rate towards its original voltage. After a further delay of 20μS (T4), the counter is used to measure the time (T5) to regain the original voltage. The count is displayed to indicate the voltage being measured. Between measurements (period T6), S1, S4 and S5 are closed, putting the d.c. amplifier, integrator amplifier and comparator into a zero correction loop with the error voltage being stored on the zero correction capacitor (Fig. 5).

Note that if a 600kHz crystal is fitted, the integration period becomes $33\frac{1}{3}$ ms.

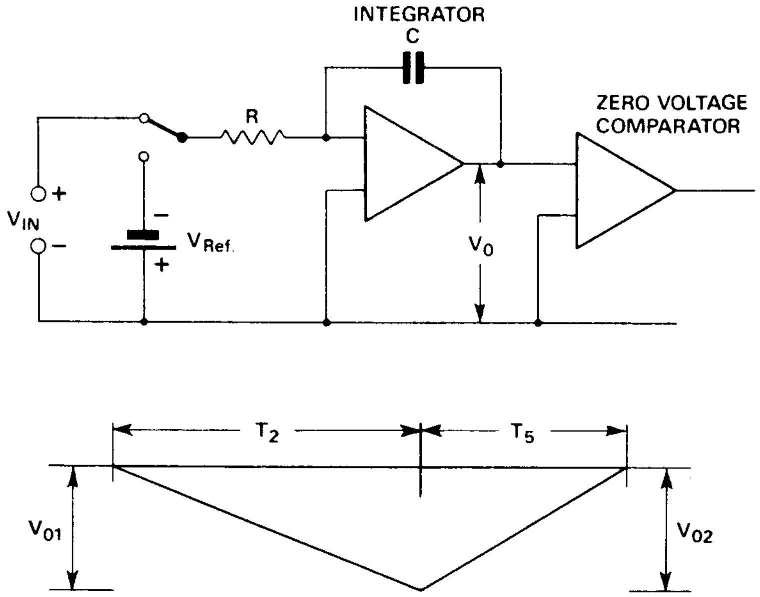


Fig. 2 Simplified dual slope integrator

4.3 CRYSTAL OSCILLATOR (Fig. 9)
The 500kHz oscillator consists of two T.T.L. logic inverters, IC225d and IC225e, d.c. biased into their active region and a.c. coupled by C207. The 500kHz series resonant crystal, X201, applies the feedback. IC225f is an output buffer. An optional 600kHz crystal is available for use with 60Hz supplies to maintain the normal mode rejection performance.

4.4 MEASUREMENT TIMER (Fig. 9)
A reset pulse is used to initiate a measurement and is obtained from the unijunction, TR226, which triggers approximately 5 times a second and is synchronised to the a.c. supply frequency. When the instrument "Auto ranges", the subsequent measurement is delayed by temporarily adding capacitors in parallel with C212 to allow sufficient time for the analogue circuits to stabilize, preventing premature range change decisions. For the d.c. and kΩ functions, C211 is switched in parallel with C212, and for the a.c. function a longer delay is obtained by switching both C211 and C210 in parallel with C212. The front panel switch, S3, in the 'measure' position, connects the reset pulse to TR223 and buffer, IC225a, allowing readings to be taken at 5 times a second. When S3 is in the 'hold' position no measurement will take place. If a printer output unit is fitted the measurement rate is under external control (see printer output section 4–8).

4.5 DISPLAY (Fig. 9)
The display consisting of 5 numerical indicator tubes and a plus/minus indicator for d.c., has an anode supply of +190V. The cathodes of the 10^0, 10^1, 10^2 and 10^3 decades are driven from B.C.D. to decimal decoder integrated circuits, IC201–204. The B.C.D. inputs, stored by 4 quadruple latch integrated circuits, IC205–208, are loaded from the counter at the end of each measurement by a pulse from TR217. The '0' and '1' cathodes of the 10^4 decade are driven by TR215 and 216 from the B.C.D. stored by IC209. The '2' cathode of the 10^4 decade is pulsed by transistor, TR214, driven from a multivibrator, TR212–213. The multi-

vibrator is gated 'on and off' by the output of the storage integrated circuit, IC209. The 'plus' and 'minus' indicator, ILP206, is driven by TR210 and TR211 from the polarity information stored by IC209. When a.c. or kΩ functions are selected, ILP206 is turned off by closing contact, S107b, reducing the anode voltage.

The lamps illuminating the function switches, ILP103, ILP104 and ILP105, are operated from the relay supply switched by the function switches. ILP106 illuminating the Auto ranging lamp, is operated from a contact on the Auto ranging switch. The lamps illuminating the ranges are selected and switched by the appropriate range relay drive from IC216 (see 4–8).

4.6 COUNTER AND TIMING BISTABLES (Figs. 6, 9)

The counter consists of four individual decades, IC210–213, and two divide by two bistables, IC214ab, to give a count from 00000 to 39999. At the start of a measurement the counter is reset to 19000, reset is also applied to bistables, IC218a, IC218b and IC226a cross coupled with IC226c. The output of IC218b is used to switch the d.c. amplifier to the input. The clock input gate, IC226b, is now open, applying the 500kHz clock to the counter input. After 1000 counts (2ms period T1), the counter reaches 20000, and the output of IC214b is used to clock IC218a, switching the integrator to the d.c. amplifier. After a further 20000 counts (40ms T2), the counter reaches 00000 and the output of IC214b clocks IC218a, switching off the integrator from the input, similarly the output of IC214a clocks IC218b, switching the amplifier from the input signal to zero volts. The output of IC218a defines the 40ms period (T2) for integrating the input; IC218b defines the period 'reset' to the end of the 'input integration' (T1 and T2). The output of IC218b is also applied to the 'clear' input of IC217b, closing the gate, IC221b between the 1st and 2nd decade. After 10 counts (20μS T3), the output from IC210 clocks both inputs of IC217, IC217a which is now enabled by IC217b, changes state to define the time to 'reverse the references'. This in turn enables IC217b which changes state at the next clock pulse, producing a further delay of 10 counts (20μS T4). Gate, IC221, is now open and the counter continues until a stop pulse (T5) reverses the state of IC226a, IC226c, closing the gate, IC226b. The information in the counter is now loaded into the storage integrated circuits. The train of clock pulses are gated to the printer output for the periods, T1, T2 and T5, by IC226d, IC217b closes the gate for the period, T3 and T4.

4.7 REFERENCE SELECTION AND STOP (Figs. 6, 8)

The cross coupled bistables, IC305a–IC306a and IC305d–IC306c, are used to select the references and the output of IC306b 'Low' defines 'stop'. IC218a holds the bistables in the 'reset state', inhibits the 'stop' output and reference selection during the period T2.

The buffered output of the comparator, IC303, is fed to the select negative reference bistable (IC305d, IC306c) and the inverse to the select positive reference bistable (IC305a, IC306b). After period, T2, when IC218a changes state, the input has been integrated causing the output of the comparator to be positive or negative and setting the appropriate reference selection bistable. IC309 reverses the information and selects the opposite reference for the period, T3, until the output of IC217a and its inverse from TR321, changes state; IC309 now selects the correct reference. After a time, T4 + T5 (T5 is proportional to the input voltage), the comparator output will change state, selecting the opposite reference bistable, enabling 'STOP' gate IC306b. 'STOP' inhibits any further reference selection. IC304a which selects the negative reference, also sets the polarity memory bistable, IC224a, IC224b.

4.8 RANGE SELECTION MANUAL AND AUTO (Fig. 9)

The instrument's range is selected by a 4 bit 'up-down' counter, IC215, which is fed into a B.C.D. to decimal decoder, IC216. IC216 with open collector outputs directly drives the range relays and the lamps illuminating the range buttons. IC216 also drives transistors, TR218–221 which are inverting buffers, selecting the correct decimal point driver transistors. For manual range selection, the 'load' input of IC215 is held at 0V (Low) by S106a, the 'AUTO' switch, making the B.C.D. outputs entirely under the control of the data inputs. The five manual range switches are wired to address the data inputs with B.C.D. 0–4 for the ranges 1–5. For automatic range selection the load input of IC215 is held high (+ve) by R242 so that the counter is under the control of the count-up and count-down inputs. The count-up and count-down gates, IC220a and IC220c, are strobed by a short pulse, generated by IC223 and IC225, from the stop signal low (–ve edge). A count-down will occur when the bistable, IC221c and d, remains reset because the reading is less than 1800 and the lower range limit (1) is not detected by IC219b. A count-up will occur when a reading of greater than 19999 is reached (IC214a) and the upper range limit (5) is not detected by IC219f. When a range change is detected by bistable, IC222b and c, the stop signal in the printer output is inhibited and IC219d selects the extra delay on the measurement timer. If a range outside limits is selected, IC220b will reset the range counter.

4.9 F.E.T. SWITCHING CIRCUITRY (Fig. 8)

The f.e.t. driver transistors are connected between the +15V line and –15V line. These are driven by transistors switched from T.T.L. logic levels connected to the 0V line. All the field effect transistor switches are of the N channel junction type. When a driver transistor is turned off its collector is pulled down to –15V, forward biasing the diode in series with the f.e.t. gate. A current flows through the high value resistor connected between the gate and source of the f.e.t. biasing off the switch. When the driver transistor is turned on (fully saturated), the collector is at +15V, reverse biasing the diode in series with the f.e.t. gate. The high value resistor between the gate and source holds the f.e.t. with zero bias and turned on.

4.10 D.C. INPUT AMPLIFIER (Fig. 8)

The input amplifier integrated circuit, IC301, preceded by a f.e.t. pair, TR303 and TR304, is connected in a non-inverting configuration to provide extremely high input impedance. The output swings of the amplifer is ±6 volts for the 0.2 and 2 volt ranges, with the gain being accurately determined by the feedback divider, R318, R319 and R321. TR350 is a constant current supply for TR303 and TR304, and R311 and R312 are adjusted to balance the gate source voltages. R410 and R408 bootstrap the drain supply on the 2 volt range but TR333 is used to switch the drain supply to the +15V line for the 0.2 volt range. R320 adjusts the gain on the 2 volt range only. TR301 and TR302 are series shunt switches, where TR301 connects the amplifier to the input voltage for the periods, T1 and T2 (Fig. 6). TR302 connects the amplifier input to zero volts via R333 for the periods T3, T4, T5 and zero correction period T6. A zero voltage offset is applied to the source of TR302 by feeding a current into R333 from R322 and R180, the zero adjust potentiometer. The bias resistors, R315 and R316, for TR301 are bootstrapped to the amplifier feedback point while TR301 is turned on. TR306 shorts the junction of R315 and R316 to 0V while TR301 is biased off (periods T3, T4, T5 and T6).

4.11 INTEGRATOR AND COMPARATOR (Fig. 8)

During the zero correction period, T6, the integrating amplifier, IC302, is connected to the d.c. amplifier via TR307 and the integrating resistor, R324. The output of IC302 will integrate positive or negative due to feed-back applied by the integrating capacitor, C309, and depending upon the polarity and amplitude of the com-bined offsets of the input amplifier and IC302. The high gain, high speed comparator amplifier, IC303, has its inverting input connected to the output of IC302 and its non inverting input referred to 0V. The output of IC303 is fed back to the non-inverting input of IC302 via TR310, completing the correction loop. The sum of the amplifier offset voltages to keep the comparator in its active region (0V–5V) with the d.c. amplifier input at zero volts, is stored on the correction capacitor, C310. C310 provides bias to IC302 via an impedance buffer f.e.t. TR309, during the measurement periods. At the start of a measurement, TR307 and TR310 are switched off. After a period, T1, when the input d.c. amplifier has settled, TR307 is switched on again and the input is integrated for the period, T2. The output of IC302 integrates positive for negative input voltages, since IC302 is connected in the inverting mode. The output of IC303 saturates at +0.2V for a positive output of IC302, and +4.5V for a negative output of IC302. After period, T2, TR307 is switched off and the logic determines the input polarity from the output of IC303. A reference voltage of the same polarity as the input voltage is switched on to R324, by TR311 positive ref. or TR318 negative ref. and integrated for a period, T3. The opposite polarity reference is selected by the logic after T3 and the output of IC302 ramps towards its original voltage during periods, T4 and T5. When the original voltage is reached, IC303 output changes state to define 'STOP' – the end of period T5 and start of T6.

4.12 REFERENCE VOLTAGES (Fig. 8)

The reference voltages are obtained from two very stable reference diodes driven by stable constant current supplies. TR312 and D314 are used as a zener diode reference for TR313 supplying the constant current for the positive reference, D313. The negative reference, D316, is similarly driven by TR319, D317 and TR320. The amplifier, IC310, is connected in the non-inverting configuration with a gain of 1 and is used to bias the reference diodes to the d.c. amplifier output offset voltage to which the integrator was corrected. The input of IC310 is clamped by diodes, D326, D328, D329 and D330, when the output of IC301 exceeds 1.6 volts. The resistors, R337 and R338, and the potentiometer, R329, add to the integrating resistor, R324, while the positive reference is selected and are adjusted to calibrate the instrument for negative inputs on the 0.2V range. Similarly R350 and R351, and potentiometer, R352, are used to calibrate the instrument for positive inputs on the 0.2 volt range.

4.13 D.C. VOLT RANGES (Figs. 7, 8)

For 0.2 volt and 2 volt ranges, RLD connects the HIGH input terminal to the d.c. amplifier input via the two stage input filter, R106/C301 and R301/C302. The amplifier gain is switched from X30 for the 0.2 volt range, to X3 for the 2 volt range. The input is protected by R106 caught by ILP101 and again by R301/R407 into D301/D302. For the 20, 200 and 1000 volt ranges, RLA connects the 10MΩ divider chain across the input. The input is first divided by 100 (adjusted by the potentiometer, R102) and is then connected to the d.c. amplifier input by RLE for the 20 volt (amplifier gain X30) and 200 volt (amplifier gain X3) ranges. The divide by 1000 attenuator step (adjusted by the potentiometer R104) is connected to the d.c. amplifier by RLF, for the 1000 volt range.

