AVO International

Megger LCB2000 and LCB2500
Service Manual

Warning: Only suitably trained and qualified persons should undertake servicing of this product after reading the section on safety precautions.

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This document refers to instruments built with PCBs 5440-251/252 Editions A

Contents

Introduction

The Megger LCB2000 and LCB2500 series of compact battery powered multi-function test instruments designed to enable an electrician to speedily test electric installations to national and international standards. Earth, Loop resistance and RCD tests can be carried out. The instrument is designed for safety and complies with EN 61010-1 (1993) and parts of EN61557.

The LCB2500 includes results storage and serial (RS232) communication with a printer or PC. The LCB2000 has the following differences:

No RCL switch position
No small RS232 board, and no 9 way ‘D’ connector
No serial communications circuits on the main board.
Different label and key switches

The only other difference in operation is that it is not possible to store results on the LCB2000. As in the test of the LCB2500 the instrument serial number is stored, if this is blank it is assumed that the instrument is an LCB2000 and result storage is disabled.

The LCB includes the no trip loop test first introduced on the Megger LT7. In this service guide you may find references to this test as the 'LT7 test'. An alternative to the 'LT7' test is also included that allows a **three wire** no trip test to be performed to a resolution of 0.01Ω. The LCB series was launched at the end of Jan 2000. They carry a great deal of circuitry that is similar to the CM500 , the major difference being that continuity and insulation functions have been removed. The instrument was launched as a combined RCD/loop tester with all the relevant live system installation tests.

PCB Part Number and Edition

This manual refers to PCB 5440-251 (A5) Power Board and PCB 5440-252 (A5) Main and display Board . The part number and edition of the PCB in the instrument you have can be found by marks in the copper next to the power resistor in the top left of the power board and at the bottom of the component side of the PCB with the switch on .

Safety Precautions

- While servicing the instruments suitable protection from mains supply voltages will need to be provided. This can include a 30mA RCD, isolation transformers and barriers. Note that for test and fault-finding purposes most RCD, Loop and Earth tests can be done after a 30mA RCD by connecting the 'PE' connection to neutral.
- **Never carry out an RCD, Loop or Earth test with a low voltage earthed supply instead of a battery as 0V is live during these tests.**
- Take care to mark the position of all cable and wire fastenings on dismantling the instrument, and reinstate these after service.
- All replacement items must be of a type approved by AVO International Ltd to maintain product safety.
- Before a repaired instrument is returned to the user a full test must be performed to ensure that the instrument is safe to use. All protective devices (including thermal cut-outs and fuses) must be present and fully operational.
- A 4kV flash test is normally performed between all supply inputs (L, N & PE) and all pins of the serial connector (LCB2500).

Critical Components

The following components are safety related and if faulty must be replaced by an approved part. When inspecting an instrument for a suspected fault, these components must be checked for damage before connecting the instrument to any supply voltage.

HIGH INTEGRITY COMPONENTS

The following components are HIGH INTEGRITY. This means that the safety of the customer relies on these components. You therefore need to be sure that the correct components are used.

High Integrity

Description		Manufacturer and Reference
Resistor 10M VR37	26837-130	BC Components VR37 5%
Resistor 390k VR37	26836-134	BC Components VR37 5%

Safety related mains rated components.

Circuit reference	Description	Part Number	Manufacturer and Reference	Rating
R569,R566	BC Components 1.8 MΩ VR25	26836-624	BC Components 1.8 MΩ VR25	
RL500…RL502	Relays	25980-057	Takamisawa JS5-K	1 kV a.c. rms
FS500…FS501	7A Fuse	25411-854	SIBA 70-094-63/7A	440V 50kA
D501,D502,D503,D504	Diode 1N4007	28863-082	1N4007 (1000 V)	1kV
TX500	Isolation transformer	27900-032	Newport 1001	2kV
R500,R507…R509	Resistor 2.4 12W/7W	26837-115/133	VTM KF216-4/KH216-4 (x4)	
R594	Resistor 200R 12W	26837-131	Welwyn W24	
ZD504,ZD505	Interferance Suppression	27920-039	SGS P6KE440P (x2)	440V
	Thermal cutout	28863-352	Microtherm T11-C172-V102	250V
	Thermal fuse	25950-046	Elcut	250V, 2.5A
TR507	FET	28940-043	SGS/Siemens BUZ80A 800V	800V
TY500	SCR	28940-044	BTW69-1000	1kV

Disassembly and Reassembly

1. Disassembly

First disconnect all test leads, open the battery compartment and unclip the battery holder from the instrument. Remove the four screws, and lift the rear part of the case off. To remove the PCB pull the range knob off, and remove the PCB retaining screw from the middle of the PCB's. The PCB's can then be taken out of the front panel .

There are a total of three PCBs (four for the LCB2500). The main PCB holds the main measurement and control circuits. The display and main boards are attached to the front cover by one central screw . This display board holds the display, microprocessor, ADC, a portion of the RCD current control circuit, relay control circuit and -5V generator and RS232 communications.

The power board holds the input relays and line and neutral fuses, together with the input resistors used to measure the supply voltage and frequency. A transformer is used to detect if a plug is in the 4mm socket and the four diodes of a bridge rectifier are also on this PCB.

In the LCB2500, a completely isolated serial board is mounted in the back of the case; two way optical communication is by LEDs.

When the PCB's are removed the main and display board can be taken apart using a suitable lever to disengage the 3mm board spacers. Be careful not to damage the tracks or the inter-board insulator. The PCB can then be laid out flat ready for diagnostic work to be carried out or components to be replaced. Particular attention needs to be paid to the inter-board edge connections, to ensure that they are not over flexed and snapped. To remove the Power board from the main display board the tie wraps securing the wiring loom will need to be taken off (3 Off). The power board can then levered off in the same manner as the display board.

2. Display removal

There are components under the display, and unfortunately removal of the display is difficult because of the large number of pins that need to be unsoldered. If a display fault is obvious (e.g. marks or cracks), it is easier to cut the legs with a pair of wire cutters and then clean up the PCB afterwards. If the backlight must be removed, extreme caution should be used if damage is to be avoided. This component is quite fragile, as the four connection points are not metal pins, but small strips of double-sided PCB material which can easily break off. Re-assembly is straightforward, but it is worth checking that everything is working correctly beforehand. Clean the PCB holes of solder and bend the legs of the display slightly outwards so that it can be 'sprung' into place with the legs making contact with the PCB. (The epoxy seal on the display should be on the left-hand side, when viewed from the front). If there are contact problems, water can be applied sparingly with a small paint brush to each leg in turn, which will make adequate connection for a short while. Do not get water onto any other part of the circuit, as some parts are very sensitive to leakage. Dry the board afterwards with gentle heat, such as warm air from a hair-dryer. Do not forget to fit the backlight before final re-assembly.

3. Rotary switch

This is a low voltage switch of simple construction, and indication of its position is provided by two voltages. To switch the instrument off, it shuts down the switched mode and linear power supplies. See circuit diagram, sheet 9 for a table of expected voltages.
The fixed contacts are copper PCB pads, coated with Electrolube grease to reduce oxidation. The moving contacts are nickel-silver discs, one each side of the board, each having three points of contact. Two helical springs hold the discs in contact with the board. The spring pressure is sufficient to clean away dirt and

contamination as the discs rotate. The resistance of the switch should not exceed 5Ω at each point of contact.
Life expectancy is 100 000 operations with the correct lubricant, when the discs will need replacing. A similar life will be obtained even without lubrication, the main purpose of which is to prevent the build up of copper oxide when the instrument is not used regularly. If the switch is disassembled and cleaned, it may be re-lubricated with almost any contact grease.
The switch can be disassembled by removing the centre screw. Re-assembly can be difficult and it is best to leave the springs out the first time just for practice. This gives you a chance to see how the parts fit together before they going flying all over the room.

4. Reassembly

This is reversal of the disassembly process. If tie wraps have been cut on the power board these will need to be pre-fitted before the boards are fitted together as fitting after this stage is difficult. Ensure that the switch mechanism is fitted with an 'O' ring and that the interboard insulator is fitted. Check that the rotary switch is in a valid position - OFF is the best if you are unsure. Place the PCB into the front panel, and check that the interboard insulator is folded round the main PCB correctly , so that it is in between the main PCB . The PCBs can be screwed into place using the a short screw located in the centre of the PCB's, and the wires attached. Labels for the holes are marked in the PCB resist, and the must be attached as follows

N	Blue
L	Black
E	White
Touch	Orange
Test	Brown & Orange (polarity not important)

Now check that the rotary switch and push buttons work as expected. A battery can be temporarily attached at this point to check the instrument powers up.

Cable ties are now used to ensure that the wires can not cause a hazard if the solder joint fails. These are needed:

1. Around touch wire (Orange) and through hole in power PCB.
2. Around earth wire (White) and through hole in power PCB.
3. Around neutral wire (Blue) and through hole in power PCB.
4. Around line wire (Black) and through hole in power PCB.
5. Around touch wire(Orange)and thermal trip wire(Yellow) creating a loom.
6. Around all wires including Battery wire creating a loom, PCB end.
7. Around all wires including Battery wire creating a loom, 5 way socket end.
8. Around the 5 way socket and touch wire(orange)
9. The back can now be screwed onto the front panel of the instrument with the original four screws.

Circuit Description

1. Brief Outline.

1.1 Functions

The instrument has the following capabilities:

a. Measurement of voltage (ac and dc)
b. Measurement of frequency
c. Indication of sense of rotation of three-phase system
d. RCD testing
e. Loop impedance testing

LCB2500 Only

g. Permanent storage of test results
h. Recall of stored results to display
i. Printout of stored results to optional printer
j. Download of stored results to a personal computer

1.2 Organisation

The overall arrangement within the instrument is that essentially independent blocks of circuit for each type of test (RCD, loop etc.) share a common core which is responsible for control, measurement and display. To reduce battery drain, parts of the circuit are powered down when not required.

The central core consists of:

a. Power supplies
b. Microcontroller system + display.
c. Input/output expansion (PLD)
d. Input switching (relays)
e. Input amplifiers
f. Range switching (rotary switch)
g. A/d converter & associated multiplexers
h. EEPROM and RS232 interface for result storage/download

When a test is carried out, the particular block of circuit relating to that test is connected to the a/d converter circuits via semiconductor multiplexers, and to the instrument terminals by means of mains-rated relays.

1.3 Test and Pretest

If a function has been selected by the rotary switch and the 'TEST' button has not been pressed, (or if a test has been completed) the instrument is said to be in 'pretest' mode. The voltage on each pair of terminals is analysed and the voltage is displayed, together with appropriate indicators, such as 'neons' or three-phase arrows. The input frequency can be seen by pressing the 'DISPLAY' button. All relays are normally de-energised during 'pretest'.

When the 'TEST' button is pressed to request a test, any of the following events may occur, depending on the prevailing conditions of voltage and frequency:

a. Conditions acceptable - test proceeds immediately.

b. Voltage too low - up to 30 seconds is allowed for conditions to become suitable for the test. If this happens the test proceeds automatically.

c. Test cannot proceed - instrument indicates the reason.

Once a test has been completed, the system returns automatically to 'pretest' mode, displaying the result.

2. Power Supplies

2.1. General

The LCB uses power management techniques to reduce the battery drain. After a few minutes of inactivity, the instrument will go into its low power shutdown mode. The instrument can be re-activated by pressing any button (except the TEST button, which is ignored by software), or by turning off & on again with the rotary switch.

Battery	Powers 5V linear regulator, 20V generator and battery check circuit
Vcc	A +5V rail which supplies the microcontroller system. Always present, (even in auto shutdown), unless the instrument is turned off via the rotary switch.
-5V lpp / +5V lpp -5V / +5V	Following the CM500 design, we have two power supplies. However, in practice, both the ‘LPP’ and standard supplies are switched on at the same time. The negative rail is produced directly from the positive rail by a charge pump
Relay power	This rail is derived from 5V lpp, either via a semiconductor switch (providing 5V), or via a diode, providing about 4.2V. The full 5V is applied to 'pull in' a relay, but once the relay has operated, the supply is reduced to minimise power consumption.
20V	For certain analogue circuits in the RCD/loop circuits. Switched on only when required
0V	Three 0V rails are available : 0V(D) - ground for digital circuitry. 0V(A) - ground for analogue circuitry. 0V - ground for signals.

2.2. Vcc

(circuit diagram sheet 2)

This supplies the microprocessor, display controller etc, and is supplied from a linear regulator (VR1). The output is +5V ±1%. The supply (‘switched battery’) comes from TR9, controlled by the rotary switch.

2.3. +5V lpp.

(circuit diagram sheet 8)

This is the output from TR11, controlled by the processor. It is switched off when the instrument powers down.

2.4. -5V lpp

Circuit diagram sheet 2 Main.
This is generated by IC13 on the display board. This is a charge pump IC which simply inverts '+5V lpp', producing a nominal -5V (unloaded), which is actually about -4.15V (loaded).

2.5. +5V

Circuit diagram sheet 2 Main.
The section of FET switch TR3 with pin numbers 1,2,7,& 8 is turned 'on' by taking signal 'gen power off' to a low level, thereby pulling the gate pin of the FET low, and connecting +5V to +5V lpp. Normally on at the same times as +5V lpp.

2.6. -5V

Circuit diagram sheet 2 Main.
This is generated by IC12 on the main board. This is a charge pump IC which simply inverts '+5V', producing a nominal -5V (unloaded), which is actually about -4.15V (loaded).

2.7 Relay power

Circuit diagram sheet 2 Main.
The signal 'relay ps' is normally high, so that switch TR3 pins 3,4,5 & 6 is 'off'. The power to the relays is then obtained from +5V lpp via D18, which provides a supply of about 4.3V. This is enough to hold in a relay which has already been energised, and saves power which would otherwise be wasted in the relay coils at 5V. However to reliably operate a relay, the full 5V must be applied. Thus for about 50ms, while the contact changeover takes place, the signal 'relay ps' is taken low, turning on TR3 and connecting the relay coils directly to +5V lpp.