4.14 AC–DC CONVERTOR (Figs. 3, 7)

The a.c. input voltages are converted to d.c. by diodes, D107 and D108, incorporated in the a.c. amplifier feedback path. The amplifier has a f.e.t. pair, TR106 and 107, to provide high impedance and low bias current inputs. This is followed by TR108, an inverting amplifier stage; TR109 an emitter follower; and the output transistor, TR110, a further inverting amplifier stage. The d.c. gain (X3) and output bias (−5V) are defined by R161 and R158, decoupled to a.c. signals by C117. The amplified a.c. output is coupled by C118 to D107 and D108. The rectified outputs are recombined in R167 and R133, to reform the a.c. waveform which is applied as negative feedback by C117. The positive half cycle from the anode of D108 is filtered by three stages, R170, C119, R171, C120, R172 and C121, and switched to the d.c. amplifier input. The a.c. gain (X5) of the positive half cycle is defined by the ratio of R181 + R168 to R167 + R133. Potentiometer, R169, is connected as a voltage divider to adjust the a.c. 2 volt calibration. RLH_2 connects the output to the potentiometer, R184, to calibrate the 0.2V range. The a.c. zero is set by feeding a current into R133 from R179 and the zero potentiometer, R178.

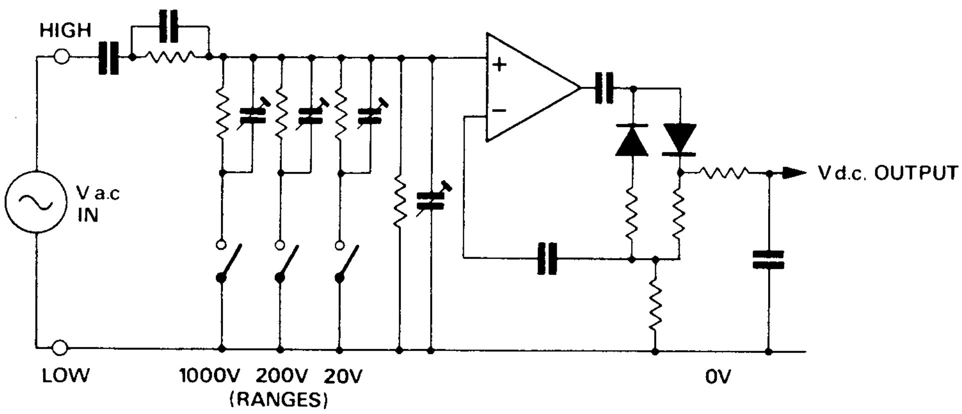


Fig. 3 A.C.–D.C. converter

4.15 A.C. VOLTAGE RANGES (Fig. 7)

The a.c. voltages are applied to the attenuator via the d.c. blocking capacitor, C104, and switch, RLB_1. For both 0.2V and 2V ranges, R144 and R151 divide the input by 2 and the d.c. amplifier is used to amplify the a.c. converter output, 0.2V (X30) and 2V (X3). For the 20V, 200V and 1000V ranges, resistors are switched in parallel with R151 to further attenuate the input. The attenuation, 20V (X.05), 200V (X.005) or 1000V (X.0005), is switched by RLK_2, RLL_2 and RLM_2. All the attenuator resistors are compensated for the upper working frequencies, by capacitors fitted in parallel. C106 is switched in parallel with C105 for additional compensation on the 0.2V and 2V ranges. The amplifier is protected against input overloads by the diodes, D103 and D104 (normally bootstrapped) clamping the input to the limiting output. D101 and D102 are to protect the contact, RLN_1, when it is open.

4.16 RESISTANCE MEASUREMENT (Figs. 4, 7)

For resistance measurements, the unknown resistance (Rx) is converted to a proportional voltage by connecting it in the feedback path of an inverting amplifier. Hence the unknown (Rx) defines the amplifier voltage gain by feeding back an equal and opposite current to the reference current applied. The amplifier input is a virtual earth, so when Rx is zero ohms, the output voltage is zero volts.

The ampliifer has a f.e.t. input pair, TR103 and TR104, to provide high input impedance and low bias current to the integrated circuit, IC101. TR105 is biased as a constant current supply to the sources of TR103 and TR104. The reference current is derived by switching the appropriate accurate resistors to the stable reference diode, D110, by means of the range relays. D110 is supplied with a stable constant current from TR102. The amplifier zero is adjusted (R133) by providing the necessary voltage offset to the gate of TR104 from the potential divider, R132 and R131. The output to be measured is switched to the d.c. amplifier from the potentiometer (R140 2kΩ CAL) connected across R139 in the output potential divider chain, R138, R139 and R143.

The ranges 20kΩ, 200kΩ and 2000kΩ, are calibrated by adjusting the reference resistors, which are increased from the fixed R101 (2kΩ range) in decade resistance steps. The 20,000kΩ range is calibrated by adjusting the voltage reference to R116 from the voltage divider, R117, R118 and R120, which is across D110. The RESISTANCE CONVERTER is protected against input voltages applied in error, by D150 and D151 clamping the amplifier input to the ±15V supplies, and D115 and D117 clamping the amplifier output. Fuses, FS2 and FS3, (60mA) protect against excessive voltages applied to the kΩ ranges.

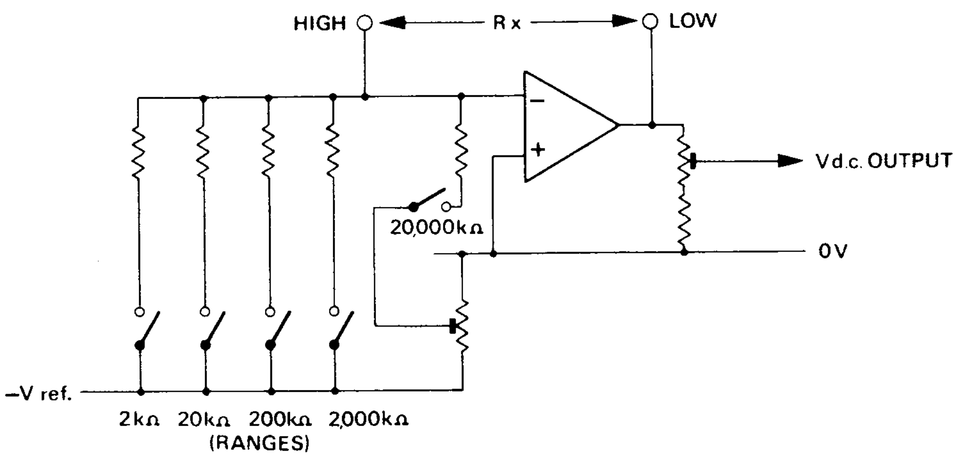


Fig. 4 Ohms–D.C. converter

4.17 PRINTER POWER SUPPLY (Fig. 10)

The a.c. voltage from the secondary of the transformer, T1, (in the Main frame of the instrument) is rectified by the bridge rectifier, MR501, and smoothed by the capacitor, C508. The d.c. from C508 is applied to the Monolithic Voltage Regulator, IC518, and the output is decoupled by C509–512. The monolithic circuit used has high stability, low ripple output and is protected against overloads and short-circuits at the output. All circuits directly connected to the instrument are powered by the internal +5V guarded supply of the instrument.

4.18 PRINTER OUTPUT INTERFACE CIRCUITS (Fig. 10)

In order to provide an isolation of 1000 volts between the instrument and the printer, two types of interfacing circuit are employed. The signals from the instrument which give the reset, polarity and range B.C.D. (1,2,4) information, are interfaced through optical coupler circuits. The optical couplers consist of a light emitting diode (l.e.d.) and a photo transistor contained in a 6 lead dual-in-line package. Each signal is inverted and buffered by a TTL inverter, coupled through the optical device and further inverted and buffered by another TTL inverter.

After interfacing, the polarity signal is fed to the bistable formed by IC504 c & d. After the reset pulse has been interfaced, it is used to reset the polarity bistable and the dual J.K flip-flop, IC506, which provides the B.C.D. (1,2) signals for the 10^4 decade. This reset signal is inverted by IC515f and used to reset the decade counters, IC511–514.

The train of 500kHz clock pulses from the instrument (IC226d) is inverted and buffered by a TTL inverter, IC501d, and capacitor coupled by C503, into the primary of the pulse transformer, T501. The signal from the secondary of the transformer is shaped by the Schmitt Trigger formed by IC504a and IC515b, then buffered and inverted by IC515c.

The "stop on range" signal is interfaced by an optical coupler circuit and used to load the storage devices on the output board. This signal is capacitor coupled (C505) into the monostable print command pulse generator formed by IC504b and IC515d. The value of C506 may be adjusted, if necessary, to vary the length of the pulse. $T \simeq 0.7C$ (T in ms, Cin/μF). IC515e is used to buffer out the pulse which may be either positive going or negative going (from +5 volts). The sense of the pulse is determined by an adjustable link – see section 3 and table 2.

The hold/digitize circuit is operated by applying either a high or a low load to the hold/digitize pin. The hold output (connected to the instrument) provides an inversion of the level on the pin. If a positive-going edge is applied to the pin, the digitize output will give a low-going pulse from the monostable circuit formed by IC502a and b. This pulse is inhibited from occurring again until the measurement which the last pulse initiated, has been completed.

4.19 PRINTER B.C.D. OUTPUT (Fig. 10)

The counter chain on the B.C.D. Output board is very similar to that in the instrument itself. The chain consists of a dual J.K flip-flop, IC506, and four decade counters, IC511–514. The reset signal from the interface circuits sets the chain to a reading of 19000. The B.C.D. outputs from the counter chain and the polarity bistable are stored in the quad latches, IC505 and IC507–10. The information stored in these devices is transferred to the printer when they are loaded by a pulse from TR501 which is driven from the "stop-on-range" interface circuit.

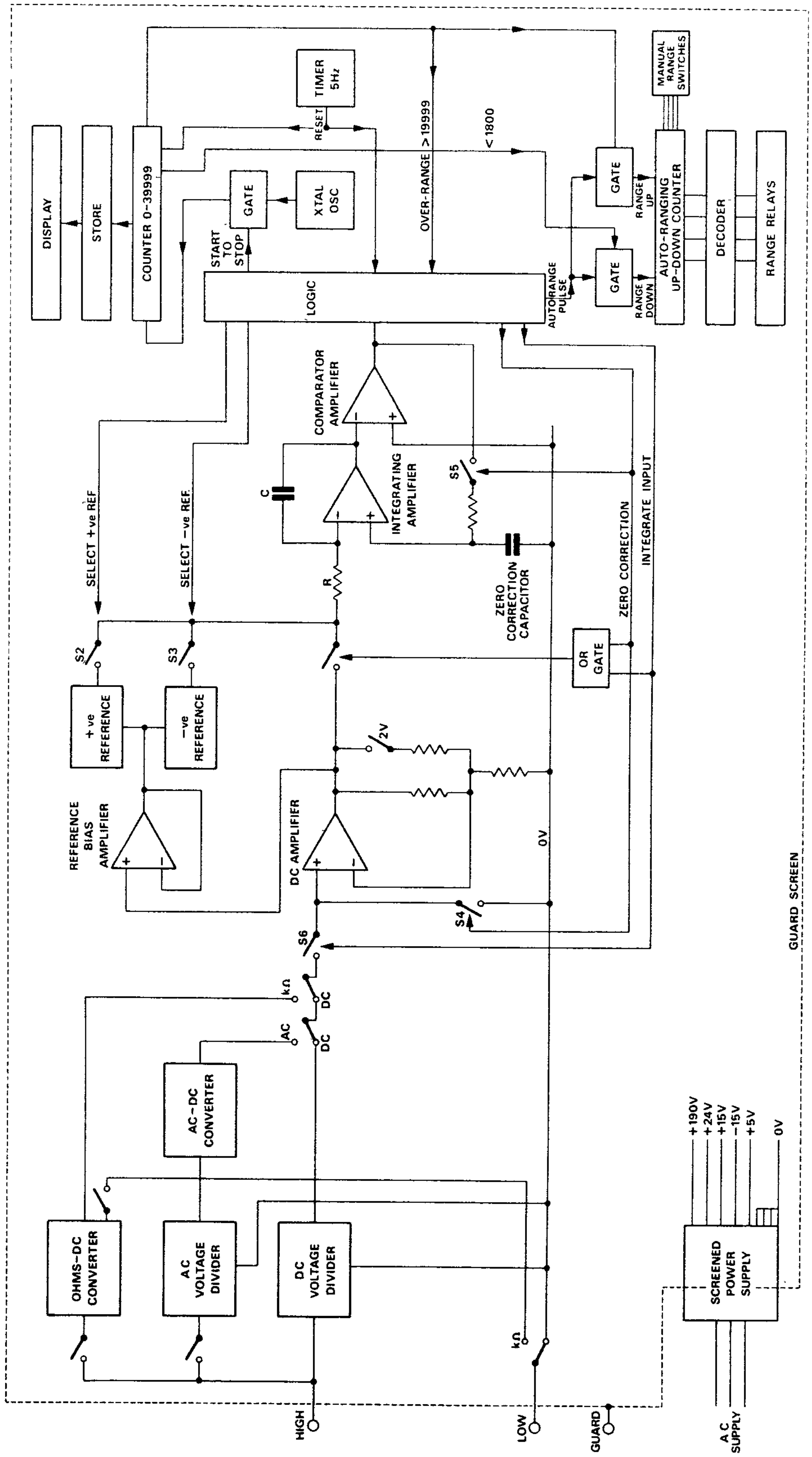


Fig. 5 Block Diagram

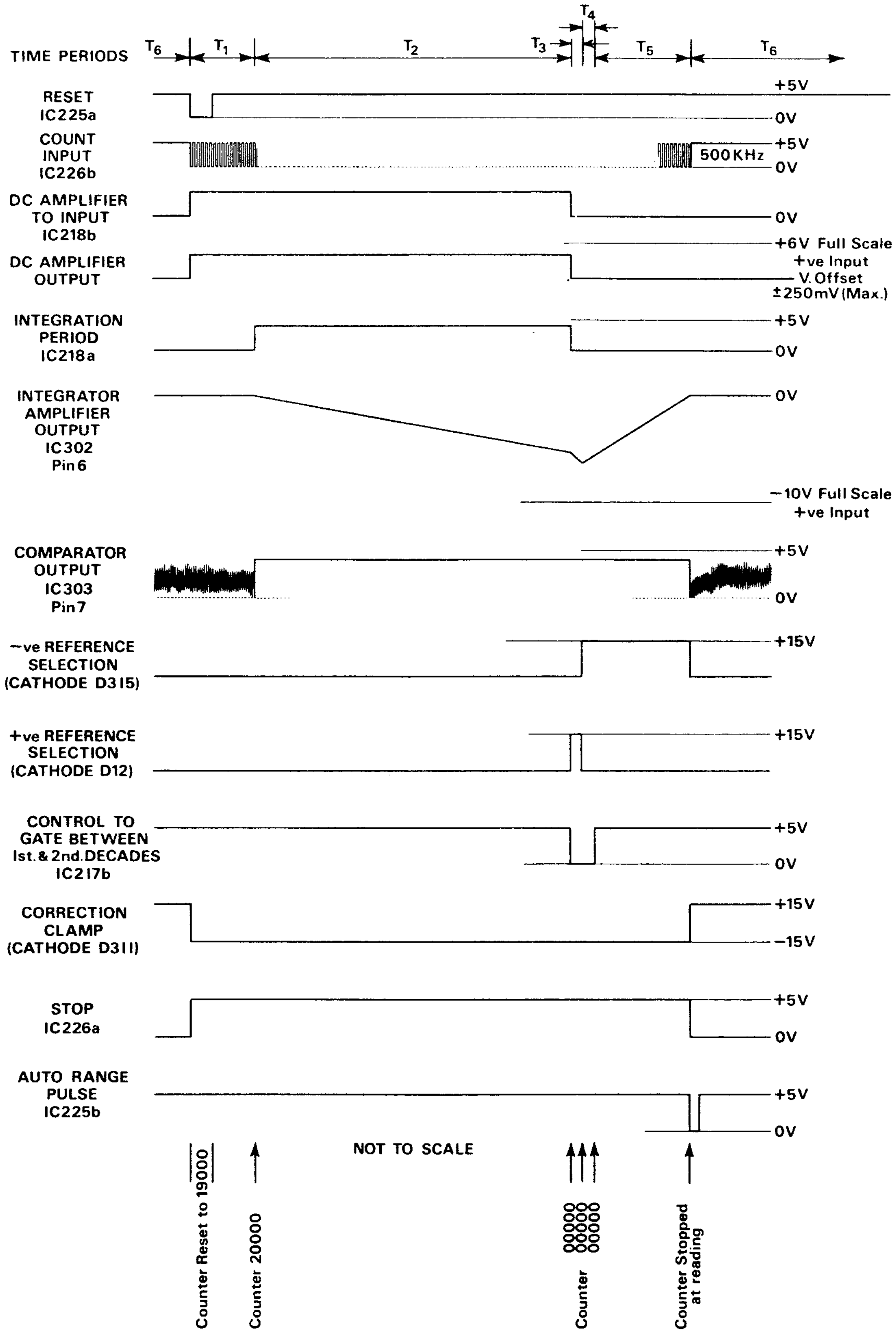


Fig. 6 Timing Diagram

5.1 DISMANTLING THE INSTRUMENT (Figs. 11, 12, 13)

Disconnect the a.c. supply to the instrument to prevent accidental short-circuits. Also disconnect any input which is connected to the guard screen. The top and bottom covers may be taken off after removing the four fixing screws. By removing a further four screws the top and bottom guard screens may be removed.

To remove the top printed circuit board (analogue board), take out the seven retaining screws shown in Fig. 11. Lift the board vertically from the instrument until the socket at the rear is disconnected. The board will still be joined to the instrument by the coaxial input lead but this is long enough to allow the board to be operated on the servicing adaptor provided (see section 5.5). However, to remove the board completely, unplug the input lead from the sockets, SKD and SKE, on the bottom board (ranging board).

To remove the bottom printed circuit board (ranging board), disconnect the lead from the HIGH and LOW in-put terminals by removing the 'Faston' connectors Fig. 11. Disconnect the output lead from SKD and SKE. Remove the six fixing screws and slide the board forward until it is clear of the multiway socket, SKF Fig. 13. Lift the rear end of the board clear of the instrument and slide it backwards until the push buttons are clear of the front panel. The a.c. attenuator screen can be removed by taking out the one screw indicated in Fig. 12 and lifting clear.

5.2 LAMP REPLACEMENT

To replace a function or range switch lamp, pull off the button and with a lamp extractor or snipe nose pliers carefully withdraw the bulb from its socket through the front panel without twisting.

5.3 FUSE REPLACEMENT

The supply fuse, FS1, is located on the rear panel of the instrument and can be withdrawn after disconnecting the a.c. supply, by unscrewing the cap from the holder. Replace with a 250mA SLO-BLO 20 mm x 5 mm fuse for 240V a.c. supply or 500mA SLO-BLO 20 mm x 5 mm for 120V a.c. supply. The −15V supply protection fuse, FS301 is located on the analogue board which must be removed to locate the fuse holder. Replace with a 150mA 20 mm x 5 mm fuse. The +24V relay supply fuse, FS201, and the +5V logic supply fuse, FS202, are located on the fixed display board. Replace FS202 with a 1A 20 mm x 5 mm fuse and FS201 with a 250mA 20 mm x 5 mm fuse.

When an excessive voltage is applied to an OHMS range, the protection fuses, FS2 and FS3, will blow. They are located on the side of the instrument and may be withdrawn from the holders by unscrewing the caps. Replace both FS2 and FS3 with 60mA 20 mm x 5 mm fuses.

5.4 RECALIBRATION (Figs. 11, 12)

Adjustments MUST be made in the following sequence.

1. With the instrument measuring on the 0.2V d.c. range, short-circuit the HIGH and LOW input terminals and set R180 (front panel zero) for zero reading.
2. Apply +200mV ± 0.005% (or better) to the input terminals and adjust R352 for a reading of +.20000. The most significant '2' digit will be 'flashing'.
3. Apply −200mV ± 0.005% to the input terminals and adjust R339 for a reading of −.20000.
4. Select the 2V d.c. range and apply + or − 2V ± 0.005% to the input and adjust R320 for a reading of + or − 2.0000.
5. Select the 20V d.c. range and apply + or − 20V ± 0.005% and adjust R102 for a reading of + or − 20.000.
6. Select the 1000V d.c. range and apply + or − 1000V ± 0.005% and adjust R104 for a reading of + or − 1000.0.
7. Select the 2kΩ range. Short-circuit the input terminals with a low impedance (less than 0.1Ω). Adjust R133 for zero reading.
8. Connect 2kΩ ± 0.005% (or better) to the input terminals and adjust R140 for a reading of 2.0000.
9. Select the 20kΩ range. Connect 20kΩ ± 0.005% to the input terminals and adjust R111 for a reading of 20.000.
10. Connect 200kΩ 0.005% to the input terminals and adjust R113 for a reading of 200.00.
11. Select the 2000kΩ range. Connect 2MΩ ± 0.01% to the input terminals and adjust R115 for a reading of 2000.0.

12. Select the 20000kΩ range. Connect 20MΩ ± 0.05% to the input terminals and adjust R119 for a reading of 20000.
13. Select the 0.2V a.c. range. Short-circuit the input terminals and adjust R178 for zero reading. The guard screen is required to be in position to eliminate pick-up while calibrating the a.c. ranges.
14. Select the 2V a.c. range and apply an input 2V a.c. ± 0.02% r.m.s. 800Hz sinewave. Adjust R169 for a reading of 2.0000.
15. Apply an input of 2V a.c. ± 0.02% r.m.s. 15kHz sinewave and adjust C108 for a reading of 20000.
16. Select the 200mV a.c. range and apply an input of 200mV ± 0.02% r.m.s. 800Hz sinewave. Adjust R184 for a reading of 200.00.
17. Select the 20V a.c. range and apply an input of 20V a.c. ± 0.02% r.m.s. 800Hz sinewave. Adjust R150 for a reading of 20.000.
18. Apply an input of 20V a.c. ± 0.02% r.m.s. 15kHz sinewave and adjust C114 for a reading of 20.000.
19. Select the 200V a.c. range and apply an input of 200V a.c. ± 0.02% r.m.s. 800Hz. Adjust R148 for a reading of 200.00.
20. Apply an input of 200V a.c. ± 0.02% r.m.s. 15kHz and adjust C112 for a reading of 200.00.
21. Select the 1000V a.c. range and apply an input of 1000V a.c. ± 0.02% r.m.s. 800Hz. Adjust R146 for a reading of 1000.0.

5.5 GUIDE TO SERVICING

All voltages are measured with respect to 0V unless otherwise stated.

(a) General

Switch off before removing links, boards, etc. Ensure all gold plated edge connections are thoroughly clean before inserting in sockets, but do NOT use abrasive cleaners. Take care not to short-circuit the guard screen to the instrument case (mains ground) by fitting screws incorrectly or trapping any conducting material between them.

(b) Power Supplies

Nominal voltages and currents.
+190V supply −15mA.
Transformer secondary voltage 125V a.c., d.c. output +190V half wave voltage doubled 160V peak.
+24V supply −100mA.
Voltage across C216, 34V; d.c. stabilized voltage, +24V d.c. 7mV peak-peak ripple.
+15V supply −90mA.
Voltage across C317, 25 volts; stabilized voltage, 15V, 3mV peak-peak, −25mV peak-peak spikes at 100Hz.
−15V supply −90mA.
Voltage across C318, 25 volts; stabilized, 15V; 5mV peak-peak ripple.
+5V supply −300mA.
Voltage across C217, 9.7V; stabilized, 5V; 10mV peak-peak ripple.

(c) Integrated Circuit Logic Levels

	INPUTS		OUTPUTS		TYPICAL OPERATION
LOGIC TYPE	Logic 0 (max)	Logic 1 (min)	Logic 0 (max)	Logic 1 (min)	
Low Power TTL	+0.7V	+2V	+0.3V	+2.4V	0 1 0.15V 4.5V

(d) Amplifier Voltages

(i) d.c. input amplifier voltages with zero input volts
TR305(b) −8V; TR305(c) +2V; IC301(2) 0.2V d.c. range, +13.2V; IC301(3) 0.2V d.c. range, +13.2V; IC301(2) 2V d.c. range, +7.3V; IC301(3) 2V d.c. range, +7.3V; IC301(6) +250mV to ± 250mV.

Output voltage IC301(6) for the period T1 + T2 Fig. 200mV range

0.2V range:	input +200mV d.c.:	IC301(6) +6V:	Gain Ω x 30
0.2V range:	input −200mV d.c.:	IC301(6) −6V:	Gain Ω x 30
2V range:	input +2V d.c.:	IC301(6) +6V:	Gain Ω x 3
2V range:	input −2V d.c.:	IC301(6) −6V:	Gain Ω x 3

(ii) Voltage follower, IC310 (biasing the reference diodes).
IC310(6) for periods T3, T4, T5 and T6, ± 250mV
IC310(6) for periods T1 and T2, ± 1.6V (max)

(iii) Integrating amplifier, IC302.
TR309(d) +6V to −6V, depending on input signal for period T2.
+6V or −6V, depending on the reference selected for periods T3, T4, T5.
+250mV to −250mV for the period, T6.
IC302(6) Linear ramp of slope 0V to +10V for full scale −ve input
IC302(6) Linear ramp of slope 0V to −10V for full scale +ve input

(iv) Comparator amplifier, IC303.
IC303(7) between measurements (period T6)
+1.5V to +3V d.c. level, with ± 1V peak-peak noise
IC303(7) > +4.5V for positive inputs
IC303(7) > +0.4V for negative inputs

(v) OHMS Converter (with the kΩ function 2kΩ range selected).
TR102(b) +7.2V with respect to the −15 volt supply
TR102(c) −5.9 volts to −6.5 volts
Junction of R126/D111, +6.8 volts
TR105(b) −10.4 volts
IC101(3) and IC101(2) +6 volts
IC101(6) 0V with the HIGH and LOW input terminals short-circuited.
IC101(6) +2V with 2kΩ between the HIGH and LOW input terminals

(vi) AC−DC Converter
TR106(g) and TR107(g) 0V
TR108(c) +1.8 volts
TR109(e) + 1.1 volts
TR110(b) −13.6 volts
TR110(c) −4.4 volts

(vii) +15 volt Regulator
IC307(8) +25 volts
IC307(4) +7.0 volts
IC307(1) +15.0 volts
IC307(2) +7.0 volts

(viii) −15 volt Regulator
IC308(6) −8.4 volts
IC308(4) −7.3 volts
IC308(3) −10.8 volts
IC308(5) −15 volts

(e) Reference Voltages

TR313.b −7.2 volts with respect to the +15 volt supply
TR313.c +5.65 volts to +6.75 volts
TR320.b +7.2 volts with respect to the −15 volt supply
TR320.c −5.6 volts to +6.75 volts

(f) F.E.T. Drive Circuit – Voltages for positive input voltages

Period	TR314c,	TR316c,	TR322c,	TR324c,	TR326c,	TR328c,
T1	Off	Off	Off	Off	Off	On
T2	Off	Off	Off	On	Off	On
T3	Off	On	Off	Off	On	Off
T4	On	Off	Off	Off	On	Off
T5	On	Off	Off	Off	On	Off
T6	Off	Off	On	On	On	Off

ON voltage is greater than +13 volts
OFF voltage is greater than –13 volts
For negative input voltages reverse colours TR314c, TR316c.