2.8. 20V

Circuit diagram sheet 2 Main.
This is the output from IC15, which is configured as a switch-mode unit operating in step-up mode. The principal components forming the switch-mode supply with IC15 are the inductor L1, the schottky diode D21 and the output capacitor C49, plus the timing components C46 and R118. The basic operation is as follows. A switch inside IC15 is turned 'on', causing a current to flow from the 12V battery, through L1, and into the supply ground (pin 7). This current increases linearly until the switch in IC15 turns 'off', at which point the inductor discharges its stored energy into the load via D21.The output voltage is stabilised by means of feedback from the output divider (R115/R116/117) to pin 2. The control circuitry inside IC15 acts so as to maintain pin 2 at 1.245V, resulting in an output of about 22V (1.245V x (1 + (R115+R116)/R117)). The 20V supply is switched on as required under micro control, by connecting it to the battery, via FET switch TR11 (pins 1,2,7 & 8). The '20v on' signal turns 'on' TR10, hereby pulling low the gate of TR11.

2.9. 0V(D)

The origin of this is at the negative side of the battery connector.

2.10. 0V(A)

The analogue ground is tapped off from 0V(D) adjacent to the LT1129 GND via LK1, in order to supply the high voltage inverter transformer.

2.11. 0V

The signal ground is picked up from the LT1129 GND via LK2 . Virtually no current flows along this connection so that its potential is the same everywhere on the pcb. 0V provides the low potential reference point for the a/d converter and all quantities measured by it.

3. Microcontroller system.

3.1 General

This sub system comprises:

Microcontroller
Display & display controller
Watchdog/Reset/NMI circuit
Push button circuit
PLD

3.2 Microcontroller

(circuit diagram sheet 6 Main)

The micro has on-board 4k RAM and 128k ROM (containing the program instructions). It runs from an 8MHz crystal, and the master clock signal is outputted on the 'phi' pin. It has a built-in 10-bit 8-channel a/d converter with a conversion time of a few microseconds, numerous timers, interrupt pins and a serial interface. Port usage is mostly general purpose input/output, but some ports have special functions:

Port 2 bits 1 & 2 control the eeprom.
Port 3 is used as a pseudo data bus to interface with the external a/d converter, DACs and display.
Port 4 is used to control the relays.
Port 6 handles the display controller.
Port 7 is an 8 channel 12-bit fast a/d converter. One external multiplexer (IC300) has been added to expand the input capability to 9 channels.
Port 9 bits 1 & 3 ('serial in' & 'serial out') are used for the RS232 interface.
Port B bits 0 & 1 ('l-e freq' & 'n-e') are used as edge detectors for a variety of tasks, such as frequency measurement.
Port B higher bits interface with the push buttons.

Interrupt pins used are:

- A/d converter (IC314, 7109) status signal ('ad/STAT') is on irq0 (port 8 bit 0)
- Push button press signal ('keypress-') is on irq2 (port 8 bit 2)
- Frequency measurement, rcd zero current detection, and general purpose edge detection on timer capture pins 3a and 3b ('l-e freq' & 'n-e', port B bits 0 & 1).
  (Note: irq1 interrupt is not used on LCB)

Timer pins used are:

- Buzzer driver signal ('buzz') from timer 1 output pin a (port A bit 4)
- Frequency measurement signals ('l-e freq
  ' & 'n-e') on timer 3 input capture pins a and b (port B bits 0,1).

Timers are also used for:

- Frequency measurement
- RCD test and trip timing
- A/d converter (7109) control
- Watchdog reset control
- Key autorepeat timing

3.3 Display and display controller

(circuit diagram sheet 7 Main)

The display has 87 separate segments and is driven in 3-way multiplex, 1/3 bias mode, by 3 'common' signals and 29 'driver' signals from the controller chip IC301. For the display to be enabled, the 'disp off'

signal must be taken low to provide bias for the drivers in IC301. The bias levels are tapped off from the resistor chain R322, R321, R328 & R327. Components R308 & C302 set the frame frequency of the multiplexing.
To write to the display controller, 'disp ce-' and 'disp we-' are taken low, and 'disp ready' should respond by going high. Data can then be set up on the data bus and latched into the display controller by taking 'disp we-' high again. In the LCB, the controller is used in 'bit manipulation' mode, i.e. display segments are turned on or off singly and sequentially, rather than in groups.
Display pinout and segments are shown in appendix 11.

3.4 Watchdog and Reset Circuit

(circuit diagram sheet 9 Main)

IC304 is configured as two independent monostables, one for the watchdog circuit and one for the microcontroller reset. In the LCB instrument, the reset circuit is only used at power-up. Initially C315 & C316 are discharged, resetting the right-hand half of IC304 and forcing pin 4 ('reset-') high. C316 then rapidly charges, and the positive edge on pin 3 causes a negative transition on 'reset-' and starts the monostable action. At a time determined by C317 & R359, the monostable times out (see 74HC123 data sheet) and 'reset-' returns to a high level. Thus a negative reset pulse of about 40ms is generated. Now consider the watchdog circuit. During normal running, a 10us long positive-going pulse is applied by the micro to the 'watchdog' pin (IC304 pin 10) at least every 32ms, maintaining pin 12 (nmi) at a low level. This line also serves to enable operation of the 'test' relays. If the micro 'crashes', the regular 'watchdog' pulse ceases, causing time-out on the left-hand monostable and the 'nmi'/'rl test disable' signal will go high. This immediately causes IC307 pins 10 & 13 to go low, thereby de-energising 'test' relays and disconnecting the input terminals, making the instrument safe. An nmi is generated and the microcontroller responds by shutting down all the systems in a controlled manner and then generating a reset internally. This reset signal is outputted (for information purposes only) on the 'Vpp' pin. A similar sequence of events will occur in the case of a 'brownout'. If the +5V lpp supply dips excessively, IC11 pin 13 (sheet 3 Main) pulls the 'brownout' signal low, and this has the same effect as a watchdog failure.
During auto-shutdown, all microcontroller activity ceases and special precautions are taken in software to prevent the watchdog/nmi mechanism from restarting the system.

3.5 Push buttons

(circuit diagram sheet 6 Main)

The push buttons connect directly to port 4 on the microcontroller, and also to 'nor' gate IC307 pins 4,5 & 6. If any key is pressed, a negative going edge is produced on pin 4, and on the irq2 pin of the microcontroller, causing an interrupt. The ensuing interrupt routine then reads the key pattern. Sometimes it is necessary to determine if a key has been released, but this does not generate an interrupt, and so the microcontroller also polls port 4 at regular intervals. The keypress interrupt also enables the instrument to be woken from standby mode after auto shutdown has occurred. The interrupt routine in this case cause an internal reset to be generated, as in the case of a watchdog failure.

3.6 PLD

(circuit diagram sheet 10 Main)

The PLD has two main functions, and replaces two ICs on the CM500 circuit. It provides extra output lines for the control of measurement circuits and controls the loop resistance measurement and current flow during tests.

Normally the ‘CE’ signal is held low. In order to write data into the pia, the microcontroller first sets up the appropriate data on the pseudo-data-bus and the PLD port address on A0 and then latches in the data by momentarily pulsing ‘CE’ low. The PLD is refreshed regularly using a RAM copy of its output data to combat possible corruption due to external interference on the control lines.

The two registors control external port lines, or the action of the RCD/Loop state machine. The functions of the state machine is discribed in the measurement section.

PORT0		PORT2	
0	Spare Output	0	(LOAD SEL A)
1	ADCinA	1	(LOAD SEL B)
2	ADCinB	2	SPARE
3	AC/DCinA	3	20V ON
4	AC/DCinA	4	RELAY PS
5	(MODE 0)	5	LOAD ON
6	(TRIGGER)	6	(HI I LOOP)
7	IN A	7	(MODE 1)

4. Miscellaneous

4.1. Range selection

(circuit diagram sheet 2 Main)

The rotary switch utilises two of the 12 channels of the microcontroller's on-board a/d converter. A chain of 6 resistors between 0V(A) & +5V (R120 etc.) provides a set of voltage tappings, two of which are selected in different combinations according to switch position. The two voltages are measured by the a/d converter which then uses a look-up table to determine the actual switch position. See sheet 2 Main for details of voltage tappings for each range.

4.2. Buzzer.

(circuit diagram sheet 5 Main)

One of the microcontroller's internal timers is used to toggle a port bit at 2kHz (Port A bit 4). Power level is increased for the buzzer drive by emitter follower TR304 (sheet 5 Main). R369 limits the current, and D306 protects TR304 against back-emf from the inductive load.

4.3 Touch Contact.

(circuit diagram sheet 2 Power)

This circuit detects if the potential on the 'EARTH' input is greater than 70V or so from the local earth in a similar fashion to a neon screwdriver. During normal operation of the instrument, 'EARTH' can be up to 200V or so away from the instrument's internal 0V, and this difference must be rejected by the touch contact circuit. This is done by means of a differential amplifier (IC500 pins 2,3 & 1) with both inputs connected to 'EARTH'. Thus under normal circumstances, once the common-mode rejection has been adjusted by means of R513, the output of IC500 should be near-zero. However if 'EARTH' is at a high potential with respect to local earth, current can be drawn from the touch contact - typically 1uA through the human body. This upsets the balance of the amplifier giving a measurable a.c output at pin 1. After level shifting, this is measured by one channel of the micro's on-board a/d converter.

4.4 Analogue to Digital Converter

(circuit diagram sheet 8 Main/3 Main)

The 7109 12-bit integrating converter (IC314) is used for all accurate voltage measurements. The a/d reference voltage is constant for some types of measurement and variable for others. The fixed references are obtained by dividing down the 2.5V developed across bandgap diode D20, either to 0.987V for voltage measurement, 26mV for lt7-style low current loop/earth tests and 254mV for all other loop/earth results. For continuity & insulation tests ratiometric mode is used (variable reference). The input and reference to the a/d are switched by the 4-channel multiplexer IC14 . The nominal operating frequency of IC314 is set by R396/C333/C334 at 25kHz, giving an integration time of 100ms to ensure good 50/60 Hz hum rejection. Conversions are controlled by the micro using the 'ad/run' control line. The 'ad/stat' signal is connected to one of the micro's interrupt pins to indicate that a conversion is complete.

4.5 Relays

(circuit diagram sheets 1 Power / 9 Main)

The following tasks are performed by three high-voltage relays (see sheet 1 Power):

a. selection of required pair of input terminals
b. safety isolation of input terminals
c. connection of inputs to test circuits

Hardware control of the relays is direct from the microcontroller except for the test relays, for which special precautions are taken. As long as the watchdog is running, the NMI signal is low and 'nor' gates IC307 on sheet 9 Main allow the relays to be energised. Should the watchdog fail for any reason, the relays automatically disconnect the input terminals from the measurement circuits. Transistors TR301 etc. are required because the micro has insufficient output current to drive the relays directly.
In 'pretest' mode (no test in progress), all relays are de-energised unless d.c. voltage is detected, in which case the discharge resistor will be connected.

5. Pretest

Pretest refers to the operation of the instrument before a test is attempted, or after a test has been completed.

A cyclic sequence of measurements is carried out in a loop which repeats about once per second.

The sequence is as follows:

1. Check to see if line-earth input is a.c. or d.c.
2. Check to see if neutral-earth input is a.c. or d.c.
3. Determine the direction of three-phase rotation if appropriate.
4. Check battery.
5. Read temperature of FET TR507
6. Perform quick measurements (10-bit) on all three input voltages.
7. Refresh hardware settings
8. Measure line-earth voltage accurately (12-bit) if required
9. Measure line-earth frequency if appropriate
10. Measure neutral-earth voltage accurately (12-bit) if required
11. Measure neutral-earth frequency if appropriate
12. Measure line-neutral voltage accurately (12-bit) if required.
13. Check touch-button sensor.
14. Display results, symbols etc. as required.
15. Transmit results via RS232 link (special test modes only)

Note that if circumstances permit, frequency and voltage measurements are performed simultaneously to minimize the cycle time.

5.1 Supply Voltage measurement.

(circuit diagram sheet 2 Power/8 Main)

Each pair of terminals L-E, N-E, & L-N, has its own differential amplifier which divides the relevant input voltage by a factor of 202. See IC502 & IC500 on sheet 2. Two types of measurement are performed on these outputs.

a. 10-bit measurements
For these, we use three channels of the microcontroller on-board a/d. Outputs from the op-amps, (which swing either side of 0V), are level-shifted into the range of the a/d (0 - +5V) by resistor networks (sheet 8 Main). See R50/R51 etc. The 10-bit measurements are not particularly accurate and are used during pretest to determine which 'neons' if any, should be shown on the display. Regardless of switch position, all three input voltages are monitored.

b. 12-bit measurements.
For the actual displayed result, the 7109 integrating converter is used for the measurement. Only one input voltage is accurately measured according the range switch setting. The required output from the differential amplifiers is selected by multiplexer IC9 (sheet 4 Main),and passed to the ac/dc converter circuit IC10. Positive inputs to IC10 are handled via diode D14, negative inputs via D15, resulting in an output at pin 7 which is always positive. The output of ac/dc converter IC10 is then handled directly by the a/d converter (sheet 8 Main). The reference for the a/d during voltage measurement is 0.987V,selected by multiplexer IC14.