(g) **Range Code**

200mV 2k	2V 20k	20V 200k	200V 2000k	1kV 20000k	(a.c. and d.c. ranges) (kΩ ranges)
0	1	2	3	4	B.C.D. Code

The range switches are wired to address the range counter IC215 with the b.c.d. code shown.

The range counter, IC215, drives the decoder, IC216, with the same code for manual and auto ranging. The output of the range decoder, IC216, is decimal 0.4 for the five ranges. Each output is an open collector driving the respective range relays and lamps directly.

5.6 FAULT LOCATION

Follow the suggested sequence for fault finding in association with the circuit description (section 4) (Figs. 7, 8, 9, 13).

(i) **Power Supplies**

FAULT	*CHECK IN THE FOLLOWING SEQUENCE*
No Front Panel Display Indicator or range lamps	1. Supply connection to the instrument. 2. Supply Fuse, FS1. 3. Supply through L1 to the primary of T1. 4. T1 secondary windings and instrument supplies.
No digital indicator display	1. +190V voltage doubling supply. 2. Wired connection to the indicator anodes resistors.
No function or range illumination	1. +24V Regulated supply. 2. +24V fuse/FS201. 3. Connection from digital board to the ranging board. 4. Wiring to the front panel switches.
'Fuzzy' Digital display	1. +5V Regulated supply. 2. +5V fuse, FS202.
Permanent reading of 19000	1. –15V fuse, FS301. 2. –15V Regulated supply.
Permanent reading of 0000	1. +15V Regulated supply.

(ii) Digital to Analogue Conversion

FAULT

No measurement on any range

Remove the ranging board and printer output boards Fig. 13.
All the decimal points will be displayed.
Connect the analogue board to the service adaptor provided (Fig. 13).
The instrument will be on the 200mV d.c. range. Short-circuit PLD and PLE.

Checks to be made in the following sequence

1. Regulated supplies. Input protection diodes, D301 and D302.
2. Crystal oscillator output, IC225f.
3. Reset pulse, IC225a.
4. Load pulse, TR217c.
5. Counter runs through. (Short TR217b to 0V for the display to directly follow the counter).
6. Digital timing periods, T1 + T2 (IC2186).
7. Integration period, T2 (IC218a).
8. Reference selection periods, T3 and T4, IC217.
9. Stop bistable, IC226a and IC226c.
   If IC226a output remains high, check for STOP(L) at IC306b.
   With no 'stop' pulse, the digital sequence cannot be completed.
10. F.e.t. Drive, T328(c).
11. F.e.t. Drive, TR326(c).
12. F.e.t. Drive, TR324(c).
    Before carrying out the remaining checks switch front panel switch, S3, to 'HOLD'. This will keep the instrument in the zero correction mode which enables the analogue section to be checked. If when in this condition, IC306b output is high, force the state by shorting T330b to 0V.
13. F.e.t. Drive, TR322(c).
14. D.C. Amplifier output, IC30 pin 6.
15. Input to the integrator, TR307(d), is equal to IC301 pin 6.
16. The d.c. level at the output of the comparator, IC303(7), is in its linear region (see 5.5 (iv)).
    If the output is saturated at $>$ +4.5V or $<$ +0.4V, check the closed loop feedback via the integrator amplifier as follows:–
17. TR310(s) voltage –(3.3V to 5.6V) from IC303(7).
18. TR309(g) the same voltage as TR310(s).
19. TR309(s) +250mV to –250mV.
20. IC302(3) +250mV to –250mV.
21. IC302(6) +250mV to –250mV.
22. IC310(6) +250mV to –250mV.
    Switch S3 on the front panel to the measurement position, and apply an input of 100 to 200mV.
23. Reference selection, IC304a (–ve ref.) or IC304b (+ve ref.) via selection bistables, IC305d and IC306c or IC306a and IC305a.
24. F.e.t. Drives, TR316c or TR314c, driven from IC309.
25. Voltage at TR313(c) +5.7V to +6.7V.
26. Voltage at TR319(c) –5.7V to –6.7V.
27. Ensure a reference voltage is switched to the integrator for periods, T3, T4 and T5.

The instrument should now be working on the 200mV d.c. range and the ranging board can now be replaced.

(iii) D.C. Attenuator

FAULT	*CHECKS*
Reads incorrectly on 200mV and 2V d.c. ranges	Select 200mV d.c. range and short-circuit HIGH and LOW terminals. If the instrument will not read zero, remove the bottom cover and guard screen, unplug PLD PLE and apply 0V then 200mV. If the instrument still will not read correctly by readjusting the front panel zero or 0.2V calibration potentiometers, follow the fault procedure (ii). Having established the instrument works correctly with an input applied to PLD and PLE, continue with the following checks. 1. Continuity from Low input terminal to SKE. 2. Continuity from HIGH input terminal to RLD and RLA. 3. Continuity through reed insert switch, RLD_1. If the switch is open, measure the coil (RLD) voltage. See Fault (vi). 4. Continuity of S108d and S109c to PLSKD.
Does not read on 20V, 200V, 1000V d.c. ranges	1. Continuity of reed insert switch, RLA_1. 2. Measure the voltage to the coil, RLA (See FAULT (vi)).
Does not read on 1000V d.c. range.	1. Continuity of reed insert switch, RLF_1. 2. Measure the voltage to the coil, RLF. (See FAULT (vi)).

(iv) AC–DC Converter

Reads incorrectly on 2V a.c. range	Assuming the instrument operates correctly on all d.c. ranges. Select the 2V a.c. range and continue with the following checks. 1. Continuity of the reed insert switches, RLB_1 and RLN_1. If RLB or RLN is open, measure the voltage applied to the coils, RLB and RLN. (See Fault (vi)). 2. Measure the a.c. amplifier voltages listed in section (5.5 (d) (vi)). Now apply 1 volt to 2 volts a.c. input. With an oscilloscope measure the following:– 3. The a.c. voltage at TR106(g) is approximately half the input voltage. 4. The a.c. voltage at TR110(c) is approximately 5 x TR106(g) or the a.c. voltage output at TR110(c) is limited at the peaks. 5. The +ve half cycle at the cathode of D108. 6. The –ve half cycle at the anode of D107. 7. Re-combined a.c. voltage at the junction of C117 and R167 equals the voltage at TR106(g). 8. The +ve half cycle is filtered to a d.c. voltage across C119 and C120 and finally C121. 9. Continuity from R173 to SKD.
200mV a.c. range will not calibrate	1. Continuity of the reed insert switch, RLH2. If RLH_2 is open, measure the voltage across the coil. (See Fault (vi)).
20V a.c. range reads incorrectly	1. Continuity of reed insert switch, RLK_2. If RLK_2 is open, measure the voltage applied to the coil RLK. (See Fault (vi)). 2. R149, R150 and C114.

200V a.c. range reads incorrectly

Select the 200V a.c. range.
1. Continuity of reed insert switch, RLL_2. If RLL_2 is open, measure the voltage applied to the coil, RLL. (See Fault (vi)).
2. R147, R148, C111 and C112.

1000V a.c. range reads incorrectly

Select the 1000V a.c. range.
1. Continuity of reed insert switch, RLM_2. If RLM_2 is open, measure the voltage applied to the coil, RLM. (See Fault (vi)).
2. R145, R146, R119, C109 and C110.

(v) OHMS Converter

Reads incorrectly on 2kΩ range

Assuming the instrument operates correctly on all d.c. ranges. Select the 2kΩ range and continue with the following checks.
1. Fuses, FS2 and FS3 (60mA).
2. Measure the ohms converter amplifier voltages listed in section (5.5 (d) (c)) with a short-circuit input and then 2kΩ connected across the HIGH and LOW input terminals.
3. With 2kΩ across the input measure the d.c. voltage via R140, R141 and S109c, to SKD.

(vi) Range Selection Manual and Auto

No range or function relay drive.

Select d.c. function.
1. The +24V supply is connected to one side of RLA, RLD, RLE and RLF.
2. Manually select the 200mV range.
3. The b.c.d. drive to IC215.
4. The output B.C.D. from IC215 to IC216.
5. Only the 0 output of IC216 is low.

Repeat for the other four ranges. If more than one output from IC216 is low, check the gating diodes connecting the appropriate lines.

Select a.c. function.
6. The +24V supply is connected to one side of RLM, RLL, RLK, RLH, RLB and RLN.
7. The appropriate drive from IC216 is connected via the diodes to the a.c. range relays.

Select kΩ function.
8. The +24V supply is connected to one side of RLM, RLL, RLK, RLH, RLJ and RLC.
9. The appropriate drive from IC216 is connected via the diodes to the kΩ range relays.

Auto ranging is inoperative

Assuming all the ranges on the kΩ function operate correctly under manual selection:–
Select kΩ AUTO range. If the 2kΩ, 20kΩ or 200kΩ range is selected, open-circuit the input so the instrument will read 'over range' requiring a step-up of range.
1. IC215(11) is high.
2. Stop input to C205.
3. Pulse output of IC225b.
4. IC220 (pin 2) is low at the end of the measurement.
5. IC219f is low.
6. IC215(5) for a low-going pulse.

The instrument will not range down	Assuming the instrument will range up to the 20000kΩ range with an open circuit input, short-circuit the input HIGH and LOW terminals and check the following:– 1. Bistable, IC221c/IC221d, remains reset. 2. IC219b output is high. 3. IC220(c) pin 11 high pulse. 4. IC215(4) for a low pulse.
Erratic ranging on Auto position	1. Bottom range limit stop, IC219(b) output. 2. Top range limit stop, IC219(f) output. 3. IC216 decoder outputs. 4. Outside range detector, IC220. 5. Bistable, IC222a/IC222c, is set when a measurement demands an auto range signal. 6. T225 turns on, connecting C211 in parallel with C212. 7. For a.c., TR224 turns on, connecting C210 in parallel with C211 and C212.

(viii) Display

Any one indicator extinguished	1. Voltage at the anode of the indicator is greater than +150V. 2. The decoder drive to the cathodes. 3. The indicator.
Double numbers or no numbers in any one indicator	1. The decoder drive to the cathodes. 2. The indicator.
The 'Most Significant' '2' digit does not 'flash'	1. IC209(16) is high. 2. Multivibrator, TR212, cross-coupled with TR213 is running. 3. TR214 cathode drive.
Plus-Minus indicator inoperative	1. Anode voltage at R208. 2. Switch contact, S107b. 3. Cathode driver transistors, TR210 and TR211. 4. Bistable, IC224a/IC224b, is reset and then set by –ve reference selection.

Table 1. DVM Master Board Interconnection
(Viewed from copper side right–left)

Connections to ANALOGUE BOARD PLG Pin	Connections to pins for PRINTER OUTPUT cableform	Connections to DIGITAL BOARD	Connections to RANGING BOARD SKF Pin
		Pin to the Ω Protection Fuse.	1. Ω Protection Fuse.
		Pin to the Ω Protection Fuse.	2. Ω Protection Fuse.
2.			3. −15V.
1.		Pin to the 0V screen of T1	4. 0V (ANALOGUE).
3.			5. +15V.
4.		1. 0V	
5.		2. 15V a.c.	
6.		3. 15V a.c.	
7.			6. Zero.
		4. + − inhibit.	7. ± inhibit.
8.	Pol.	5. Pol.	
9.			8. $\overline{\text{d.c.}}$
10.			9. $\overline{\text{d.c.}}$
11.		6. Relay drive (4)	10. Relay drive (4).
KEYWAY			
13.		7. Relay drive (3)	11. Relay drive (3).
			12. KEYWAY
		8. Relay drive (2)	13. Relay drive (2).
		9. Relay drive (0)	14. Relay drive (0).
14.		10. Relay drive (1)	15. Relay drive (1).
	Range B.C.D. output (4)	11. Range B.C.D. output (4).	
		12. MAN. range input (2)	16. Man. range input (2).
	Range B.C.D. output (2)	13. Range B.C.D. output (2).	
	Range B.C.D. output (1)	14. Range B.C.D. output (1).	
		15. Man. range input (1)	17. Man. range input (1).
		16. Man. range input (4)	18. Man. range input (4).
		17. Auto	19. Auto.
15.			20. RLQ drive (kΩ & a.c.).
	Stop on range	18. STOP on range.	
	Reset	19. Reset.	
16.		20. Reset–Ref. selection (Hi).	
17.		21. Input ramp (Lo).	
18.		22. Input ramp (Hi).	
19.		23. Reset–Ref. selection (Lo).	
20.		24. Reverse Ref.	
	Clock	25. Clock.	
		Pin to the Ω Protection Fuse.	21. Ω Protection Fuse.
		26. A.C. delay	22. A.C. delay.
22.		27. STOP.	
	Inverted Stop	28. Inverted Stop.	
	Digitise	29. Digitise.	
	Hold	30. Hold.	
		31. Dec. pts. volts.	23. Dec. pts. volts.
		32. Dec. pts. kΩ	24. Dec. pts. volts.
24.		33. +24V	25. +24V.
25.	+5V	34. +5V.	
26.	0V	35. 0V (DIG)	26. 0V (DIG).

PINS 21 & 23 SPARE.

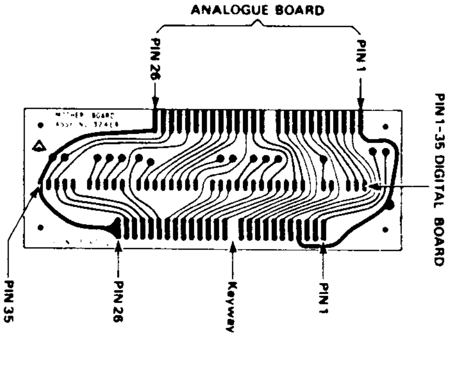


Table 2. Printer Output Connections

Pin No. Printer Output Master Board	Pin No. Printer Output Socket SKX	
528	36	0V
507	35	Digitise (measurement command input)
508	33	Print Command Output
529	32	+5V
511	25	POLARITY
506	23	BCD 4 RANGE
505	22	BCD 2 RANGE
504	21	BCD 1 RANGE
509	18	BCD 2 x 10^4
510	17	BCD 1 x 10^4
513	16	BCD 8 x 10^3
515	15	BCD 4 x 10^3
514	14	BCD 2 x 10^3
512	13	BCD 1 x 10^3
517	12	BCD 8 x 10^2
519	11	BCD 4 x 10^2
518	10	BCD 2 x 10^2
516	9	BCD 1 x 10^2
521	8	BCD 8 x 10^1
523	7	BCD 4 x 10^1
522	6	BCD 2 x 10^1
520	5	BCD 1 x 10^1
525	4	BCD 8 x 10^0
527	3	BCD 4 x 10^0
526	2	BCD 2 x 10^0
524	1	BCD 1 x 10^0

Notes:

1. +5V. 20mA maximum output current to 0V.
2. Outputs are positive logic '8421' code TTL
   Logic 0 <0.5V able to sink 8mA.
   Logic 1 >+2.4V Logic 1 <+5V.
3. Print command pulse.
   Link (b) for +ve pulse Logic 0 to logic 1 for 4ms typ.
   Link (a) for −ve pulse Logic 1 to logic 0 for 4ms typ.
   Increase C506 for a longer print command pulse or decrease C506 for a shorter print command pulse.
4. With the front panel switch S3 in the hold position apply <0.8V (0V min.) to the digitise input to hold a reading. Apply >2V (+5.5V max.) or open circuit for >200ms to the digitise input to read.
   With the front panel switch S3 in the measure position apply <0.8V (0V min.) to the digitise input to hold a reading. Apply a +ve edge (transition <+0.8V to >+2.4V, <2μS rise time) to initiate a measurement cycle.
5. +ve Polarity logic 1, link 501–503.
   −ve Polarity logic 1, link 503–502.
6. Range BCD code / Range:

Range BCD code		0.	1.	2.	3.	4.
Range		.2V	2V	20V	200V	1000V
	or	2kΩ	20kΩ	200kΩ	2000kΩ	20000kΩ

ABBREVIATIONS USED FOR COMPONENT DESCRIPTIONS

RESISTORS

CC	Carbon Composition	½W	10%	unless otherwise stated
CF	Carbon Film	⅛W	5%	unless otherwise stated
MO	Metal Oxide	½W	2%	unless otherwise stated
MF	Metal Film	¼W	1%	unless otherwise stated
WW	Wire Wound	6W	5%	unless otherwise stated
CP	Control Potentiometer			
PCP	Preset Potentiometer Type MPD, PC			

CAPACITORS

CE(1)	Ceramic		+ 80% - 25%	
CE(2)	Ceramic	500V	± 10%	unless otherwise stated
SM	Silver Mica			
PF	Plastic Film		± 10%	unless otherwise stated
PS	Polystyrene			
PE	Polyester		± 10%	unless otherwise stated
PC	Polycarbonate			
E	Electrolytic (aluminium)		+ 10% - 50%	
T	Tantalum		+ 10% - 50%	

RANGING BOARD

Ref	Value	Description	Tol %±	Part No.
RESISTORS				
R101	9M9	MF Matched Set R101, 103, 105	.1	32642
R102	10k	CP		31862
R103	89k7	MF See R101	.1	
R104	10k	CP		31862
R105	9k97	MF See R101	.1	
R106	100k	WW	10W	32643
R107				
R108	100k	CF		21819
R109	5k83	WW	.1	32644
R110	58k1	WW	.25	32645
R111	500Ω	CP		32664
R112	581k	MF	.25	32646
R113	5k	CP		32665
R114	5M81	MF	.25	32647
R115	50k	CP		33629
R116	20M	MF	.25	32648
R117	4k	WW	.1	32650
R118	500Ω	CP		32664
R119	24k	MO		28807
R120	2k	WW	.1	32649
R121	10k	CF		21809
R122	820Ω	CF		28724
R123	150k	CF		21821
R124	1k8	CF		28725
R125	1k8	CF		28725
R126	1k2	CF		21800
R127	68Ω	CF		28716
R128	68Ω	CF		28716
R129	4k7	CF		21805
R130	2k2	CF		21802
R131	1k	CF		21799
R132	1M	CF		31840
R133	20k	CP		31843
R134	39Ω	CF		28713
R135	4R7	CF		32663
R136			A.O.T.	
R137	1k5	WW		598
R138			A.O.T.	
R139	4k7	CF		21805
R140	5k	CP		32665
R141	150k	CF		21821
R142	10k	CF		21809
R143	200k	MF		32651
R144	1M	MF	.25	32652
R145	508Ω	MF	.1	32653
R146	47k	CP		28335
R147	5k03	MF	.1	32654
R148	47Ω	CP		29365
R149	55k2	MF	.1	32655
R150	470Ω	CP		28524
R151	1M	MF	.1	32656
R152	8k2	CF		21808
R153	2k2	CF		21802
R154	2k2	CF		21802
R155	8k2	CF		21808
R156	22k	CF		21812
R157	10k	CF		21809
R158	10M	MF	10	32661
R159	18k	CF		21811
R160	1k	CF		21799
R161	3M3	MF	10	32662
R162	1k	CF		21799
R163	120Ω	CF		28718
R164	330Ω	CF		28721
R165	3k3	CF		21803
R166	2k2	CF		21802
R167	450Ω	MF	.25	32658
R168	1k98	MF	.1	32657
R169	10k	CP		32823
R170	100k	CF		21819
R171	100k	CF		21819
R172	100k	CF		21819
R173	27k	CF		21813
R174	39Ω	CF		28713
R175	39Ω	CF		28713
R176	500Ω	MF		32659
R177	50Ω	MF		32660
R178	100k	CP		26582
R179	1M	CF		31840
R180	50k	CP		27180
R181	10Ω	CF		21793
R182			A.O.T.	
R183	10k	CF		21809
R184	10k	CP		32823
R185	1Ω	MF		27315
R186			A.O.T.	
R187	270Ω	MF		26742
CAPACITORS				
C101	220pF	CE(2)		22379
C102	.1μF	CE(1)	30V	19647
C103	.1μF	CE(1)	30V	19647
C104	.1μF	PF	400V	2385
C105	2pF	SM	2kV	32666
C106	22pF	SM	2kV	33319
C107	8.2pF	SM		4503
C108	10pF	Trimmer		33200
C109	3900pF	PS	30V	32975
C110		PS	A.O.T.	
C111	220pF	SM	A + B	11587
C112	20pF	Trimmer		32519
C113				
C114	10pF	Trimmer		32669
C115	150pF	CE(2)		22378
C116	.01μF	CE(2)	250V	22395
C117	.47μF	PE	160V	31381
C118	10μF	PF	63V	32822
C119	.22μF	PE	160V	31379
C120	.47μF	PE	160V	31381
C121	.47μF	PE	160V	31381
C122		SM	A.O.T.	
C123		SM	A.O.T.	

RANGING BOARDS (cont.)

Ref	Value	Description	Tol%±	Part No.
TRANSISTORS				
TR101		BSX26		28735
TR102		BC107		26790
TR103 TR104		AE19 Matched Pair		A32670
TR105		BC107		26790
TR106		BFW11		30526
TR107		BFW11		30526
TR108		2N3906		21533
TR109		2N3904		24146
TR110		2N3904		24146
DIODES				
D101		IN3595		29330
D102		IN3595		29330
D103		IN3595		29330
D104		IN3595		29330
D105		Zener	5V1	20218
D106		Zener	15V	4669
D107		IN4148		23802
D108		HP2800		32671
D109		IN4148		23802
D110		IN3497		29601
D111		Zener	6V8	4666
D112		IN3595		29330
D113		IN3595		29330
D114		Zener	5V6	4109
D115		IN4148		23802
D116		Zener	6V2	4032
D117		IN4148		23802
D118		IN4148		23802
D119		IN4148		23802
D120		IN4148		23802
D121		IN4148		23802
D122		IN4148		23802
D123		IN4148		23802
D124		IN4148		23802
D125		IN4148		23802
D126		IN4148		23802
D127		IN4148		23802
D128		IN4148		23802
D129		IN4148		23802
D130		IN4148		23802
D131		IN4148		23802
D132		IN4148		23802
D133		IN4148		23802
D134		IN4148		23802
D135		IN4148		23802
D136		IN4148		23802
D137		IN4148		23802
D138		IN4148		23802
D139		IN4148		23802
D140		IN4148		23802
D141		IN4148		23802
D142		IN4148		23802

Ref	Value	Description	Tol%±	Part No.
DIODES (cont.)				
D143		IN4148		23802
D144		IN4148		23802
D145		IN4148		23802
D146		IN4148		23802
D147		IN4148		23802
D148		IN4148		23802
D149		IN4148		23802
D150		IN3595		29330
D151		IN3595		29330
D152		Zener	6V2	4032
D153		IN4148		23802
D154		IN4148		23802
MISCELLANEOUS				
IC101	μA741C			28636
ILP101		Neon 16L		29201
ILP102		Neon 16L		29201
ILP103 -111	40mA	Lamp (Part S101-9)	28V	33610
RLA		Switch, Reed 1kV Coil, Reed 24V		32674 32677
RLB		Switch, Reed 1kV Coil, Reed 24V		32674 32677
RLC		Switch, Reed 1kV Coil, Reed 24V		32674 32677
RLD		Reed Relay 5kV		32978
RLE		Switch, Reed Coil, Reed 24V		32977 32679
RLF		Switch, Reed Coil, Reed 24V		32676 32679
RLH		Reed Relay		32982
RLJ		Reed Relay		32983
RLK		Reed Relay		32984
RLL		Reed Relay		32984
RLM		Reed Relay		32984
RLN		Switch, Reed Coil, Reed 24V		32676 32679
S101 –109		Switch P.B. Range and Function		A4/32741
L101		Choke		A4/32976
FS2		Fuse, Bulgin F270	60mA	32337
FS3		Fuse, Bulgin F270	60mA	32337
SKA		Terminal B/LEE L1568/231 kit 2/Red		32965
SKB		Terminal B/LEE L1568/231 kit 2/Black		32966
SKC		Terminal B/Lee L1568/231 kit 2/White		32967
SKD		Connector Single Pole Red		32986
SKE		Connector Single Pole Black		32987