5.2 Frequency Measurement & Three-phase detection.
(circuit diagram sheet 2 Power)

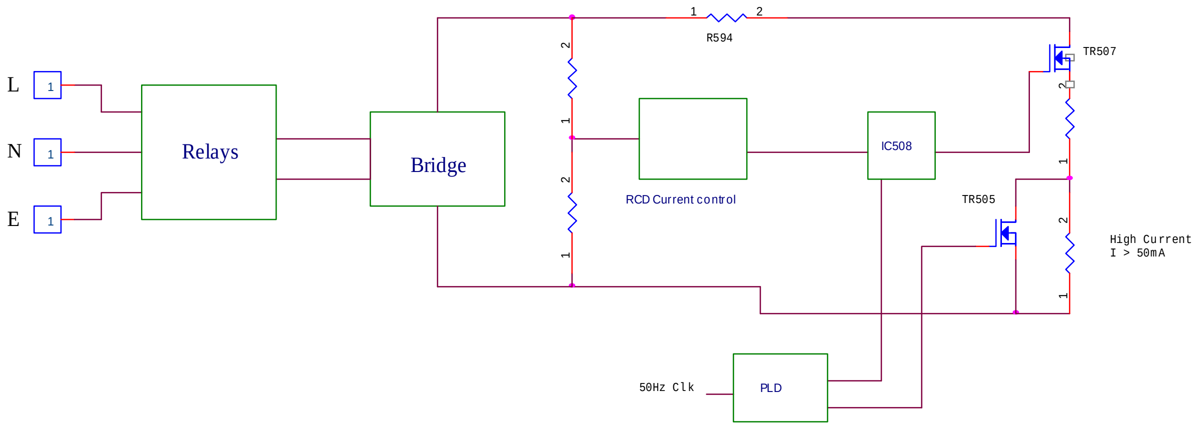
First, the incoming a.c. waveform is conditioned to provide a digital-type signal for compatibility with the microcontroller. Consider the line-earth input, for example. The output of the differential amplifier (IC502 pin 1 on sheet 2 Power) is taken to a window comparator on the display section of the pcb (IC2 on sheet 5 Main), which detects zero crossings and produces a train of narrow pulses at twice the input frequency. For 230V 50Hz input, these have a width of about 175us. An identical block of circuit processes the neutral-earth input waveform. Both outputs (IC2 pins 1 & 2) go to microcontroller edge detecting pins, the 'n-e' signal by direct connection, and the 'l-e' signal via multiplexer IC9 (sheet 4 Main). Negative going edges on both signal are simultaneously counted and timed by the micro for a period of around 300ms. The frequency is calculated from this data, and if the connection is 3-phase, the rotation sense can be determined from the same data by looking at the difference in timing between the 'l-e' edges and the 'n-e' edges.

6. RCD, Loop and Earth Testing

6.1 Test Current Control
RCD testing involves drawing a controlled test current from the mains supply, and timing when the RCD trips. This test current is also used during loop and earth resistance measurement.

A outline circuit is shown below:

The relays connect the mains input to the bridge rectifier. Relays and diodes are on the relay board, shown on sheet 1 on the Power Board circuit diagram. See section 4.6 for more information.
Note that normally approximately 2mA of 'leakage' will be drawn by R575 ,R574 and R583 all the time the relays are on. This ensures that the diodes are turned on, important during a loop resistance measurement. The test current is controlled by the RCD current control section, the timing controlled by the PLD. See the section on current waveforms for the test sequences on the various positions.



6.2 Output drive

Power PCB sheet 3

This is a constant current source; the current drawn is Vin (RCD Drive)/R53. For a sinusoidal current, RCD Drive needs to be sinusoidal, and therefore this is taken from the supply, the voltage controlled by the RCD current control section. The timing is controlled by STROBE, which is normally high to ensure no current flows. The 20V supply is required for the op-amp. There are two ranges – for currents greater than 50 mA, TR505 shorts out R584.

The temperture on TR507 is monitored by IC505 – if this is too great, tests are not allowed and the 'thermometer' symbol is shown on the display.

6.3 RCD current control

(Power PCB Sheet 3 and Sheet 11)

This provides a potted down voltage of the rectified mains voltage available to IC 508, which together with R589, R588 or R584 controls the test current.

IC504 buffers the potential divider. The voltage is controlled by two DACs shown on sheet 11, on the display board. The first DAC is made up of half of IC311 and IC313.

The value written into DACA is 50400/(voltage measured at the terminals). Note therefore that the correct voltage needs to be measured for correct current output. The value written is halved if the voltage measured is less than 200V (this is compensated for later).

The value written to the DAC by the processor is calculated so that the voltage at TP456 is always 1.3V (0.65V if Vin < 200V)

6.4 25A current control

(Sheet 1 Power/10 Main)

This is misnamed as it puts a 10Ω resistor across the supply, and thus the current is supply voltage dependant (10 - 48A). The resistor is R500,507,508,509 and this is controlled by TY500, an SCR which is connected directly to the output of the relays (RCD/LOOP1, RCD/LOOP2) and not via the bridge rectifier. C507 provides suppression against the SCR switching on when the relays are switched.

As 0V is connected to RCD/LOOP by a bridge rectifier, we need to isolate the drive to TY500. This is done by TX500; to switch the SCR on, IC306 (7555 running as an oscillator) is enabled.

There are two levels of thermal protection. A thermostat is attached to R509, and this prevents current flowing through the primary of TX500, and is indicated during a test by the symbol on the display. It this fails, there is a solder link on R500 which will interrupt the current when this resistor gets too hot. A repair to this can be remade with a sparing amount of solder.

6.5 PLD Clock

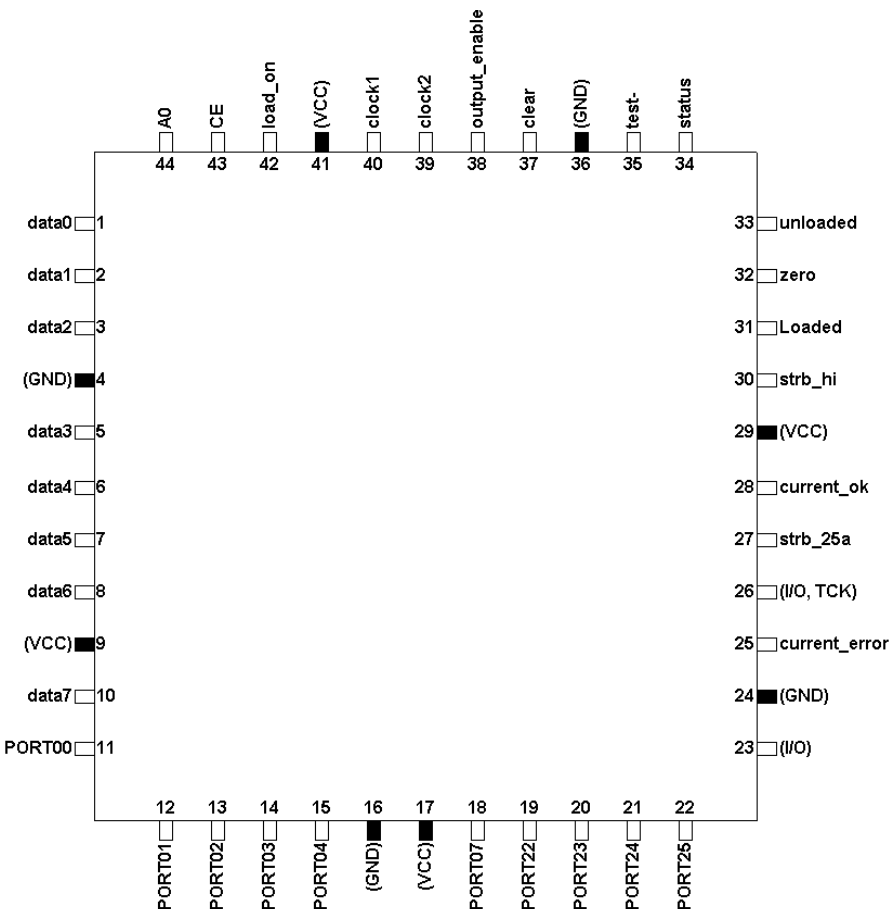
(Sheet 3 Power/10 Main)

The PLD (described below) is a state machine and needs to be clocked on each zero crossing of the incoming supply. This function is performed by IC310and IC309(Sheet 10 Main) and IC504 (Sheet 3 Power). IC504 divides down RCD/LOOP1 and RCD/LOOP2 by 212.77. For a 230V input we would expect a 1.08 Vrms sine wave at 50Hz CLK. IC310 (Sheet 10 Main) is a comparator that will convert this into a square wave. R371 is some positive feedback, R370 is the pull up for the open collector output and R379/R380/R381 provide a slightly negative reference voltage. R368/D305 protect IC309 from the -5V output of IC310. IC309 is a dual monostable; one half is triggered on a positive going edge and the other on a negative going. The advantage of the monostable is that any noise near the zero crossing will not result in a false clock. The time period is about 0.6 ms.

6.6 PLD

(Sheet 10 Main)

This is a Programmable Logic Device, and the symbol for the programmed device and pinout is shown below. As well as providing more outputs (replacing the PIA on the CM500 design), this device controls the timing of the test current, and controls the analogue switches for loop resistance measurement. There are various modes; these are controlled by the inputs MODE1, MODE2, SELA, SELB, LOAD_ON and HI I LOOP as described below. The device is a state machine and the states change on the rising edge of clock2 or clock1 - i.e. every zero crossing of the connected supply.



The PLD controls the operation of the PCB and Loop tests. The design is dervived from the CM500 version and further intergration as been achecived by adding two eight bit latches which both control the state machine and provide 10 output ports. For historical reasons these are called PORT0 and PORT2 on the PLD design and PORT0 and PORT1 on the circuit diagram. A device with more ‘cells’ (EPM7064STC44) is required.

These ports are written to by the microprocessor by selecting the port with A0 and taking CE high. Whilst high, the ports are write through and latched when the CE goes low. The ports have the following functions:

PORT0		PORT2	
0	Spare Output	0	(LOAD SEL A)
1	ADCinA	1	(LOAD SEL B)
2	ADCinB	2	SPARE
3	AC/DCinA	3	20V ON
4	AC/DCinA	4	RELAY PS
5	(MODE 0)	5	LOAD ON
6	(TRIGGER)	6	(HI I LOOP)
7	IN A	7	(MODE 1)

Those outputs in brackets are internal to the PLD.
The PORT outputs and loaded, unloaded, zero, strb_hi and strb_lo may be tri-stated by pulling OE- high.

The TEST input places the State Machine in test mode, allowing the counter to free-run. However, we have no access to the counter and therefore this is of limited value in this implementation.

Current OK and Current Error input/outputs are not used.

	HI_I_LOOP		not HI_I_LOOP
	not 25A	25A	
mode 0	single cycle	no load 25A test	No Load multi_cycle
mode 1	no load multi cycle	no load 25A test	No Load (reversed) multi_cycle
mode 2	trip test	25A test	Loaded multi cycle
mode 3	multi cycle	25A test	Loaded (reversed) multi cycle

SELA and B control the output used as shown below:

SELB	SELA	
0	0	25A
0	1	strb_lo (i.e. RCD test currents < 50 mA)
1	0	strb_hi (i.e. RCD test current > 50mA)
1	1	No output

Operation :

State:	RESET	ZERO	UNLOADED/LOADED	DONE
single cycle	state 0	state 1	state 2/3	state 4
multi cycle	state 0	states 1..15	states 16..47	state 48
trip test	state 0	All other states, output depends on LOAD ON		
25A test	state 0	state 1..4	state 5..11	state 12
hi_i_loop multi cycle	state 0	state 1	states 2...34	state 35

No load tests are exactly the same except output strobes are not asserted.

6.7 Test Current Sequences

Figure 1 shows the sequences that is to be expected in the different modes. Each sequence starts on the next zero crossing after a trigger from the microprocessor. The microprocessor checks the status line and if this is not has expected the noise symbol is shown or E34 (if status is low at the beginning). During DC Sensitive Trip Tests SELA and SELB are set to 1 when no current is required.

single cycle
This is the quickest test and is used at the beginning of all RCD and LOOP tests (expect the 150mA and LOOP L-N). This provides a quick loop resistance measurement which is used to determine whether it safe to continue the test. The supply current only flows for a single cycle (state 3) and therefore no shock hazard exists even if there is an open circuit.

multi cycle
This is used to measure loop resistance during the 1/2I RCD tests and the LOOP L-PE tests if the loop resistance is greater than about 12Ω. "strb" is strb_lo or strb_hi, depending on SELA and SELB. Outputs are used to control the test current flow and the measurement circuit analogue switches. No load is the same, but strb is always zero and therefore there is no current flow.

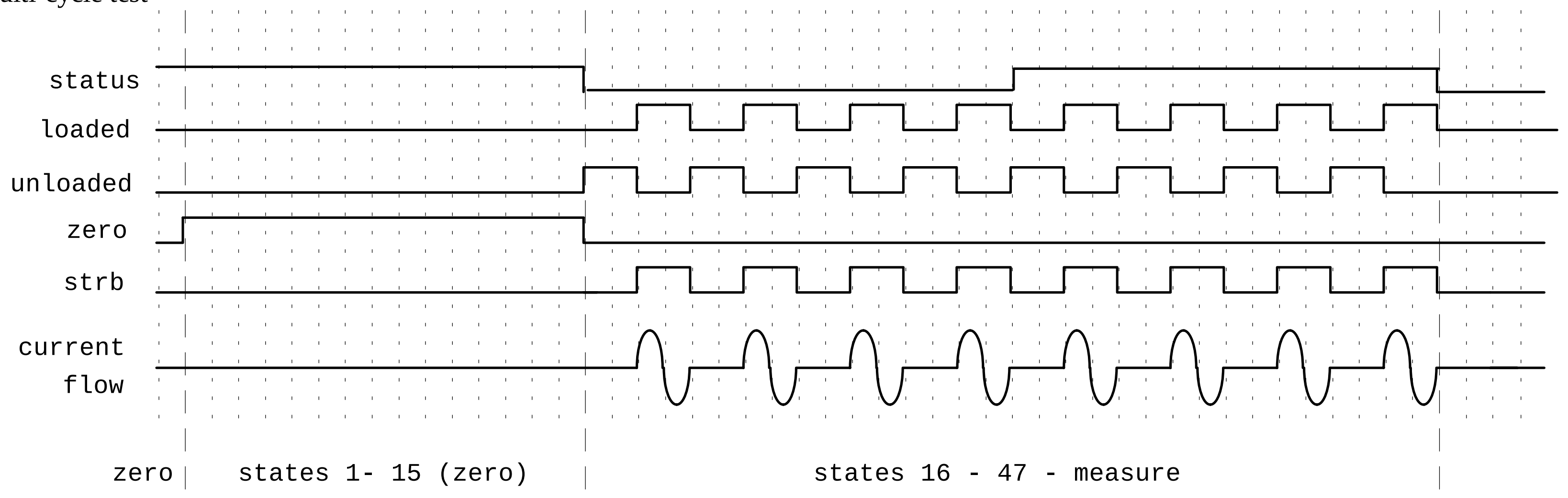
hi i loop- multi cycle
This is a new sequence for the LCB used for the no trip 15mA test. The test sequence is abbreviated as the zero phase is shorter, and instead of a 'no load' phase and then a 'load' phase used on the other tests, alternate tests are reversed.