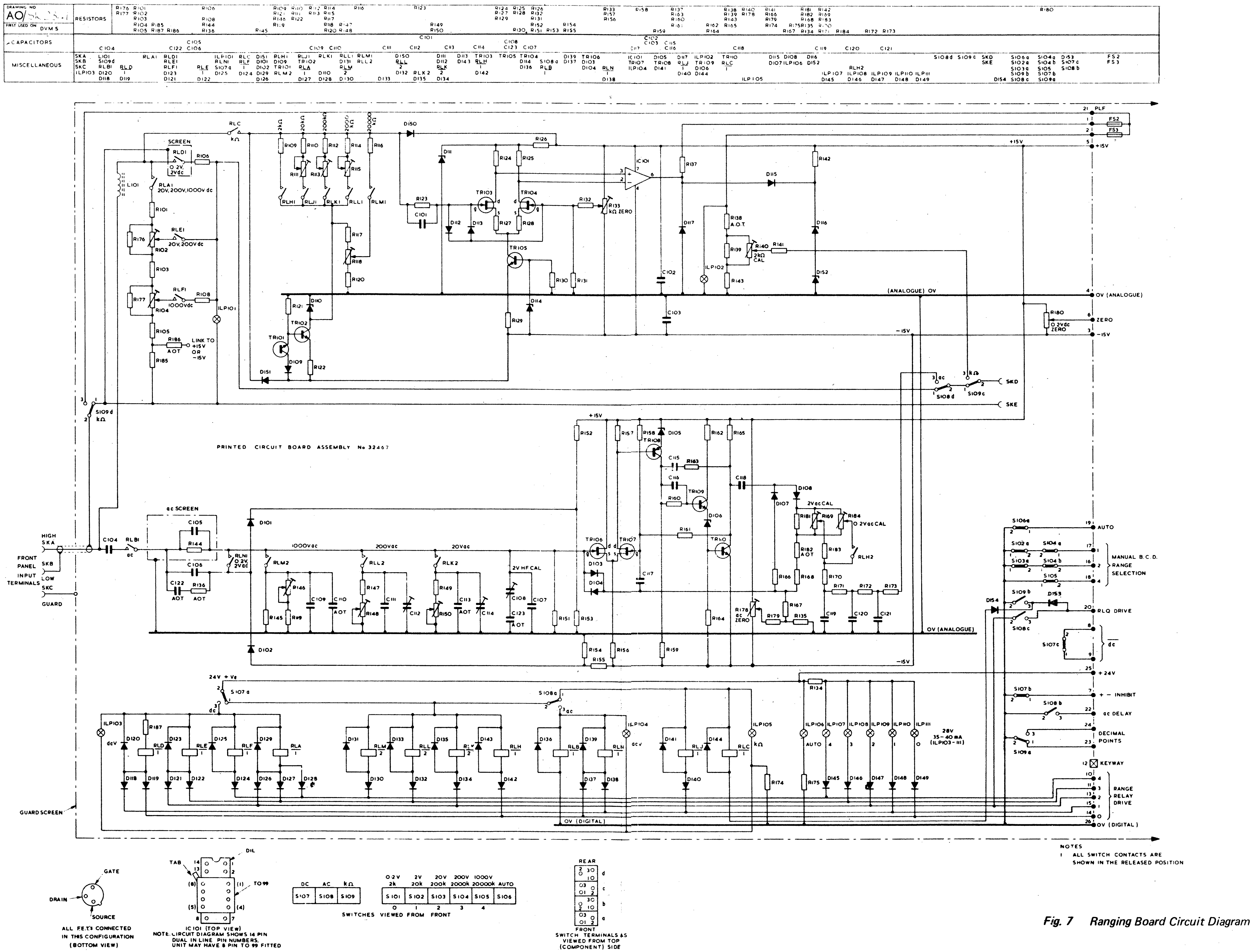


Fig. 7 Ranging Board Circuit Diagram

ANALOGUE BOARD

RESISTORS

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
R301	56k	CF		28729
R302	560Ω	CF		21798
R303	2k2	CF		21802
R304	2k2	CF		21802
R305	560Ω	CF		21798
R306	820k	CF		32360
R307	39k	CF		28728
R308	27k	CF		21813
R309	8k25	MF		32688
R310		Not Fitted		
R311	68Ω	CF		28716
R312	68Ω	CF		28716
R313	10k	CF		21809
R314	8k25	MF		32688
R315	1M	CF		31840
R316	1M	CF		31840
R317	820k	CF		32360
R318	58k	MF	1	32689
R319	4k28	MF	1	32690
R320	2k	CP		32693
R321	2k	MF	1	32691
R322	1M	CF		31840
R323	820k	CF		32360
R324	56k	MF		33228
R325	47k	CF		21815
R326	4R7	CF		32663
R327	27k	CF		21813
R328	10k	CF		21809
R329	1k	CF		21799
R330	1k	CF		21799
R331	820Ω	CF		28724
R332	100k	CF		21819
R333	10Ω	CF	A.O.T.	21793
R334	22k	CF		21812
R335	8k2	CF		21808
R336	100k	CF		21819
R337			A.O.T.	
R338	5k6	MO		22483
R339	200Ω	CP		32692
R340	2k2	CF		21802
R341	10k	CF		21809
R342	68Ω	CF	A.O.T.	28716
R343	820Ω	MO		26736
R344	330Ω	CF		28721
R345	5k6	CF		21806
R346	330Ω	CF		28721
R347	5k6	CF		21806
R348	10k	CF		21809
R349	100k	CF		21819
R350			A.O.T.	
R351	5k6	MO		22483
R352	200Ω	CP		32692
R353	2k2	CF		21802
R354	10k	CF		21809
R355	820Ω	MO		26736
R356	68Ω	CF		28716
R357	10k	CF		21809

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
R358	12k	CF		21810
R359	10k	CF		21809
R360	10k	CF		21809
R361	22k	CF		21812
R362	3k3	CF		21803
R363	3k9	CF		21804
R364	3k3	CF		21803
R365	3k9	CF		21804
R366	4k7	CF		21805
R367	330Ω	CF		28721
R368	5k6	CF		21806
R369	10k	CF		21809
R370	330Ω	CF		28721
R371	5k6	CF		21806
R372	10k	CF		21809
R373	330Ω	CF		28721
R374	5k6	CF		21806
R375	10k	CF		21809
R376	12k	CF		21810
R377	12k	CF		21810
R378	12k	CF		21810
R379	12k	CF		21810
R380	330Ω	CF		28721
R381	5k6	CF		21806
R382	12k	CF		21810
F383	10k	CF		21809
F384	4k7	CF		21805
R385	12k	CF		21810
F386	12k	CF		21810
F387	1k5	CF		21801
R388	4R7	CF		32663
R389	8k2	CF		21808
R390	6k8	CF		21807
R391	2k2	CF		21802
R392	3k3	CF		21803
R393	3k3	CF		21803
R394	12k	CF		21810
R395	3k9	CF		21804
R396	22Ω	CF		28710
R397	1k	CF		21799
R398	5k6	CF		21806
R399	22k	CF		21812
R400	5k6	CF		21806
R401	220k	CF		21823
R402	3k9	MO		26724
R403	22k	CF		21812
R404	10Ω	CF		21793
R405	560k	CF		32359
R406	10k	CF		21809
R407	22k	CF		21812
R408	2k2	MO		26730
R409	22k	CF		21812
R410	4k3	MO		26723
R411	10k	CF		21809
R412	330Ω	MO		26741
R413	330Ω	MO		26741

ANALOGUE BOARD (Cont.)

CAPACITORS

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
C301	.22μF	PE	160V	31379
C302	.22μF	PE	160V	31379
C303		Not Fitted		
C304	.1μF	CE(1)	30V	19647
C305	.1μF	CE(1)	30V	19647
C306	150pF	SM		4514
C307	.01μF	CE(2)	250V	22395
C308	.01μF	CE(2)	250V	22395
C309				
C310	10μF	PF	63V	32822
C311	.01μF	CE(2)	250V	22395
C312	6.8μF	T	25V	32685
C313	.01μF	CE(2)	250V	22395
C314	6.8μF	T	25V	32685
C315	5600pF	CE(2)	500V	22394
C316	5600pF	CE(2)	500V	22394
C317	1000μF	E	40V	52869
C318	1000μF	E	40V	52869
C319	470pF	CE(2)	500V	22383
C320	100pF	CE(2)	500V	22376

TRANSISTORS

TR301	AE20	A32694
TR302	AE20	A32694
TR303	AE18	A32440
TR304	AE18	A32440
TR305	BC107	26790
TR306	N Channel FET	32695
TR307	2N3819	28901
TR308	BC212	29327
TR309	2N3819	28901
TR310	2N3819	28901
TR311	2N3819	28901
TR312	BSX26	28735
TR313	2N3906	21533
TR314	2N3906	21533
TR315	2N3904	24146
TR316	2N3906	21533
TR317	2N3904	24146
TR318	2N3819	28901
TR319	BSX26	28735
TR320	BC107	26790
TR321	BSX20	23307
TR322	2N3906	21533
TR323	2N3904	24146
TR324	2N3906	21533
TR325	2N3904	24146
TR326	2N3906	21533
TR327	2N3904	24146
TR328	2N3906	21533
TR329	2N3904	24146
TR330	2N3904	24146
TR331	BFY51	29329
TR332	BFX88	23337
TR333	BC107	26790

DIODES

D301	LD5		32682
D302	LD5		32682
D303	IN3595		29330
D304	IN4148		23802
D305	IN4148		23802
D306	IN3595		29330
D307	IN3595		29330
D308	IN4148		23802
D309	IN4148		23802
D310	Zener	5V6	4109
D311	IN4148		23802
D312	IN4148		23802
D313	AE24		A33327
D314	IN4148		23802
D315	IN4148		23802
D316	AE24		A33327
D317	IN4148		23802
D318	Zener	6V2	4032
D319	IN4148		23802
D320	IN4148		23802
D321	IN4148		23802
D322	IN4148		23802
D323	IN4148		23802
D324	IN4148		23802
D325	Zener	7V5	22173
D326	IN4148		23802
D327	IN4148		23802
D328	IN4148		23802
D329	IN4148		23802
D330	IN4148		23802
D331	IN4148		23802

INTEGRATED CIRCUITS

IC301	μA741C	28636
IC302	μA741C	28636
IC303	LM311	32683
IC304	SN74L20N	32699
IC305	SN74L00N	32334
IC306	SN74L10N	32698
IC307	μA723C	31228
IC308	μA723C	31228
IC309	SN74L51N	32701
IC310	μA741C	28636

MISCELLANEOUS

MR301		W02	19725
RLQ		Reed Relay	32985
SKG		Connector Edge	A3/32856
FS301	250mA	L1427	32338

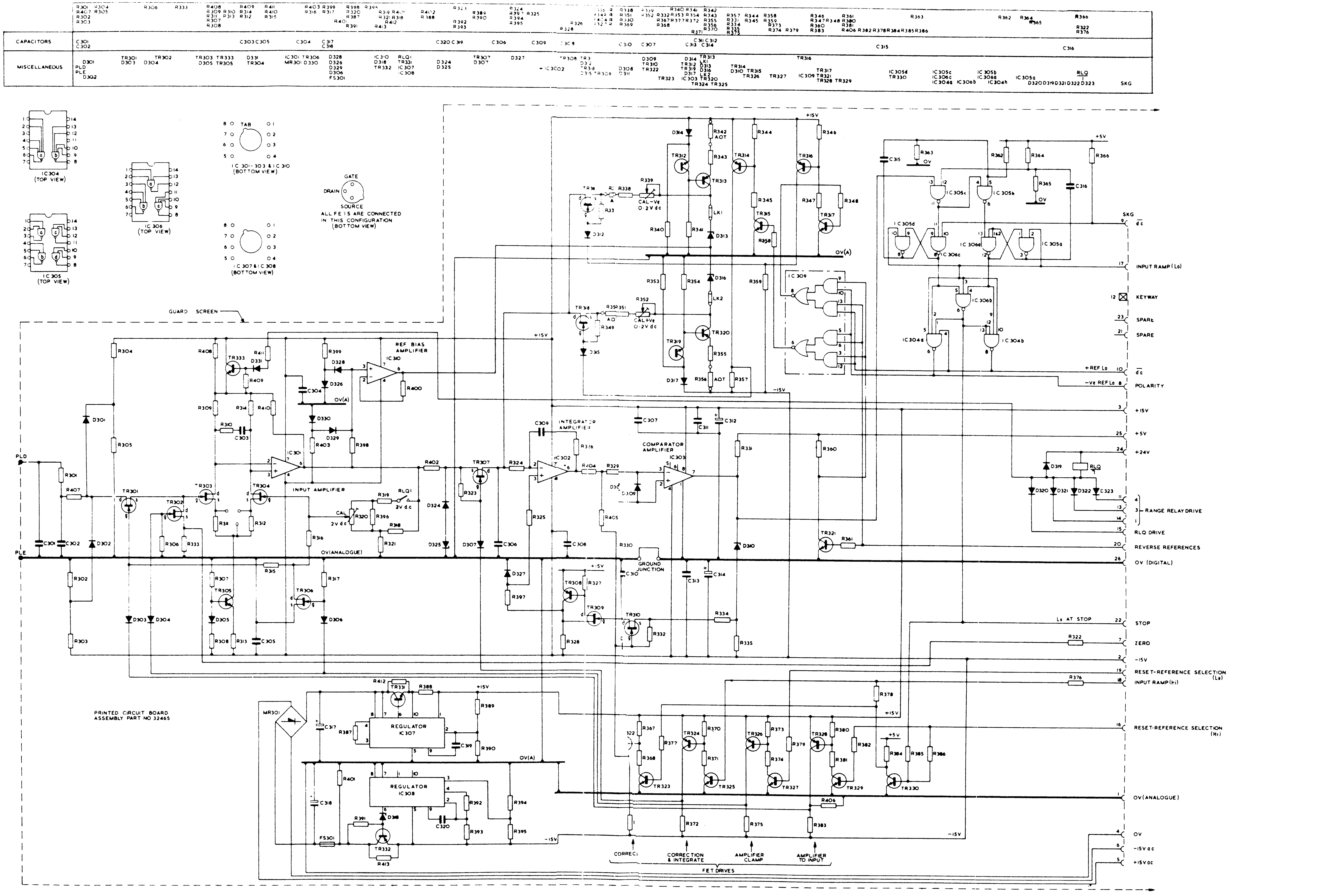


Fig. 8 Analogue Board Circuit Diagram

DISPLAY BOARD

RESISTORS

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
R201	2k2	CF		21802
R202	8k2	CF		21808
R203	2k2	CF		21802
R204	8k2	CF		21808
R205	10k	CF		21809
R206	10k	CF		21809
R207	2k2	CF		21802
R208	22k	MO		32696
R209	2k2	CF		21802
R210	2k2	CF		21802
R211	10k	CF		21809
R212	2k2	CF		21802
R213	10k	CF		21809
R214	4k7	CF		21805
R215	22k	CF	2	31837
R216	4k7	CF		21805
R217	4k7	CF		21805
R218	22k	CF	2	31837
R219	22k	CF	2	31837
R220	22k	CF	2	31837
R221	3k9	CF		21804
R222	3k3	CF		21803
R223	22k	CF	2	31837
R224	2k2	CF		21802
R225	2k2	CF		21802
R226	3k3	CF		21803
R227	390k	CF		32358
R228	4k7	CF		21805
R229	390k	CF		32358
R230	4k7	CF		21805
R231	390k	CF		32358
R232	4k7	CF		21805
R233	390k	CF		32358
R234	3k3	CF		21803
R235	390k	CF		32358
R236	4k7	CF		21805
R237	4k7	CF		21805
R238	4k7	CF		21805
R239	4k7	CF		21805
R240	4k7	CF		21805
R241	4k7	CF		21805
R242	4k7	CF		21805
R243	3k3	CF		21803
R244	3k9	CF		21804
R245	4k7	CF		21805
R246	10k	CF		21809
R247	10k	CF		21809
R248	10k	CF		21809
R249	4k7	CF		21805
R250	4k7	CF		21805
R251	10k	CF	2	32697
R252	680k	CF		31839
R253	1k	CF		21799
R254	470Ω	CF		21797
R255	4k7	CF		21805
R256	10k	CF		21809
R257	1k5	CF		21801
R258	3k3	CF		21803
R259	3k9	CF		21804
R260	3k9	CF		21804
R261	3k9	CF		21804
R262	3k9	CF		21804
R263	3k9	CF		21804
R264	270k	CF		32356
R265	1k5	CF		21801
R266	4k7	CF		21805
R267	4k7	CF		21805
R268	3k9	CF		21804
R269	560Ω	CF		21798
R270	3k9	CF		21804
R271	8k2	CF		21808
R272	1k	CF		21799
R273	100Ω	CF		21794
R274	4k7	CF		21805

CAPACITORS

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
C1	1800pF	CE(2)	1250V	28157
C2	1800pF	CE(2)	1250V	28157
C201	12.5μF	E	25V	20775
C202	12.5μF	E	25V	20775
C203	.047μF	CE(2)	12V	19657
C204	220pF	CE(2)	500V	22379
C205	220pF	CE(2)	500V	22379
C206	.022μF	CE(1)	30V	2663
C207	.1μF	CE(1)	30V	19647
C208	3300pF	CE(2)	500V	22391
C209	3300pF	CE(2)	500V	22391
C210	10μF	E(T)	10V	26451
C211	10μF	E	10V	26451
C212	4.7pF	E(T)	10V	33601
C213	1.6μF	E	25V	4453
C214	220pF	CE(2)	500V	22379
C215	8μF	E	350V	19895
C216	1000μF	E	40V	52869
C217	3300μF	E	16V	31431
C218	.047μF	CE(2)	12V	19657
C219	.047μF	CE(2)	12V	19657
C220	.047μF	CE(2)	12V	19657
C221	.047μF	CE(2)	12V	19657
C222	.01μF	CE(2)	250V	22395
C223	15pF	CE(2)		22366
C224	2200pF	CE(2)		22389
C225	0–390pF	A.O.T.		

TRANSISTORS

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
TR201		C407		20388
TR202		C407		20388
TR203		C407		20388
TR204		C407		20388
TR205		C407		20388
TR206		C407		20388

DISPLAY BOARD (cont.)

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
TR207		C407		20388
TR208		C407		20388
TR209		C407		20388
TR210		C407		20388
TR211		C407		20388
TR212		BC107		26790
TR213		BC107		26790
TR214		MPSA42		32708
TR215		MPSA42		32708
TR216		MPSA42		32708
TR217		BFY51		29329
TR218		BC107		26790
TR219		BC107		26790
TR220		BC107		26790
TR221		BC107		26790
TR222		BC107		26790
TR223		2N2369		23307
TR224		2N2369		23307
TR225		2N2369		23307
TR226		2N4871		29509
TR227		2N2369		23307
TR228		2N2369		23307
TR229		2N2369		23307
TR230		BC212		29327
TR231		2N5296		28630
TR232		BC212		29327
TR233		BFY51		29329
TR234		2N5296		28630
DIODES				
D201		IN4148		23802
D202		IN4148		23802
D203		IN4148		23802
D204		IN4007		52337
D205		IN4007		52337
D206		Zener	12V	4031
D207		Zener	4V7	4073
D208		IN4148		23802
MR201		W02		19725
MR202		W02		19725
INTEGRATED CIRCUITS				
IC201		SN74141N		32705
IC202		SN74141N		32705
IC203		SN74141N		32705
IC204		SN74141N		32705
IC205		SN74L75N		32703

Ref	*Value*	*Description*	*Tol %±*	*Part No.*
IC206		SN74L75N		32703
IC207		SN74L75N		32703
IC208		SN74L75N		32703
IC209		SN74L75N		32703
IC210		SN74L90N		32704
IC211		SN74L90N		32704
IC212		SN74L90N		32704
IC213		SN74L90N		32704
IC214		SN74L73N		32702
IC215		SN74L192N		32706
IC216		SN7445N		32700
IC217		SN74L73N		32702
IC218		SN74L73N		32702
IC219		SN74L04N		32335
IC220		SN74L10N		32698
IC221		SN74L00N		32334
IC222		SN74L10N		32698
IC223		SN74L10N		32698
IC224		SN74L00N		32334
IC225		SN74L04N		32335
IC226		SN74L00N		32334
MISCELLANEOUS				
ILP201		Indicator Neon ITT5870S		30727
ILP202		Indicator Neon ITT5870S		30727
ILP203		Indicator Neon ITT5870S		30727
ILP204		Indicator Neon ITT5870S		30727
ILP205		Indicator Neon ITT5870S		30727
ILP206		Indicator Neon ITT58-GS-S		32803
XTL201	500kHz	Crystal	.02	A4/32707
FS201	250mA	Bulgin F270		32338
FS202	1A	Belling Lee L1427/1		52162
SKH		Supply Connector B/Lee L1436/S		3302
S1		Switch Rocker On/Off		A4/32988
S2		Switch, Slider		32845
S3		Switch, Slider		A4/32843
FS1	250mA	Bulgin F270 Slo-Blo	230V	32338
or	500mA	Bulgin F270 Slo-Blo	115V	32339
L1		Choke Toroid		A28145
T1		Supply Transformer		A1/32493

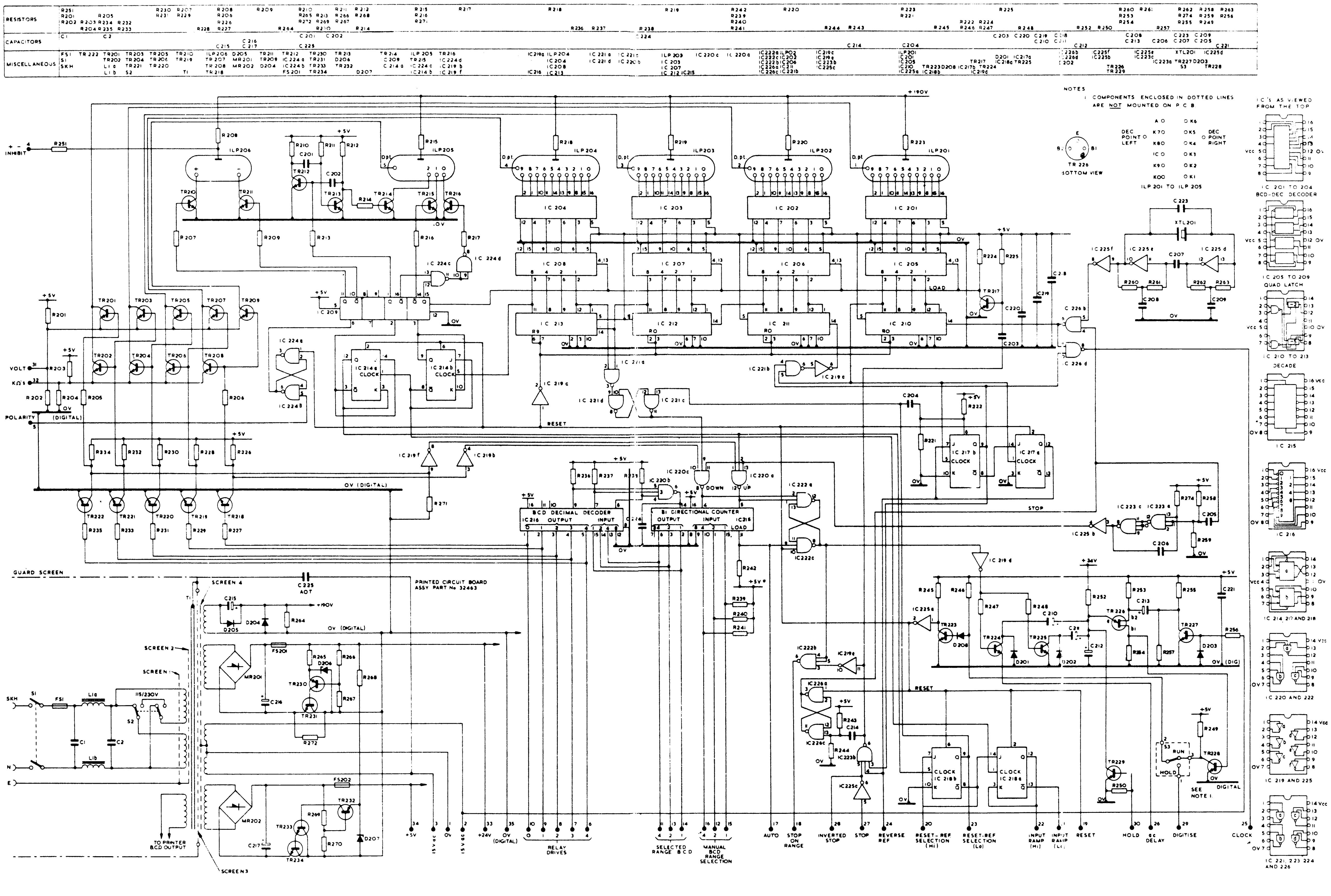


Fig. 9 Display Board Circuit Diagram

PRINTER OUTPUT

Ref	Value	Description	Tol%±		Part No.
RESISTORS					
R501	4k7	CF			21805
R502	4k7	CF			21805
R503	3k3	CF			21803
R504	3k9	CF			21804
R505	390Ω	CF			28722
R506	4k7	CF			21805
R507					
R508	390Ω	CF			28722
R509	390Ω	CF			28722
R510	390Ω	CF			28722
R511	390Ω	CF			28722
R512	390Ω	CF			28722
R513	2k2	CF			21802
R514	2k2	CF			21802
R515	390Ω	CF			28722
R516	4k7	CF			21805
R517	4k7	CF			21805
R518	3k3	CF			21803
R519	3k9	CF			21804
R520	4k7	CF			21804
R521	100Ω	CF			21794
R522	1k	CF			21799
R525	4k7	CF			21805
R526	4k7	CF			21805
R527	4k7	CF			21805
R528	4k7	CF			21805
R529	4k7	CF			21805
CAPACITORS					
C501	470pF	CE(2)			22383
C502	.047μF	CE(2)	+50 −25	12V	19657
C503	220pF	CE(2)			22379
C504	.047μF	CE(2)	+50 −25	12V	19657
C505	470pF	CE(2)			22383
C506	10μF	E	+50 −10	25V	32180
C507	820pF	CE(2)			22386
C508	1000μF	E	+50 −10	16V	32178
C509	10μF	E		10V	26451
C510	.047μF	CE(2)	+50 −25	12V	19657
C511	.047μF	CE(2)	+50 −25	12V	19657
C512	.1μF	CE(1)	+80 −25	30V	19647

Ref	Value	Description	Tol%±	Part No.
TRANSISTORS				
TR501		BFY51		29329
INTEGRATED CIRCUITS				
IC501		SN7404N		31836
IC502		SN7400N		52038
IC503		SN7404N		31836
IC504		SN7400N		52038
IC505		SN74L75N		32703
IC506		SN74L73N		32702
IC507		SN74L75N		32703
IC508		SN74L75N		32703
IC509		SN74L75N		32703
IC510		SN74L75N		32703
IC511		SN74L90N		32704
IC512		SN74L90N		32704
IC513		SN74L90N		32704
IC514		SN74L90N		32704
IC515		SN7404N		31836
IC517		SN7404N		31836
IC518		L005		52560
MISCELLANEOUS				
OC501		MOC1000		33281
OC502		MOC1000		33281
OC503		MOC1000		33281
OC504		MOC1000		33281
OC505		MOC1000		33281
OC506		MOC1000		33281
OC507		MOC1000		33281
MR501		W02		19725
D501		IN4148		23802
D502		IN4148		23802
D503		IN4148		23802
T501				A4/33411
SKX		Connector Socket		27513
SKY		Connector Edge		A3/33402
SKZ		Connector Edge		A3/33401