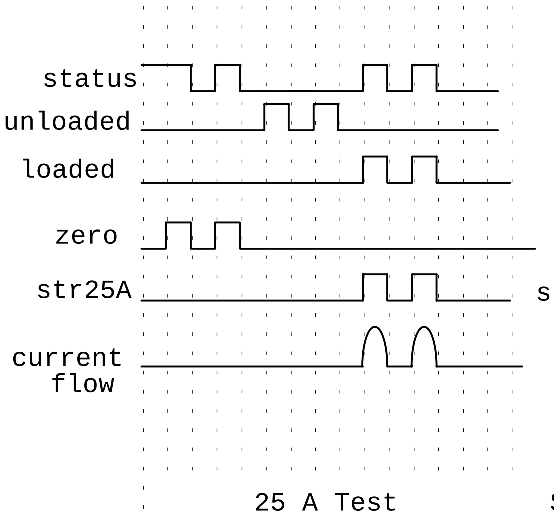
25A Test
This is used to measure loop resistance to 0.01Ω resolution on the LOOP L-PE, LOOP L-N and Re positions. Test current only flows for two 10 ms periods.

Trip Tests
The current flows continuously and no measurement is made. To ensure that the processor has not crashed during the test, the output current is dependant on LOAD CONTROL. This is a signal from IC10 (Sheet 5), and for this to be high (and stay high), the input LOAD ON (from the PIA) needs to be clocked continuously.

Figure 1 - test current sequences

multi-cycle test





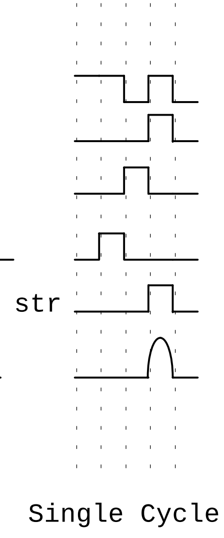
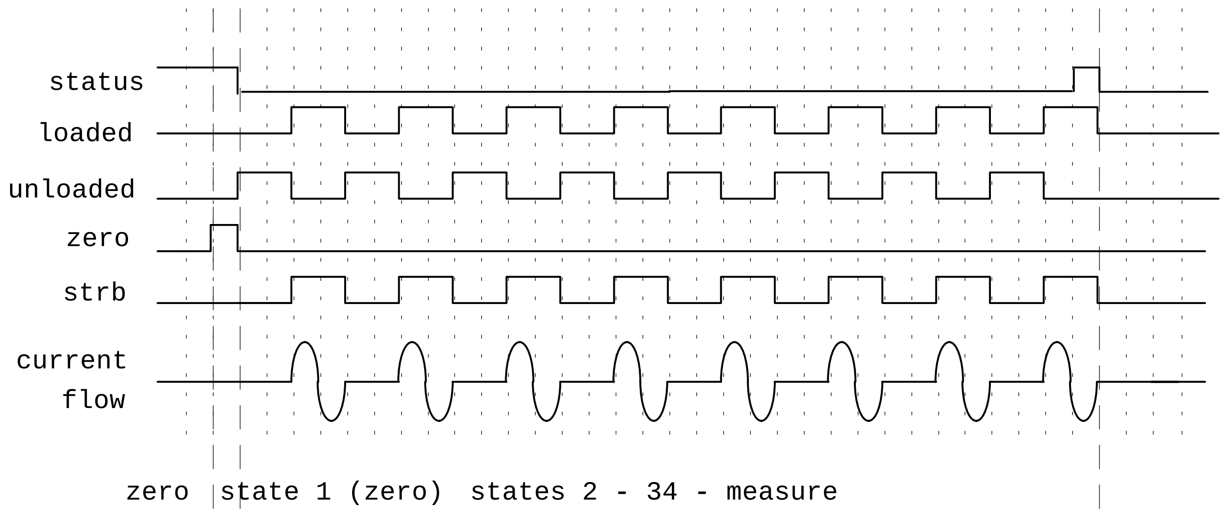
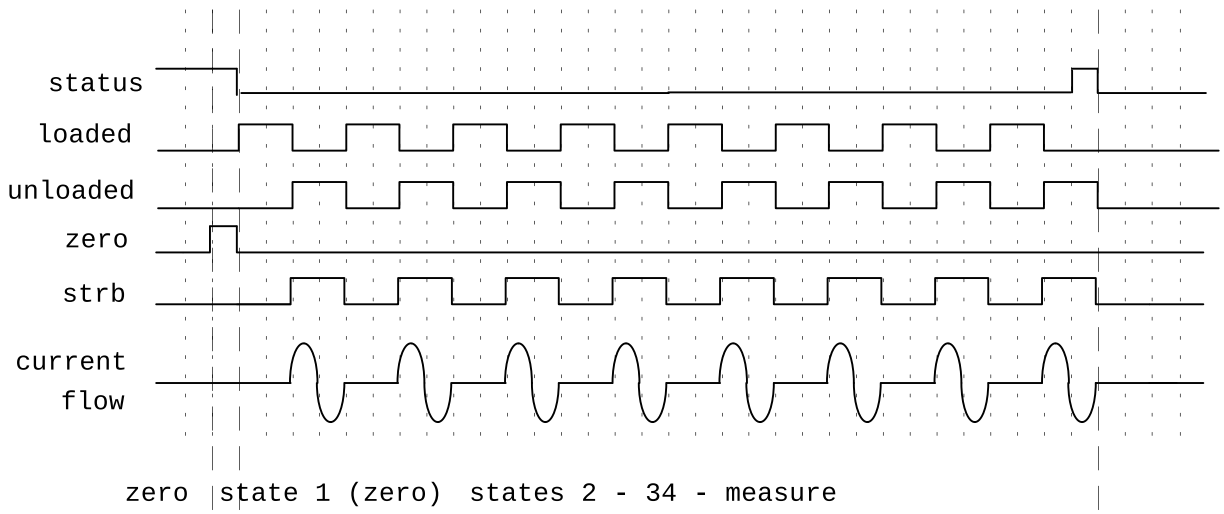


Figure 1a No trip multi cycle sequence



Normal



Reversed

7. Loop Resistance Measurements

(Sheet 1)

To measure loop resistance we measure the difference between the off load supply voltage and the voltage when we are taking a test current. This test current may be produced by the RCD current section (5 mA to 500 mA) or the 25A test current circuit. All of the ranges us this circuit; the difference is in the time of test, current used and the analysis of the results by the microprocessor.

The voltage difference is measured by charging a capacitor (C15) up during the unloaded cycles and another capacitor (C9) during the loaded cycles. IC3 measures the difference in voltage on these two capacitors and the result is VD. CMOS 4053 analogue switches are used two connect the capacitors up to the test voltage, or to discharge them before a test.

The input comes from the PSD and AMP via R5, which broadly adjusts the gain for variations in the value of the capacitors. IC5 is a Phase Sensitive Detector, which rectifies the waveform by selecting a +1 or –1 multiplication factor depending on the phase (ZERO CROSS). The circuit driving IC5 (IC11, IC5 and the three resistors) inverts ZERO CROSS signal when required (INV ZERO CROSS). It is an exor gate, but made out of spare elements. This is only used during one element of the three wire test. (Loop L-PE 0.01 Ω).

The input signal can come from any of the three input op-amp on the Power Board (L-PE, N-PE and L-N), as well as the high sensitivity L-PE and N-PE input used in the three wire test. The input is selected by IC8; IC7 buffers the high sensitive inputs.

7.1 RCD Test Sequence

Figure 2 shows in summary form the sequence which forms an RCD test. After pressing the TEST key, the current measurement of the supply voltage is checked to see if it is in range. The relays are switched on and the following checks are made:

Symbol	Reason
hot symbol	current_thermal_check Checks for a signal on ZERO_I_MON and 25A CUTOUT.
fuse symbol	fuse_check Checks for a signal on ZERO_CROSS via vm_mux
noise symbol	Indicated after loss of ZERO_I_MON and supply voltage if not an RCD test. During an RCD measurement the 'status' signal is checked and the length of the halves checked. For a 25A test the length of two pulses are checked. Frequency measurement is not used - a wide tolerance is allowed.
'no'	'trip' detected when unexcepted A 'trip' is detected by looking at ZERO_I_MON during a test and correctly measuring a low supply voltage at the end.
<1999 ms	trip detected during RCD 2s 1/2I test
>50V	The measurement of loop resistance by the single cycle test was too high to allow the test to proceed.
E32	On a LOOP L-PE or Re 25A test the measured result is <-0.05. It is excepted that this is due to no test current - i.e. the thermal fuse on one of the 2.4 Ω fuses has blown.
E33	PLD not producing correct 'status' signal During a measurement the status signal is monitored. If it does not finish quickly enough, this error is raised. Could be PLD or signals driving PLD.
E34	False trip ZERO_I_MON disappeared for too long during a test, but no reason could be found afterwards. Probably due to supply noise.

E37	Supply voltage has changed The supply voltage measured after closing the relays is compared with that before. If the difference is more than 20V, then this error is given. Could be due to high supply impedance or excessive current in the instrument.
E63	rcd status timing error 'status' changed but much too late (cf. error 33 when it doesn't change at all)

After this a single cycle test is performed. The contact voltage is calculated (= loop resistance * rated current) and if this is low enough the test is allowed to proceed. The limits are 50V for a trip test and 90V for a no trip test.
The test may abort if the supply fails (e.g. due to an RCD opening) with the message 'no', or with the noise symbol if the STATUS line to the processor was not within time limits based on the frequency measurement made before the TEST button is pressed. The thermal trip is checked again.

A no load Multi Cycle Test is performed, followed by a Loaded Multi Cycle. The noise, supply failure checks, etc. mentioned above are all carried out again. This gives a value of loop resistance and contact voltage. The contact voltage is multiplied by 1.05 as to comply with regulations it must not be low. The loop resistance is the measured value. This assumes that the test current is correct.

If a 1/2I test is selected and the 2s 1/2I test is disabled (see Appendix 1), the test finishes. If the 2s 1/2I test is enabled this is carried out. If the supply fails during this test <1999ms is displayed.

The trip test carried out depends on the TEST TYPE selected. Selective (delayed) RCDs have a 30s pause before the test, but this can be overridden by pressing the TEST key during the countdown. The normal trip time is 200 ms, or 2s for a Selective breaker. The time from applying the test current to supply failure is measured - ZERO I MON is looked at with checks for thermal trip, fuse etc. This is the time shown on the display.

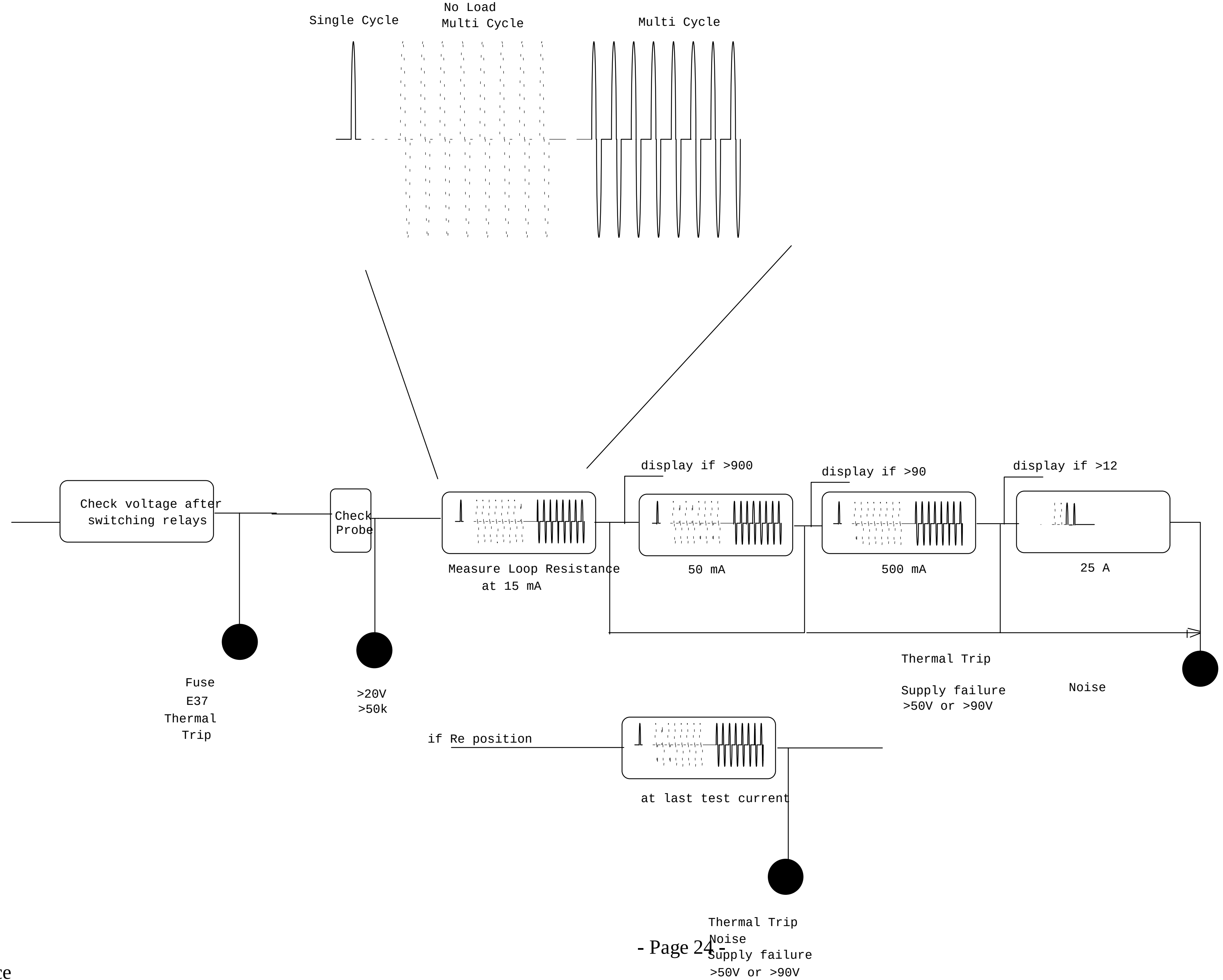
Ramp tests show the trip current; this is increased every 200ms in the ranges shown in the manual.
D.C. Sensitive tests only have one half cycle, controlled by the processor switching SELA/B as appropriate. The processor watches ZERO I MON for the zero crossings.

7.2 Loop Test Sequence

(See Figure 3)

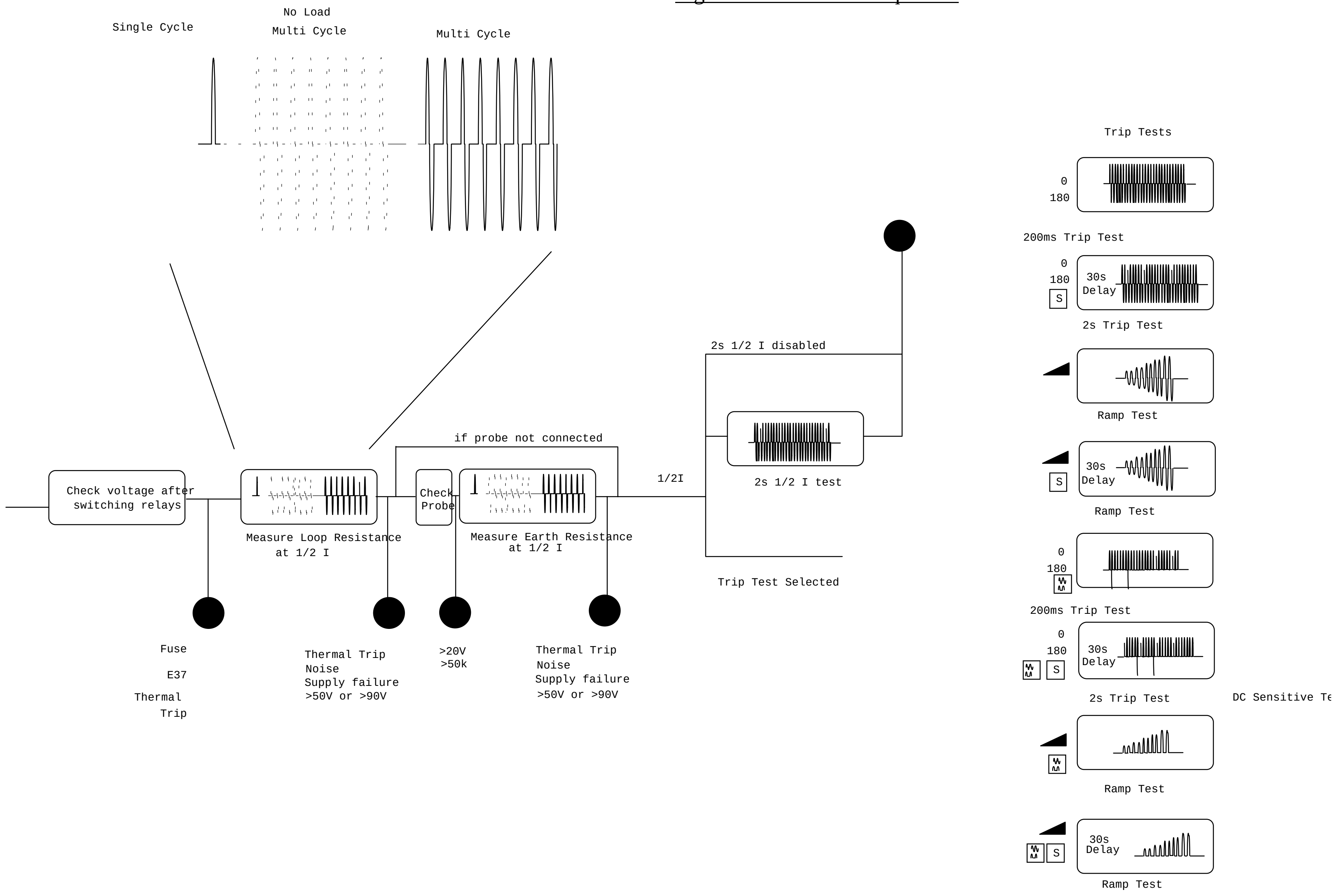
The LOOP L-PE and test sequences are very similar and are shown on Figure 3. The relays are switched on in sequence and the supply voltage checked for stability. E37 is displayed if the voltage reading has changed by more than 20V. Checks for the fuse and thermal trip are made at the same time.

Figure 3 Loop L-PE Test Sequence



Sequence

Figure 2 – RCD Test Sequencce



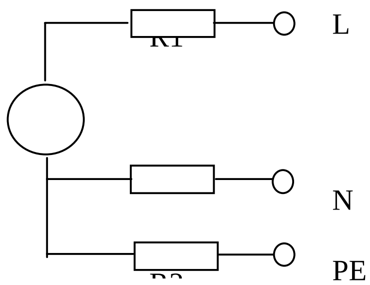
A measurement of loop resistance is made at 15mA, and displayed if the result is > 900 Ω. The measurement is repeated at 50 mA, 500 mA and then 25A. The test current fixes the resolution of the result. A test may be aborted due to noise and this is due to tests on the PLD status, and probably due to the 50Hz CLK to the PLD not being at supply frequency.
It is possible for a low current MCB to open at the 25A test. If this occurs, the result of the 500mA test is displayed.
If an earth resistance measurement is being performed, after a valid in-range loop resistance measurement an earth resistance measurement is performed at the same test current and displayed to the same resolution.

7.3 No trip Loop Test Sequence

This test starts off being the same as the LOOP L-PE test. The relays are switched on in sequence and the supply voltage checked for stability. E37 is displayed if the voltage reading has changed by more than 20V. Checks for the fuse and thermal trip are made at the same time.
A measurement of loop resistance is made at 15mA, and displayed if the result is >200 Ω. If less sequence of tests at 15mA is done using the new multi-cycle test available from the PLD. After each test the result is saved and filtered and averaged in software. If the spread of results is too great, some are thrown away and testing continues.

7.4 Three Wire No Trip Loop Test Sequence

This test is a sequence of measurements. To start with a LOOP L-N test is carried out at 25A and the L-N loop resistance measured as normal. Then the test is repeated but the voltage difference is measured L-PE, giving a value for R1 (see diagram below), as we can calculate the current flowing from the previous test.



Equivalent Circuit of a Mains Supply

Rn is calculated as the difference between the Loop LN resistance and R1.

Next R2 is measured by passing a 15 mA current L-PE and measuring the voltage difference (with the high sensitive input) N-PE. The shortened multi-cycle test is used and again after each test the result is saved and filtered and averaged in software. If the spread of results is too great, some are thrown away and testing continues. The LOOP L-PE resistance display is the sum of the R1 and R2 measurements.

Before the test the voltage N-PE is measured and the test aborted if this is greater than 20V.

8. RS232 Communications

The RS232 link consists of two transceivers, optically isolated from one another, allowing bi-directional data transfer. Thus results stored internally can be transferred to a personal computer under the latter's own control. Each transceiver uses a single led to act as both emitter and detector. The 'primary' unit is on the display section of the PCB, although the actual led is, by necessity, on the main board, in order to align with the 'floating' transceiver attached to the RS232 plug. The communications link operates at 9600 baud and the format is:

1 start bit
8 data bits
2 stop bits
No parity

8.1 Instrument Transceiver

(Sheet 5 Main)

This is the simpler of the two modules since it is not isolated, and therefore can be powered from the normal instrument supply rails. In the 'idle' condition (not sending or receiving) the 'SERIAL OUT' signal is kept high, turning off TR2 (see sheet 5 Main), and applying a -1.0V bias to IC1 pin 3. This op-amp's dc feedback is via R26 only since TR1 is cut off. Thus pins 1,2 & 3 all sit at -1.0V, leaving the LED D8 reverse biased (and off).

A. Transmit

Taking 'SERIAL OUT' low turns on TR2 applying a 2.5V signal to pin 3 . There is now additional dc feedback through R16 and TR1, equalizing pin 2 to be also 2.5V, and thereby driving a current (of around 12mA) through the led. The 'SERIAL OUT' line is fed from a special serial port on the microcontroller (port 4) which facilitates the encoding and transmission of the required data.

B. Receive

If light of its own characteristic wavelength falls on the LED D8, a small reverse current is generated, making it suitable as a detector. Keeping the led reverse biased improves the sensitivity, as in 'idle' mode with TR2 'off'. In the LCB situation, approximately 35uA is generated in D8 when the corresponding 'floating' emitter led D705 is 'on' (see sheet 12 Main). In idle condition IC1 pin 1 potential (-1.0V) is higher than the -1.5V threshold set at pin 6 by R10 & R9. The second half of IC1 is used as a comparator, and in 'idle' the 'SERIAL IN' line be at a high level. Current produced in D8 during 'receive' will drive IC1 pin 1 further negative, causing the comparator to change state and 'SERIAL IN' to be pulled low.
Connection to the microcontroller is again on the dedicated serial port, which facilitates the receiving and decoding of the bit stream on 'SERIAL IN'.

8.2 PC Transceiver

(Sheet 12 Main)

Transmitting
To transmit the board needs to be powered up (i.e. DTR or RTS >5.5V). If this is true, taking Td high (> 0 V) will turn the LED on. For this to occur IC700 (5V voltage regulator) must supply 5V. C700 need not be a Low ESR cap - this is only used to rationalise the parts used. IC702 converts the RS232 signals from the PC to TTL (and back again). It also generates its own positive and negative rails using switched capacitor techniques. C706 is used to generate about 9.0 by doubling the 5V supply (this appears on pin 2). C707 is used to invert this to -8.8V - this appears on 6 and is also used as a negative rail for parts of the circuit. However, these rails are probably not required for transmit only.
When Td goes high, IC702 pin 12 will go low, switching on TR701 and taking IC701 pin 3 to 2.5V. This will cause the op amp IC701 to switch on TR700 and current will flow through the LED.
If the module is connected to a PC and characters are sent by a serial comms program (e.g. Windows Terminal) the LED will flash briefly for each character sent. A instrument containing a board transmitting but not receiving will show 'dld' on the display if download is attempted but the download software will timeout after not receiving anything.

Receiving.
To receive IC702 must generate the positive and negative rails. With Td low (<0V), TR702 is off and IC701 pin 3 is at -1.7V. The LED is reverse biased by R710, and the LED voltage will become more negative if a bright light is shone at it. For test purposes an LED connected to a power supply is ideal and bring this to within an inch (25mm) for the voltage on IC701 pin 1 to drop. If this goes below -2.2V, IC701 pin 7 will change state. This will be +5V normally with the LED in the dark and 0V when lit. When switching the LED

off, a glitch on pin 1 of IC701 is caught by R707/C705 and prevents the PC seeing a spurious character.

8.3 Storage of results

(Sheet 6 Main)

Results are stored in the EEPROM (IC303, page 6 Main). The instrument serial number and configuration are also stored (See appendix for details).
Checks are made of the integrity of the data, and **cor** displayed if EEPROM corrupted. Pressing the test key clears all memory. A test save and download should then be done to confirm correct EEPROM operation.

Appendix 1 - Operating Modes

Cal, TST, A or b

These are available from the setup menu. To access this menu switch from OFF to the 150mA 40ms switch position holding the backlight key down. In the normal operating mode only A and b setups are available and these are summarised below:

Setting A (Europe)	Setting b (UK)
Line and Neutral swap allowed.	Line and Neutral swap not allowed
Auto Sequence RCD does 5I test	Auto Sequence RCD does 150mA test
After RCD trip test, contact voltage displayed first.	After RCD trip test, trip time or current displayed first.
2s 1/2I no trip RCD test not performed.	2s 1/2I no trip RCD test performed.

When the instrument is first switched on calibrate and test modes will be available. These may also be accessed by pressing the backlight key and then the up and down keys together in the setup menu. ‘Rst’ will appear and press enter to accept this. Cal and Tst may then be selected using the ‘I’ key.

Calibration Mode

This enables the instrument to be calibrated and the instrument functions operate in different ways to aid calibration and test of the instrument.

- Faults are enabled.
- During the no-trip tests the intermediate readings are displayed.
- Result saving is disabled.
- When certain results/readings are on the display these can be adjusted using the up/down keys or the auto-cal function. (See table below)
- The backlight key saves the calibration constants.
- Selecting a d.c. sensitive test on the RCD ranges gives a long (10-30s) test to aid measurement and adjustment of test current. (Test currents < xx mA only)
- The ‘single cycle’ voltage reading is displayed instead of contact voltage on RCD tests.
- Before any test the temperature of the FET is displayed.
- Diagnostics are available from any invalid switch position.
- On power up, the version number and date follow display test.
- Negative loop resistance results may be displayed.
- The Setup is a combination of A and b: L/N swapping and 2s ½ I RCD tests are enabled.
- The calibration constants may be viewed.

Details on how to calibrate an instrument may be found in appendix 5.

Test Mode

This mode is used in production to test an instrument.

- Faults are enabled.
- During the no-trip tests the intermediate readings are displayed.
- Result saving is disabled.

- Selecting a d.c. sensitive test on the RCD ranges gives a long (10-30s) test to aid measurement and adjustment of test current. (Test currents < xx mA only)
- Before any test the temperature of the FET is displayed.
- On power up, the version number and date follow display test.
- Negative loop resistance results may be displayed.
- The Setup is a combination of A and b: L/N swapping and 2s ½ I RCD tests are enabled.

After a LOOP L-PE 0.1Ω test, the instrument enters calibration mode. This is exited by selecting another function.

Continuous Mode

This was used when qualifying the instrument – i.e. for EMC testing. When D308 is fitted to the display board, the no-trip Loop Tests (LOOP L-PE 0.1Ω and LOOP L-PE 0.01Ω) will not complete the test. If the instrument is in test or calibrate mode when the intermediate results are shown on the display, then the effect of EM fields etc may be investigated.

LCB2000 & LCB2500

The LCB2500 has storage and communications in addition to the functions of the LCB2000. The main difference is the lack of the RCL switch position but on the LCB2500 a test is saved by pressing and holding down the enter key. This is enabled when a serial number has been stored in the instrument.

To disable store the serial number “No serial number”.

Appendix 2 - Diagnostic Mode

This mode is accessible from within calibrate mode and is useful for checking out various parts of the circuit individually. No normal testing can be carried out. The buttons, including the 'Backlight' button, have different functions and do not behave as normal.