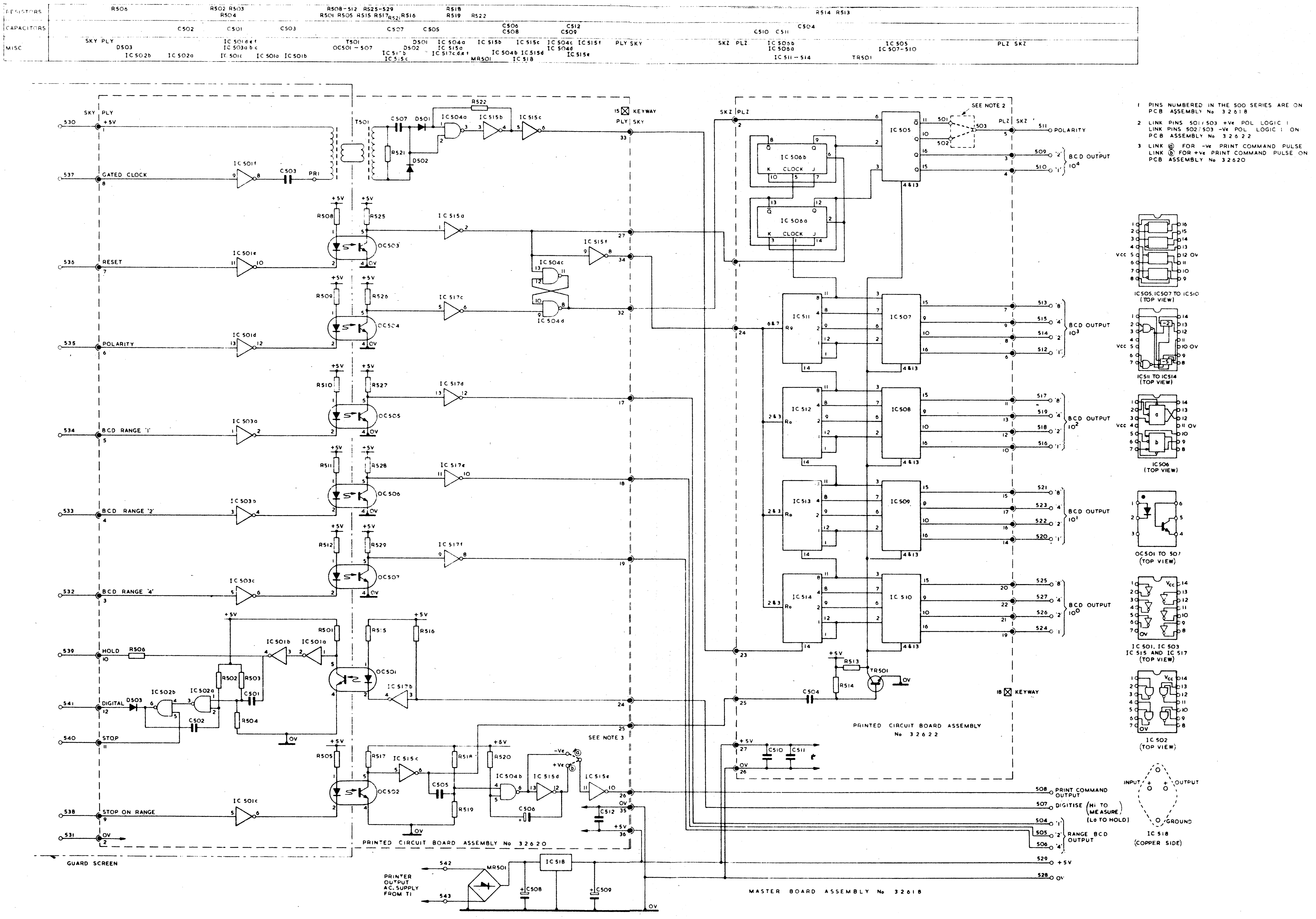


Fig. 10 Printer Output Circuit Diagram

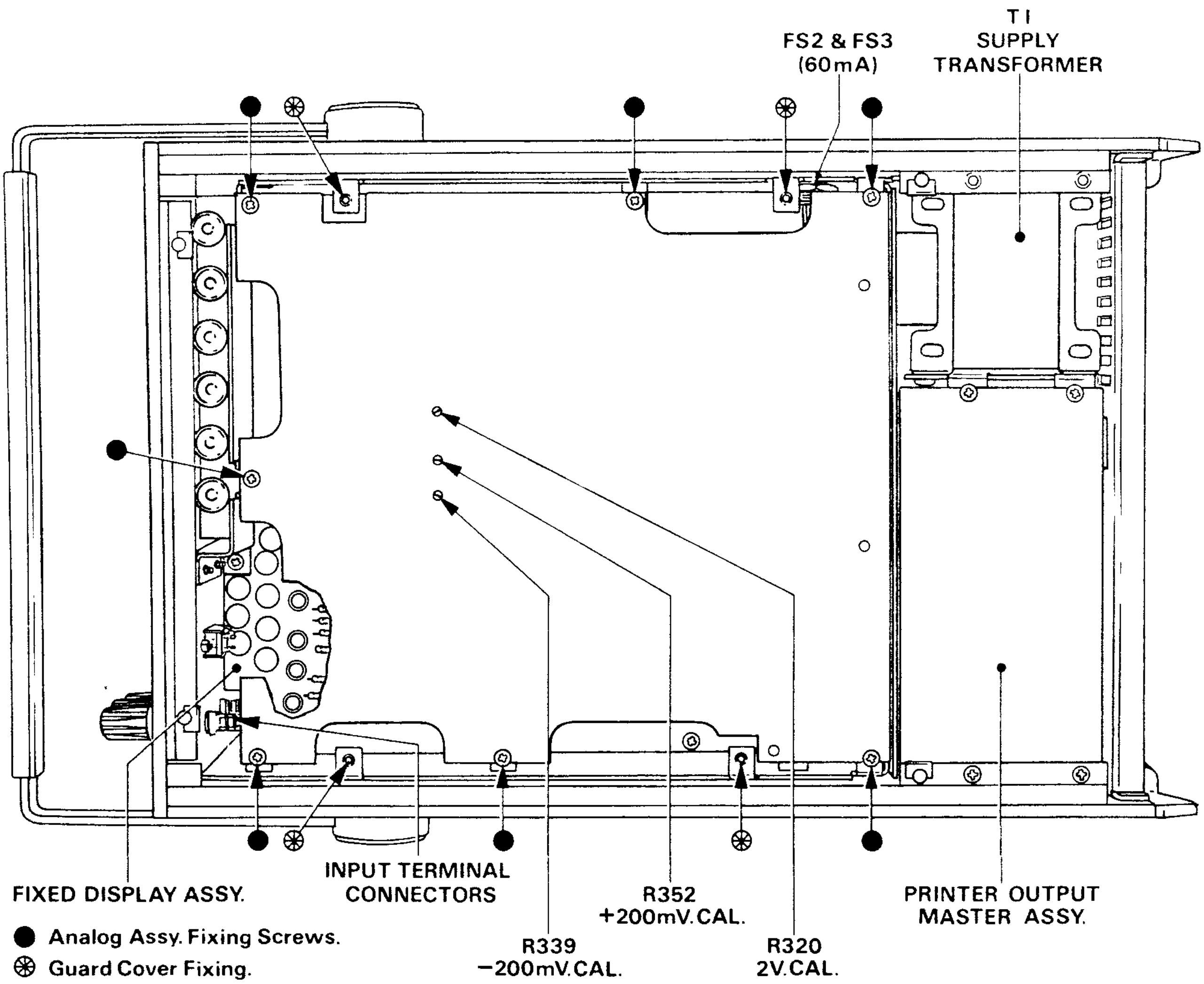


Fig. 11 Component Layout Top-view

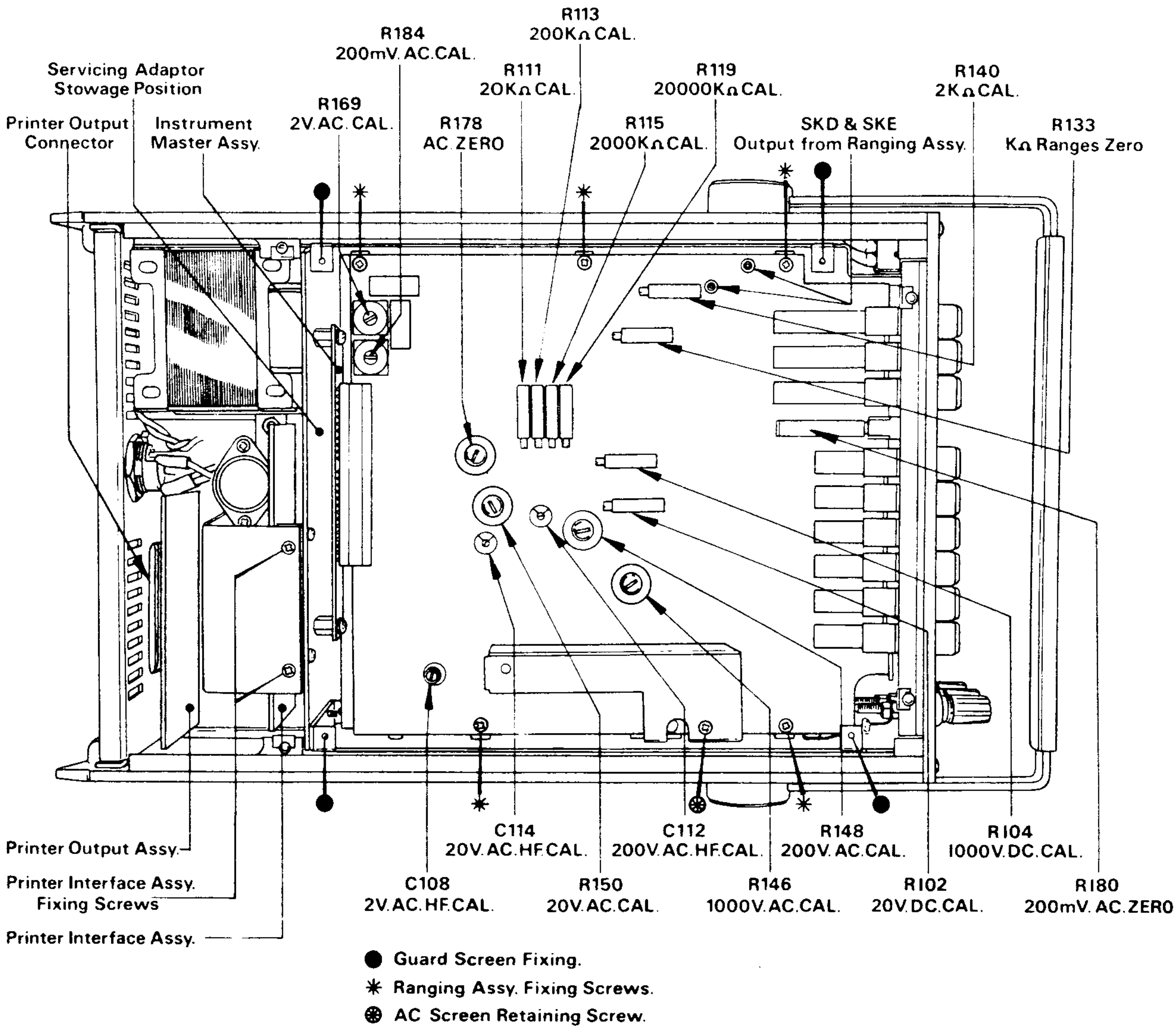
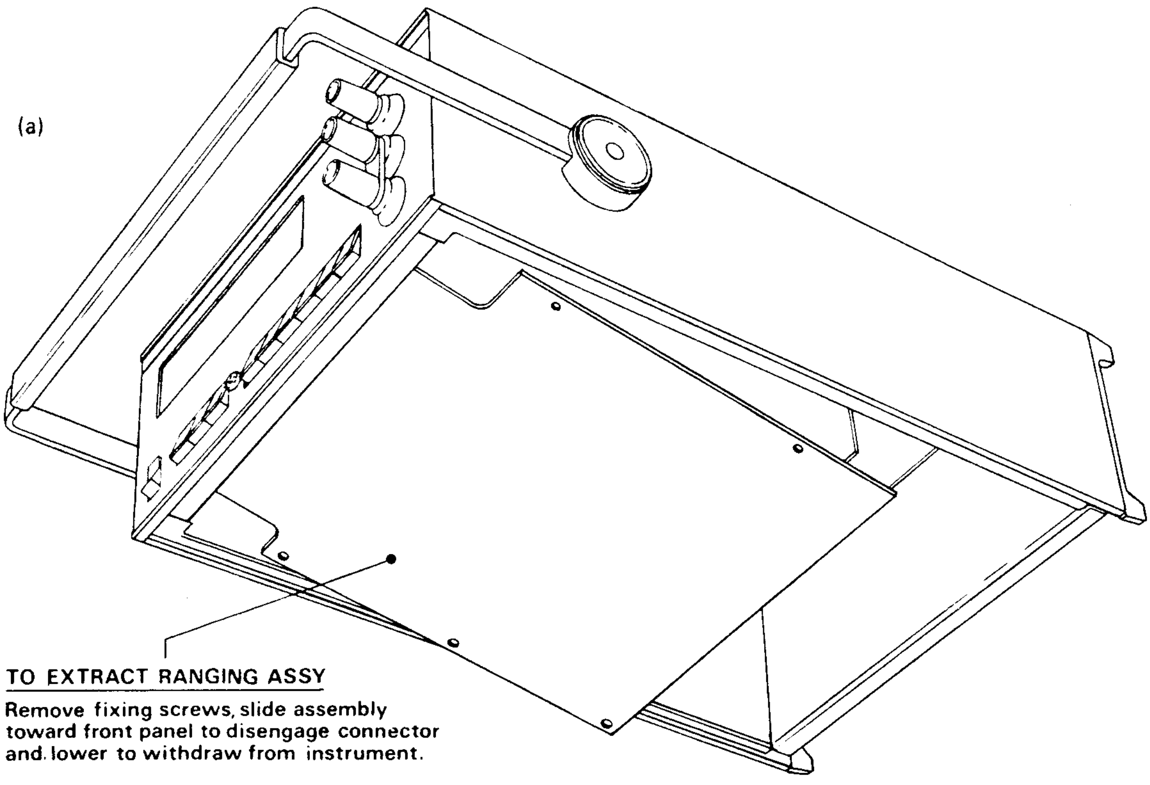


Fig. 12 Component Layout Underside-view

(a)



(b)

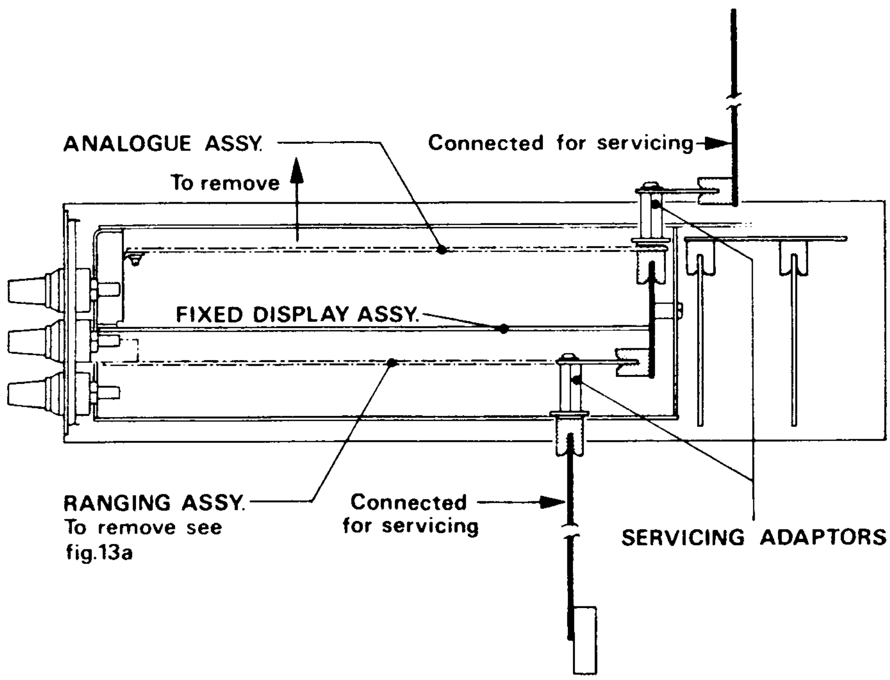


Fig. 13 Dismantling and Service Diagram