To select diagnostics do the following:
a. Place instrument into calibrate mode.
b. If the rotary switch is fitted, turn it to the normally unused position after '150mA RCD'. Diagnostics will also be selected if the rotary switch is absent.

Display indicates diagnostic mode by displaying 'd/a' for approximately one second, followed by the version number, after which the first check starts automatically.
The 'Test' button is used to through the sequence of checks.

Quick Summary of Diagnostic Tests

Test 1 - Display and power supplies
All power supplies, main board led (D1), buzzer & probe-check current are turned on.
Buttons other than 'Test' toggle buzzer on/off

Test 2 - Relays
One relay or pair of relays is energised, as indicated on display.
Buttons other than 'Test' step successively through the relays.

Test 3 - RCD DAC setups
Buttons other than 'Test' button step successively through setups for IC312/309/310

Test 4 - Frequency measurement window comparators
Display indicates the output levels of the L-PE & N-PE window comparators (IC313).

Test 5 - Internal A/D Converter
Display shows the actual readings of the internal a/d converter.
Buttons other than the 'Test' button change the selected channel.

Test 6 - External A/D Converter (7109)
The a/d converter is set into a continuous conversion mode.

Test 7 - Watchdog
The system should reset after a watchdog timeout.

Detailed Description

Test 1 - Display and power supplies
All power supplies are turned on and the relay-power-save feature is turned off.

On long connector, check..

BC 3 Pins 7, 17, 23	0V
BC 1 Pin 22 'Vcc'	5.0V
BC 1 Pin 2 & 25 '5V lpp'	5.0V
BC 3 Pin 15 '5V'	5.0V
BC 3 Pin 18 '-5V'	-4.85V nom
BC 2 Pin 8 '-5V lpp'	-4.80V nom

Also, check 'relay power' & '5V PLD', which should both be 5.0V

20V supply is turned on.

All display segments are turned on.
On display controller...
Check pins 18,19 & 20 (3 test pads in a row)
are 3.5V, 2.0V & 0.5V (values for CM300 display)
Check pin 4 for 5V square wave at 110kHz.
Check pins 25,26,27 (3 test pads right next to chip)
for square waves at 120Hz. (High level should be 5V, low level 0.5V)

Backlight is turned on.

LED on main pcb (D8) is turned on.
Check RS232 op-amp (IC1) as follows...

pin 3	2.5V nom
pin 2	as pin 3
pin 6	-1.4V nom
pin 7	4.5V min

Buzzer is turned on.

'Test' button moves on to Test 2
Other buttons toggle buzzer on/off

Test 2 - Relays
Backlight is turned off.
Twenty volt supply is turned off.
LED (D8) is turned off.
Buzzer is turned off.
Relay-power-save is activated.
Check 'relay power' signal, which should be 3.25 - 3.95V.
Display shows 'r 0' - relay 0 is energised, all others
de-energised.

'Test' button moves on to Test 3
Other buttons step successively through the relays 'r 0' - 'r 2'
Only one relay (or pair of relays) is energised at any given time.

Test 3 - RCD DAC setups

Display shows 'rc0'
'Test' button moves on to Test 4
Other buttons step successively through 'rc0' - 'rc4' setups for IC312/309/310.

----
rc0 - set current & voltage dacs to zero
rc1 - set voltage dac to half scale output
rc2 - set voltage dac to full scale output
rc3 - set current dac to half scale output
rc4 - set current dac to full scale output

These are used during calibration of the instrument.

Test 4 - Frequency measurement window comparators

Display shows L-PE & N-PE neons & '1 --'
The two dashes may be level with either the top or the bottom of the left hand '1', in order to indicate the output levels from the E-L & E-N window comparators, i.e. the signal levels present on D1/D2 from IC2 pins 1 & 2. The left-hand dash corresponds to the E-L system, the right-hand dash to the E-N system, (same order as neons).

For zero input voltage at the terminals, both dashes should be at a high level.

Differential amplifier outputs should be < 10mV.

Check as below...

PL 7	N E amplifier
PL14	L N amplifier
PL15	L E amplifier

Check reference voltages on window comparator chip...

pins 7,11, 66mV nominal
pins 4,8, -45mV nominal

Check outputs...

pins 1/14 & 2/13, > 4.0V

'Test' button moves on to Test 5
Other buttons have no function.

Test 5 - Internal A/D Converter

Display briefly shows 'c0'.
The digit indicates the microcontroller a/d channel (0 - 7)

The display then shows a number between 0 & 1023. (0 = 0V, 1023 = 5V).
This is the actual reading of the microcontroller's on-board a/d converter for the selected channel. This reading is also transmitted via the RS232 circuit, so the led on the main pcb should flash repeatedly.

The reading shown is actually the mean value of 50 consecutive measurements.

'Test' button moves on to Test 6

'I' button decrements the microcontroller a/d channel number.
'Type' button increments the microcontroller a/d channel number.

In the reference table below, the nominal readings apply to the case when all input terminals are o/c.

DISP	MUX A/D FUNCTION	NOM. READING
c0 -	A/d 0 - (e-l)	512
c1 -	A/d 1 - (n-l)	512
c2 -	A/d 2 - (e-n)	512
c3 -	A/d 3 - FET temp (+ thermometer symbol)	40 - 160
c4 -	A/d 4 - switch a (centre ring)	> 1000 or < 003**
c5 -	A/d 5 - switch b (inner ring)	< 003**
c6 -	A/d 6 - battery/2 (+ batt symbol***)	400 - 900
c7 -	A/d 7 - touch contact	512

** initial value only, as the rotary switch can be turned during this test as a fault-finding aid
*** flashing if battery < 6.0V

Test 6 - External A/D Converter (7109)

The a/d converter is set into a mode whereby a conversion is initiated about every half-second via the 'run/hold' line. At the end of each conversion, the display shows ((a to d reading)/4) and briefly puts up the 'ramp' symbol. Thus if the conversion process is running through ok, the ramp symbol should be blinking regularly. If there is a fault, the display shows the message 'Adf' (ad failed), but the 'run/hold' drive signal is maintained.

Check for activity on 7109 'run/hold' line (IC314 pin 22).
Check for activity on 7109 'status' (IC314 pin 41).
(These are slowish signals, 100 - 400 ms approx.).
Check for clock signal on IC314 pin 20.

The a/d reference is set for terminal voltage measurement and is therefore nominally 1.00V (BC3 pin 25). With the terminals o/c the a/d input should be < 10mV (BC3 pin 24) and the reading should be near zero (i.e. < 5).

If the a/d input is shorted to 0v (next pin in BC 3) the reading should be 000.
If the a/d input and reference are shorted together the reading should be 511 or 512.

'Test' button moves on to Test 7
Other buttons have no function

Test 10 - Watchdog

If the watchdog is functioning correctly, the system will reset. The message 'rSt' is shown briefly.

Buttons have no functions.

Appendix 3 – Fault Numbers

These are enabled in calibrate and test modes and perform a limited ‘self – test’ of the instrument. They are a little fussy and therefore disabled in the customer modes. When a fault occurs, operation stops with ‘Fxx’ on the display.

If the instrument is operated with a power board F94 and F28 will be displayed. To aid fault-finding without a power board attached these may be disabled by fitting D310 on the display board.

A. RS232 interface fault.

Buzzer 'ticks' - this indicates that an RS232 fault has been detected

The display will show the fault number, as normal. However, it is possible that fault-finding is being carried out with the display not fitted, which leaves only the RS232 output for notifying the fault. If the RS232 is detected as being itself faulty, the buzzer is made to 'tick' to draw attention to this.

B. Display or data bus fault.

The fault number will be transmitted from the RS232 interface as normal, but will not be displayed.

C. RS232 interface fault and display fault

If both means of notifying the fault are themselves faulty, other means of drawing attention are used. In addition to the buzzer 'tick' to indicate an RS232 fault, the backlight is flashed to indicate a display fault. If necessary, fit a backlight temporarily.

Fault No.	Description
Fault 19	ad converter (7109) fault, 'ad/stat' does not go low During the start-up sequence after reset, the 'ad/run' line (IC314 pin 22) is set low immediately before the display-all-segments test is started. The 'ad/stat' line (IC306 pin 41) is checked about 4 seconds later, after the display test, and should be low.
Fault 20	ad converter (7109) fault, 'ad/stat' does not go high If the fault 19 check is successful, and 'ad/status' has gone low, then the 'ad/run' line (IC306 pin 22) is taken high. After 7 ad converter clock cycles (approx. 350us), 'ad/stat' should go high. It is checked by the microcontroller after about 2ms.
Fault 21	battery circuit fault, measured result not stable During a battery voltage measurement, the signal 'batt/3' is checked at 10ms intervals until successive readings agree within certain limits. This fault is reported if the measurement has not settled after 20 attempts.
Fault 28	fet temperature sensor (LM50) fault Measured value out of limits (<-30 or >200 deg c) In rcd and loop test switch positions, the temperature of the high-current FET (TR507) is always monitored by the thermal sensor (IC505) fitted beneath it. The voltage on the 'FET temp' line should be in the range 0.2V - 2.5V, corresponding to a temperature between -30 and 200 Celsius. **(Disabled by ‘pwr_board_missing’ diode)**
Fault 33	PLD fault, 'status' signal is low after PLD clear operation As part of the rcd and loop test sequences, the PLD (IC305) is cleared by taking the 'SEQ clear' signal (pin 37) high for 2ms, and then low again. After this, the PLD 'status' signal (pin 34) is checked. It should be in a high condition.

Fault 81	<u>display board RS232 fault</u> 'serial in' signal is low when 'serial out' is high During the startup sequence, the line 'serial out' is set high and the 'serial in' line is checked to make sure it is also high. The RS232 led (D8) should be 'off'.
Fault 83	<u>keyboard circuit fault, output of nor gate IC307 inconsistent with inputs</u> During the startup sequence, the 5 lines from the push button switches are checked, together with the 'keypress-' signal. It is not known if any buttons are being pressed, so the only check carried out is that signals are consistent among themselves, given that the pushbutton signals are 'NOR'ed by IC307 to produce the 'keypress-' signal.
Fault 85	<u>backlight or buzzer control line pulldown fault, control line reads high</u> With the 'backlight on' and 'buzz' signals both set to be inputs, the signal levels are read back and should both be at low levels.
Fault 87	<u>main power control line pullup fault</u> With the 'gen power on' signal set to be an input, the signal level is checked and should be pulled up to a high level.
Fault 92	<u>RS232 circuit fault, 'serial in' signal is low when 'serial out' is low</u> During the startup sequence, the 'serial out' line is taken low, turning 'on' the RS232 led (D8). After a 1ms settling time, the 'serial in' signal is checked and should remain high.
Fault 93	<u>'DAC wr-' (IC302) or 'links-' pullup fault</u> With the 'DAC wr-' and 'links-' signals both set to be inputs, the signal levels are checked and should both be pulled up to high levels
Fault 94	<u>'l-e freq.' ('zero cross') fault, signal reads low</u> The microcontroller cannot look at the 'zero cross' signal directly, so the voltmeter multiplexer (IC9) is set so as to connect it through to the 'l-e freq' signal (IC15 pin 13). Both mux control pins (IC9 9 & 10) should be low. Since the relays are de-energised, there should be no signal to IC503 pin 4, and the 'zero cross' signal (IC503 pin 2) should be high. The microcontroller checks for the 'l-e freq.' line to be high. **(Disabled by ‘pwr_board_missing’ diode)**
Fault 95	<u>data bus pullup fault - data bus should read '11111111'</u> During the startup sequence the data bus is released by setting all 8 lines to be inputs, and also setting the following signals high: links- lben- hben- dac wr- All data bus lines should then be pulled up high. A similar check is also carried out during the diode-link reading routine.

Fault 96	data bus fault - data bus should read '10101010' lsb - msb During the startup sequence the data bus is released by setting the following signals high: links- lben- hben- dac wr- Bits 1,3,5 and 7 of the data bus are set to be inputs. Bits 0,2,4 and 6 are set to be outputs and are set low. The bit pattern is read back - bits 1,3,5,7 should remain high.
Fault 97	data bus fault - data bus should read '01010101' lsb – msb The data bus is released by setting following signals high: links- lben- hben- dac wr- Bits 0,2,4 and 6 of the data bus are set to be inputs. Bits 1,3,5 and 7 are set to be outputs and are set low. The bit pattern is read back - bits 0,2,4,6 should remain high.
Fault 98	display controller (IC301) 'display we-,re-,ce-,off' pullup fault With the 'display we-', 'display re-', 'display ce-' and 'display off' lines all set to be inputs, the signals are read back and should all be pulled up to high levels.
Fault 99	display controller (IC301) 'display ready' signal failed to go high During a write to the display controller, the microcontroller waits for the 'display ready' signal to go high. If this has not occurred after about 2ms,this fault is reported.

Appendix 4 – Error Numbers

Error No.	Description
Error 1	Attempt made to display number > 1999 The display number routine was called with a value too big to show. This may occur if the result of a measurement is too large.
Error 2	Invalid decimal point number The display number routine was called to show an invalid decimal point. This should not occur.
Error 3	Invalid action routine The program called an invalid routine. This should not occur.
Error 4	Event buffer overflow Too many things are going on at once.
Error 5	Invalid temperature measurement parameter The temperature measuring routine was called with an invalid parameter. This should not occur.
Error 7	Rotary switch error - invalid combination of a/b values The two A/D readings from the rotary switch do not give a valid switch position.
Error 8	Invalid multiplexer parameter. vm_mux routine was called with an invalid parameter. This should not occur.
Error 9	Invalid multiplexer parameter ad_mux routine was called with an invalid parameter. This should not occur.
Error 10	Fuse blown during RCD or loop test 'zero_cross' signal disappeared during a loop or RCD test
Error 11	'tx_data' string too long Attempt was made to send a string with more than 42 characters via the RS232 port. Software error, invalid results or strange EEPROM data.
Error 12	External a-d converter (IC 306 - 7109) failure Conversion (time from start to receipt of acknowledge) has taken too long. AD/RUN starts conversion, AD/STAT acknowledges completion.
Error 13	Invalid relay number relay_control routine called with an invalid relay number This should not occur.
Error 14	Invalid display segment Attempt to display an invalid (LCB) display segment This should not occur.

Error 15	Microcontroller a-d converter failure Conversion of one of the internal A/D has taken too long.
Error 16	Earth or loop ranging error 'auto_range_decide' was called and the earth_resistance was higher than expected. A loop or earth test auto ranges, increasing the current has shown in the table below: 15mA Range down if <900, Error 16 if >5000 50mA Range down if <90, Error 16 if >1000 500mA Range down if <12, Error 16 if >100
Error 17	RS232 transmit error We sent a character, but it did not go This should not occur ?
Error 18	Invalid PLD control parameter Call to PLD control routine with invalid parameters This should not occur.
Error 19	Loop_3w_phase out of limits or test_type = EARTH Internal variables incorrectly set. This should not occur.
Error 20	Flat Battery (not displayed) If the battery voltage measurement returns a value too low for testing to continue, error(20) is called. However, this is not displayed as an error, but the display is blanked and the ‘flat battery’ symbol shown.
Error 21	Mains_relays_on called with relays already on. This should not occur.
Error 22	EEPROM (IC304) acknowledge failure The eeprom sends an acknowledge via a sequence on the SCA/SCL lines. A command was sent but no acknowledge was received.
Error 23	EEPROM checksum error Data in the EEPROM is protected by a checksum and this was invalid. Could be due to a failure of the EEPROM, control lines or power failure during programming. Try deleting the data.
Error 24	EEPROM corrupted No end of data mark found. Try deleting the data.
Error 25 Error 26	Invalid test type Invalid test connection Data stored in the EEPROM is not in expected format. This should not occur, but try deleting the data.
Error 27	Loop_3w_phase out of range Internal variables incorrectly set. This should not occur

Error 28	fet/heatsink temperature sensor (IC505) fault - measured value out of limits This will occur if IC7 gives a voltage >3V, equal to a temperature of 250C.
Error 29	voltage attribute error Unable to determine if the input voltage was a.c., d.c. or too low to measure. This should not occur.
Error 31	RS232 receive error Data received by the LCB via the serial link was not in the correct format. Check the baud rate of the connected PC, and confirm that it is setup to communicate with a LCB.
Error 32	On a LOOP L-PE or Re 25A test the measured result is <-0.05. It is excepted that this is due to no test current - i.e. the thermal fuse on one of the 2.4 Ω fuses has blown. This is not displayed as an error, but the ‘hot trip’ symbol is shown.
Error 33	PLD not producing correct 'status' signal During a measurement the status signal is monitored. If it does behave correctly, this error is raised. Could be PLD or signals driving PLD.
Error 34	False trip ZERO_I_MON disappeared for too long during a test, but no reason could be found afterwards. Probably due to supply noise.
Error 37	Measured supply voltage has changed The supply voltage measured after closing the relays is compared with that before. If the difference is more than 20V, then this error is given. Could be due to high supply impedance or excessive current in the instrument.
Error 38 Error 39 Error 41 Error 47	RCD timing error. The measured fail time is too long. Invalid earth_i_magnitude value. Calculated value for 'current dac' exceeds 255. ‘scale’ routine called with invalid parameters These errors should not occur.
Error 48	Invalid checksum on calibration data. Calibration data is recalled from non-volatile memory and the checksum is not correct. Instrument will need re-calibration.
Error 50	Invalid lcd driver or backplane parameter. This errors should not occur
Error 51	Invalid freq/l-e interrupt An interrupt occurred due to a transition on 'l-e/freq', but no handler was enabled. This should not occur.
Error 52	Invalid n-e interrupt An interrupt occurred due to a transition on 'n-e', but no handler was enabled. This should not occur.
Error 53 Error 54 Error 55	Invalid timer4a interrupt Invalid timer2a interrupt Invalid interrupt An interrupt occurred, but it was not expected.

Error 57	's3_timeout' event seen during 15mA loop test These should not occur..
Error 59	15mA loop test aborted - unknown reason This should not occur
Error 60	Invalid microcontroller a/d converter parameter This should not occur
Error 61	Invalid switch setting during auto rcd 5i test This should not occur
Error 62	Frequency measurement error This should not occur.
Error 63	PLD status timing error 'status' changed but much too late (cf. error 33 when it doesn't change at all)
Error 64	Measured incorrect voltage before calling ac_mains_chk. This should not occur.
Error 68	Invalid functions called. This should not occur.
Error 74	PLD addressed when 5V pld power supply 'off' This should not occur
Error 75	15mA loop test failed: A/D running but A/D interrupt disabled
Error 76	15mA loop test failed: A/D not running, timer 3 problem
Error 80	Scale_and_offset called but we having read the calibration figures from non-volatile memory. This should not occur.
Error 91 Error 94 Error 97 Error 98	‘aph’ set incorrectly during auto-sequence RCD test. This should not occur.
Error 95	15mA loop test failed: PLD sequence running but did not finish.
Error 99	display fault - unlikely to be properly shown! 'display ready' not responding in the time allowed.

Appendix 5 – Instrument Calibration

Calibration mode enables the instrument to be calibrated and the instrument functions operate in different ways to aid calibration and test of the instrument.

- Faults are enabled.
- During the no-trip tests the intermediate readings are displayed.
- Result saving is disabled.
- When certain results/readings are on the display these can be adjusted using the up/down keys or the auto-cal function. (See table below)
- The backlight key saves the calibration constants.
- Selecting a d.c. sensitive test on the RCD ranges gives a long (10-30s) test to aid measurement and adjustment of test current. (Test currents < xx mA only)
- The ‘single cycle’ voltage reading is displayed instead of contact voltage on RCD tests.
- Before any test the temperature of the FET is displayed.
- Dianognitics are available from any invalid switch position.
- On power up, the version number and date follow display test.
- Negative loop resistance results may be displayed.
- The Setup is a combination of A and b: L/N swapping and 2s ½ I RCD tests are enabled.
- The calibration constants may be viewed.

There is a minimum of pots on the PCB. Most of the calibration is done with a fully assembled instrument were readings are adjusted and ‘calibration constants’ are saved in EEPROM.

Getting into calibration mode

Switch from OFF to the 150mA 40ms range holding the backlight key down. Press and hold the backlight key and then both the I and Type (right hand) keys, and ***rSt*** will show on the display. Press the enter (left hand key) and the instrument will enter calibrate mode and ***CAL*** will show on the display. Press the enter key to place instrument into calibration mode

Calibration of the instrument

This must be done in a certain sequence. The pots on the PCBs are setup in PCB test before the instrument is boxed up and the instrument is finally calibrated.

Pots

DAC

In production, this will normally be done after PCB Assembly by the automatic test gear. However, adjustment may also be done as follows:

Refer to circuit diagram, sheet 6 and sheet 11.

RCD DRIVE is a magnification of MAINS LANE, the size of which is controlled by the processor.

DACA is used to compensate for supply voltage variations. The processor measures the supply voltage and adjusts the DAC value for a constant voltage at TP456. R391/R389 therefore adjust for any **supply voltage dependency** of the RCD test current. Note that there are two ranges (using RCD OPT1), <200 V and >200V.

DACB is used to adjust the current. (There is a slight supply voltage variation in the value written, as we compensate for the 2mA leakage provided by resistors.)

Therefore, any **non-linearity of test current etc.**, can be adjusted by R393/R388. Note there are three ranges: <50 mA, 50 mA to 500 mA and 1A.

We need to inject a current into the input of IC 504 (Power Board Sheet 3), the bottom end of R575. Therefore connect approximately 10k resistor from outside end to +5V (inside end power supply switch)
Power up PCB. MAINS LANE should be about 1.0V. (Exact value doesn't matter)

Switch to dia position (Past 150 mA 40 ms). Display test will operate.
Press test key. - r 1 will show (relay test)
Press test key - rc0 will show. Check for 0V on RCD DRIVE.

Press Display key - rc1 will show
$80 is written into voltage DAC. Adjust R391 and R389 for MAINS LANE/2 on TP456

Press Display key - rc2 will show
$FF is written into voltage DAC.
Check voltage on TP456 is (255/256 x MAINS LANE) +/- 10 mV. Write down this voltage!

Press Display key - rc3 will show
$80 is written into current DAC. Adjust R393 and R388 for half the voltage you just wrote down on TP456.

Press Display key - rc4 will show
$FF is written into the current DAC.
Check voltage on TPxxx is (255/256 x TP456) +/- 10 mV.

Loop Scale/Offset

We need a complete main/display/current board assembly for this. Supply the instrument from 240V.
NB Take safety precautions. Instrument is live during tests (including the battery).

Adjust Loop Offset
Connect to low impedance supply. With instrument in calibrate mode switch to RCD 30mA. Perform a ½ I test and adjust R6 for a reading –5 to 5V (this can be later trimmed by software).

Adjust Loop Scale
Connect to a known supply with about 1000 Ω loop impedance. Perform Loop L-PE measurement and adjust R5 for a reading within 2% (this can be trimmed later by software).

Calibration constants

The instrument calibration software is designed to aid calibration at the factory test station. When a result is displayed that may be adjusted the calibrated symbol ((o)) is shown. If the first key to be pressed is the up key (TYPE key on LCB2000), then Auto-cal is called, else this value may be changed using the up and down keys (TYPE = up and I = down on LCB2000).
The RCD test currents are adjusted by selecting d.c. sensitive mode and *holding* down the up/down keys during the test. An ammeter in circuit can measure the actual current.
The procedure followed is set out in the 'Calibration Procedure' part number 6172-460. This is summarised in the table below.
Unless the Auto-cal is used, the calibration constants need to be saved by pressing the backlight key as they are reloaded from EEPROM when the rotary switch is turned.

Auto-cal

In this mode the software tries to automatically adjust the reading to a ‘target’ value. When this is reached, the calibration constants are saved automatically. The current target values are shown in the calibration procedure.

Calibration Constants

Name	Description	Range	Connection	Set at
LN_VOLTS_SCALE	Supply Voltage Scale	Loop L-N	L-N	Set reading at 240V
LE_VOLTS_SCALE	Supply Voltage Scale	Loop L-PE	L-PE	Set reading at 240V
NE_VOLTS_SCALE	Supply Voltage Scale	Loop L-PE	N-PE	Set reading at 240V
RCD_5MA_OFFSET	RCD test current zero	RCD VAR	L-PE	Set 1/2I 10mA to 4.75mA
RCD_CURRENT_SCALE	RCD test current scale	RCD VAR	L-PE	Set ½ I 100mA to 47.5mA
EARTH_LOOP_SCALE	Overall loop resistance scale ①	Loop L-PE	L-PE	Set result at 1000 Ω
SINGLE_CYCLE_NULL_LE	Single cycle zero (L-PE)	RCD ½ I 30 mA	L-PE	Set result to 0V at 0.1 Ω
SINGLE_CYCLE_NULL_NE	Single cycle zero (N-PE)	RCD ½ I 30 mA	N-PE	Set result to 0V at 0.1 Ω
HIA_LN_SCALE	High Current Scale (LN)	Loop L-N.	L-N	Set result at 10 Ω
HIA_LN_OFFSET	High Current zero (NE)	Loop L-N.	L-N	Set result at 0.1 Ω
HIA_LE_SCALE	High Current Scale (LE)	Loop L-PE	L-PE	Set result at 10 Ω
HIA_LE_OFFSET	High Current zero (LE)	Loop L-PE	L-PE	Set result at 0.1 Ω
LT7_LE_SCALE	No-trip Loop 0.1 Ω Scale (LE)	Loop L-PE 0.1Ω.	L-PE	Set result at 85 Ω
LT7_LE_OFFSET	No-trip Loop 0.1 Ω Offset (LE)	Loop L-PE 0.1Ω.	L-PE	Set result at 1 Ω
LT7_NE_SCALE	No-trip Loop 0.1 Ω Scale (NE)	Loop L-PE 0.1Ω.	N-PE	Set result at 85 Ω
LT7_NE_OFFSET	No-trip Loop 0.1 Ω Offset (NE)	Loop L-PE 0.1Ω.	N-PE	Set result at 1 Ω
HIA_NE_SCALE	High Current Scale (NE)	Loop L-PE	N-PE	Set result at 10 Ω
HIA_NE_OFFSET	High Current zero (NE)	Loop L-PE	N-PE	Set result at 0.1 Ω
HIA_LN_LE_OFFSET	High Current R1 zero	Loop L-PE 0.01Ω	L-PE	Set R1 result at 0.1Ω
HIA_LN_LE_SCALE	High Current R1 offset	Loop L-PE 0.01Ω	L-PE	Set R1 result at 10 Ω
LT7_NE_LE_OFFSET	Low Current R2 zero	Loop L-PE 0.01Ω	L-PE	Set R2 result at 0.0Ω
LT7_NE_LE_SCALE	Low Current R2 offset	Loop L-PE 0.01Ω	L-PE	Set R2 result at 10 Ω
HIA_LN_NE_OFFSET	High Current R1 zero	Loop L-PE 0.01Ω	N-PE	Set R1 result at 0.1Ω
HIA_LN_NE_SCALE	High Current R1 offset	Loop L-PE 0.01Ω	N-PE	Set R1 result at 10 Ω
LT7_LE_NE_OFFSET	Low Current R2 zero ②	Loop L-PE 0.01Ω	N-PE	Set R2 result at 0.0Ω
LT7_LE_NE_SCALE	Low Current R2 offset ②	Loop L-PE 0.01Ω	N-PE	Set R2 result at 10 Ω

① This duplicates the function of R5. If not enough adjust can be obtained using the software, then R6 may be adjusted to give a correct reading.

② These duplicate the function of R6.

Displaying the calibration constants

Switch to the RCL position, and press the backlight key. The constant is displayed with certain segments (see table below). It is stored as 8 bits (0…255) with an offset zero of 128 (so 127 is –1 and 130 is +2). The actual meaning depends on the constant displayed.

In this mode, the keys have the following meanings:

The enter key changes the constant being displayed.
The up/down keys change the value.
The backlight saves the calibration constants and takes you back to RCL.
Press and hold the enter key to reset all constants to their initial values.

	½ I	No-trip *'LT7'*	1-3 *'3-wire'*	Connect *LE/NE/LN*	Ramp *Scale*
RCD_5MA_OFFSET					
HIA_NE_SCALE				N-PE	
HIA_NE_OFFSET				N-PE	
LT7_NE_SCALE				N-PE	
LT7_NE_OFFSET				N-PE	
HIA_LE_SCALE				L-PE	
HIA_LE_OFFSET				L-PE	
LT7_LE_SCALE				L-PE	
LT7_LE_OFFSET				L-PE	
HIA_LN_SCALE				L-N	
HIA_LN_OFFSET				L-N	
HIA_LN_LE_OFFSET				L-PE	
HIA_LN_LE_SCALE				L-PE	
HIA_LN_NE_OFFSET				N-PE	
HIA_LN_NE_SCALE				N-PE	
LT7_LE_NE_OFFSET				N-PE	
LT7_LE_NE_SCALE				N-PE	
LT7_NE_LE_OFFSET				L-PE	
LT7_NE_LE_SCALE				L_PE	
LN_VOLTS_SCALE				L-N	
LE_VOLTS_SCALE				L-E	
NE_VOLTS_SCALE				N-PE	
EARTH_LOOP_SCALE					
RCD_CURRENT_SCALE					
SINGLE_CYCLE_NULL_LE					
SINGLE_CYCLE_NULL_NE					

Appendix 6 - Power - Main interboard connection

First group -- top left

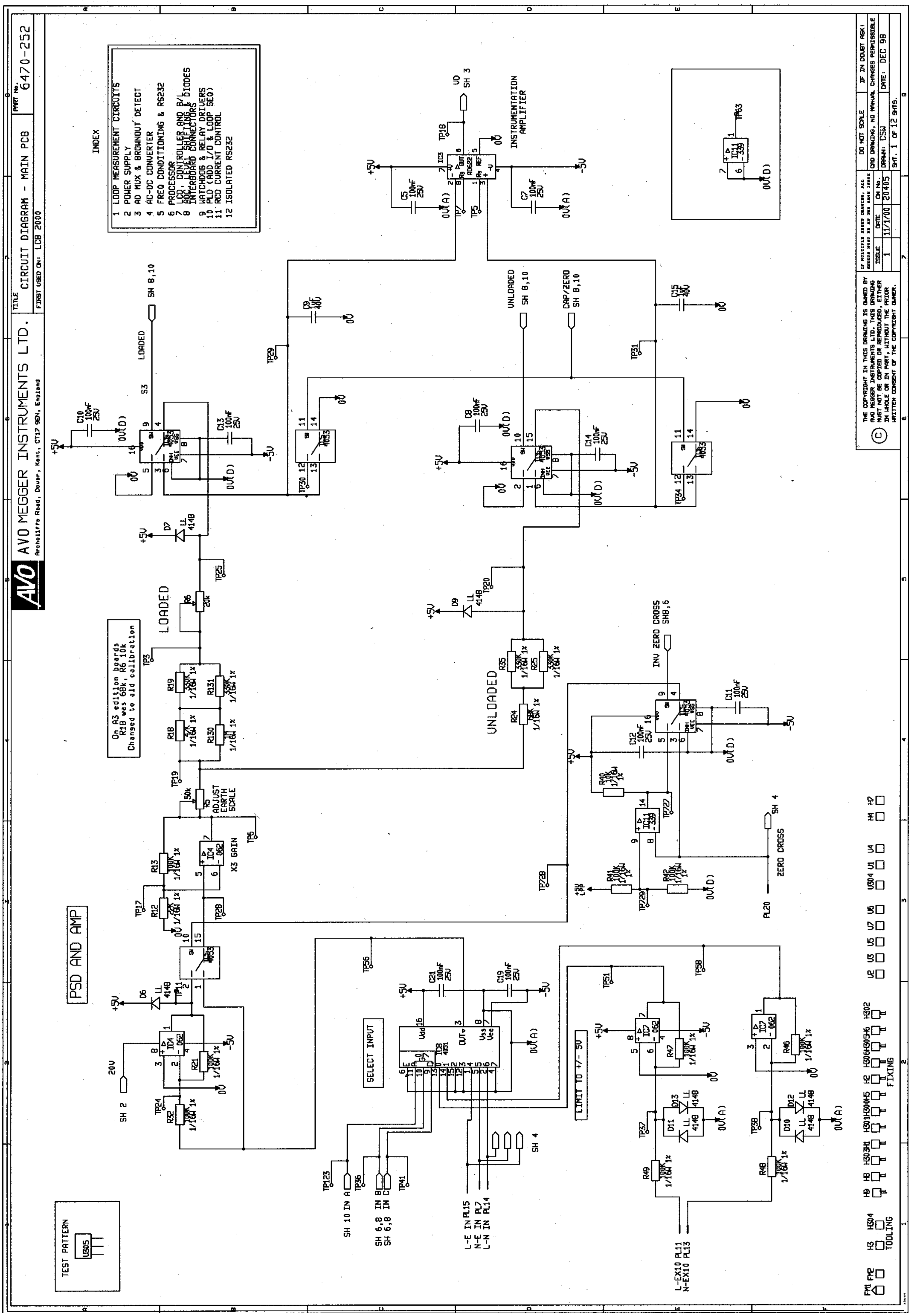
Relay Board		Main Display		Signal		Relay Board		Main & Display		Signal
S	Ref	S	Ref			S	Ref	S	Ref	
1	PL500	2	PL4	-5V LPP		1	PL501	2	PL5	+5V LPP
2	PL502	2	PL6	20V		2	PL503	1	PL7	N-E IN
1	PL504	8	PL8	25A ON		2	PL505	8	PL9	TB-E IN
1	PL506	8	PL10	25A CUTOUT		2	PL507	1	PL11	L-Ex10
1	PL508	2	PL12	-5V		2	PL509	1	PL13	N-Ex10
2	PL511	1	PL14	L-N IN		2	PL512	1	PL15	L-E IN

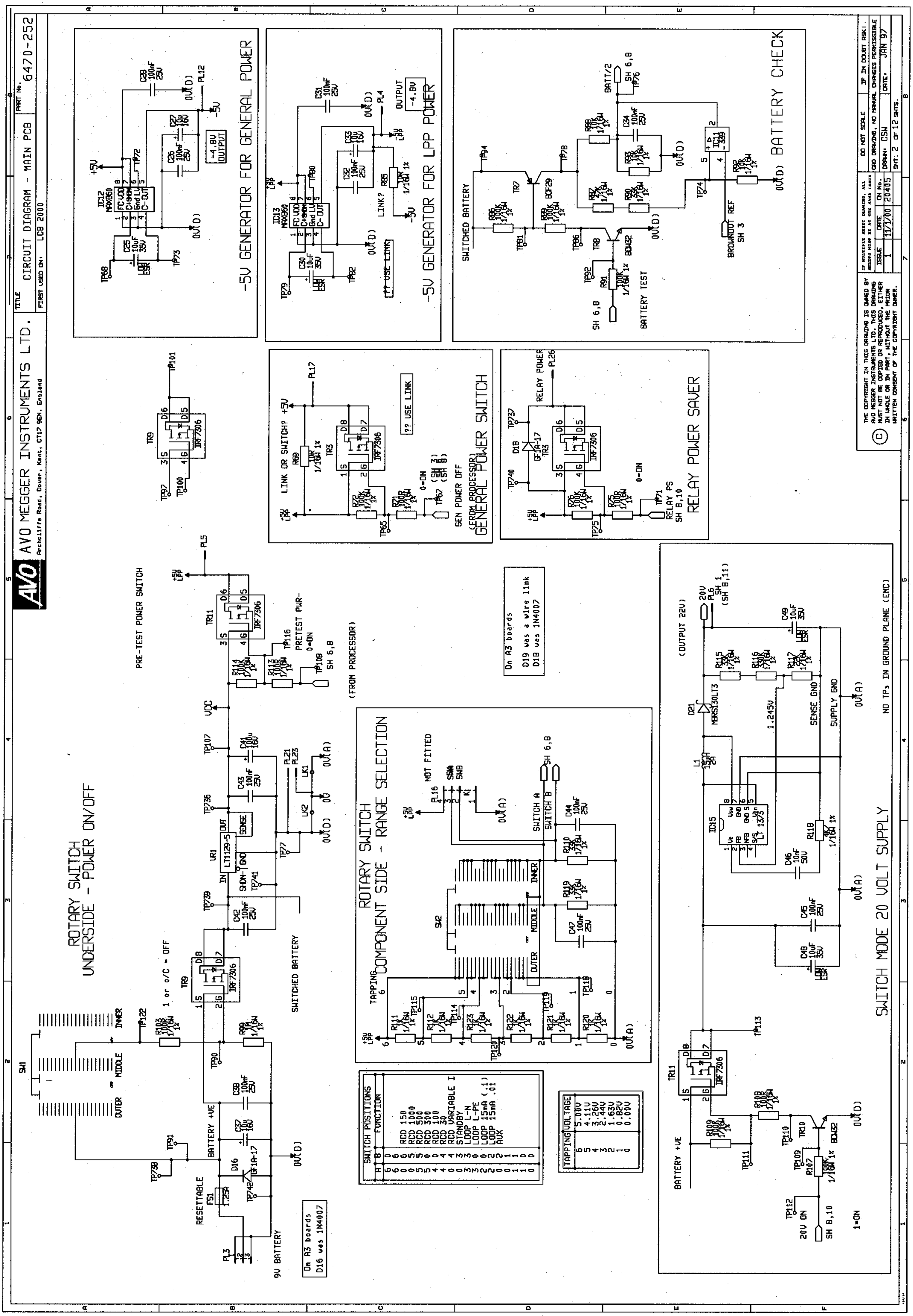
Second group - by range switch.

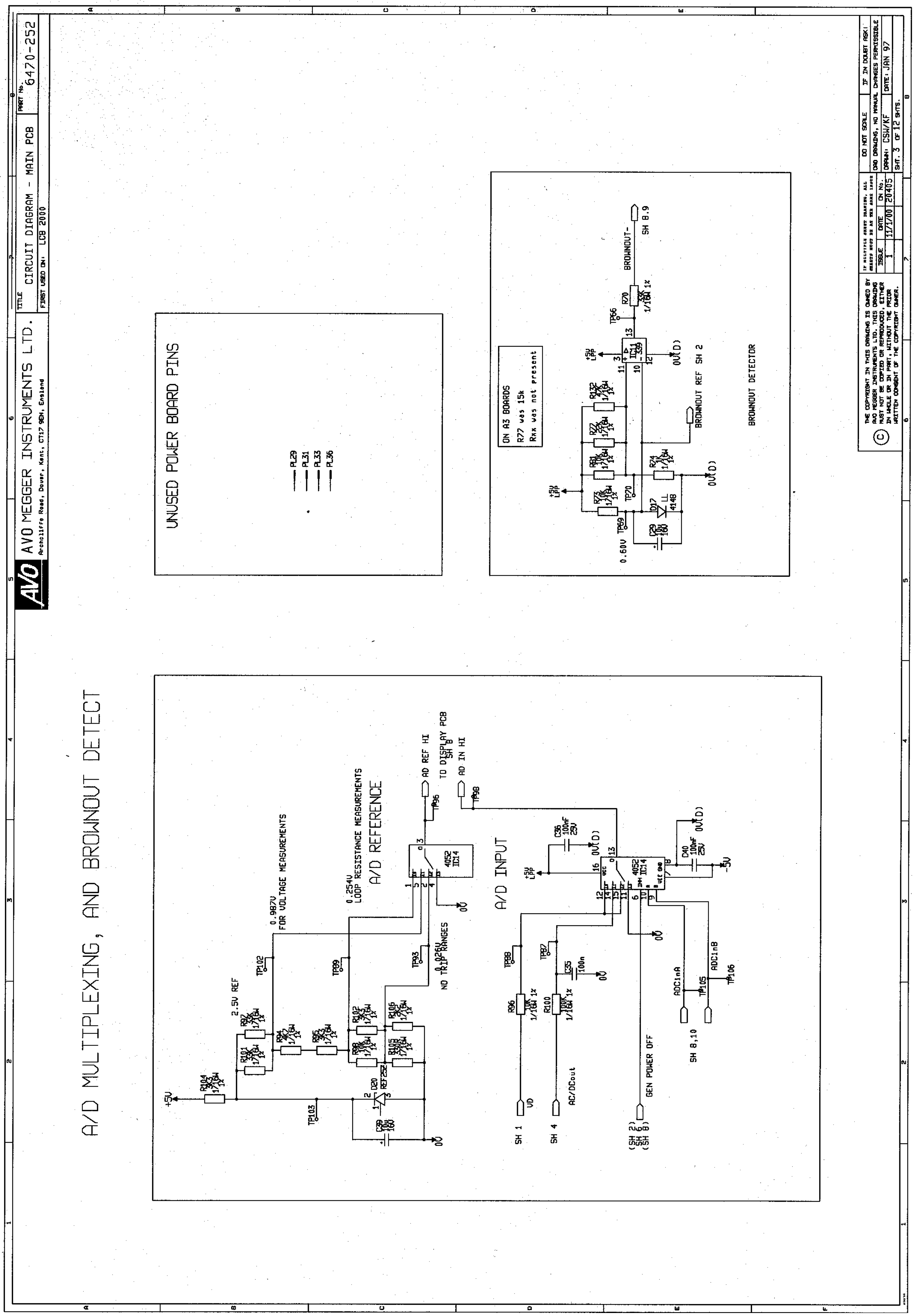
Relay Board		Main Display		Signal		Relay Board		Main & Display		Signal
S	Ref	S	Ref			S	Ref	S	Ref	
1	PL515	2	PL17	+5V		3	PL516	8	PL18	50HZ CLK
3	PL517	8	PL19	MAINS LANE		3	PL518	1	PL20	ZERO CROSS
3	PL519	8	PL21	0V(A)		3	PL520	8	PL22	ZERO I MON
1	PL521	2	PL23	0V		1	PL522	8	PL24	RL NorL
3	PL523	8	PL25	RCD DRIVE		1	PL524	2	PL26	RELAY POWER
3	PL525	8	PL27	MID RANGE		1	PL526	8	PL28	RL N
3	PL527	3	PL29	NOT USED		1	PL528	8	PL30	RL NorE
3	PL529	3	PL31	NOT USED		3	PL530	8	PL32	OV (A)
3	PL531	3	PL33	NOT USED		3	PL532	8	PL34	TEMPCD
3	PL533	8	PL35	STROBE		3	PL534	8	PL36	NOT USED

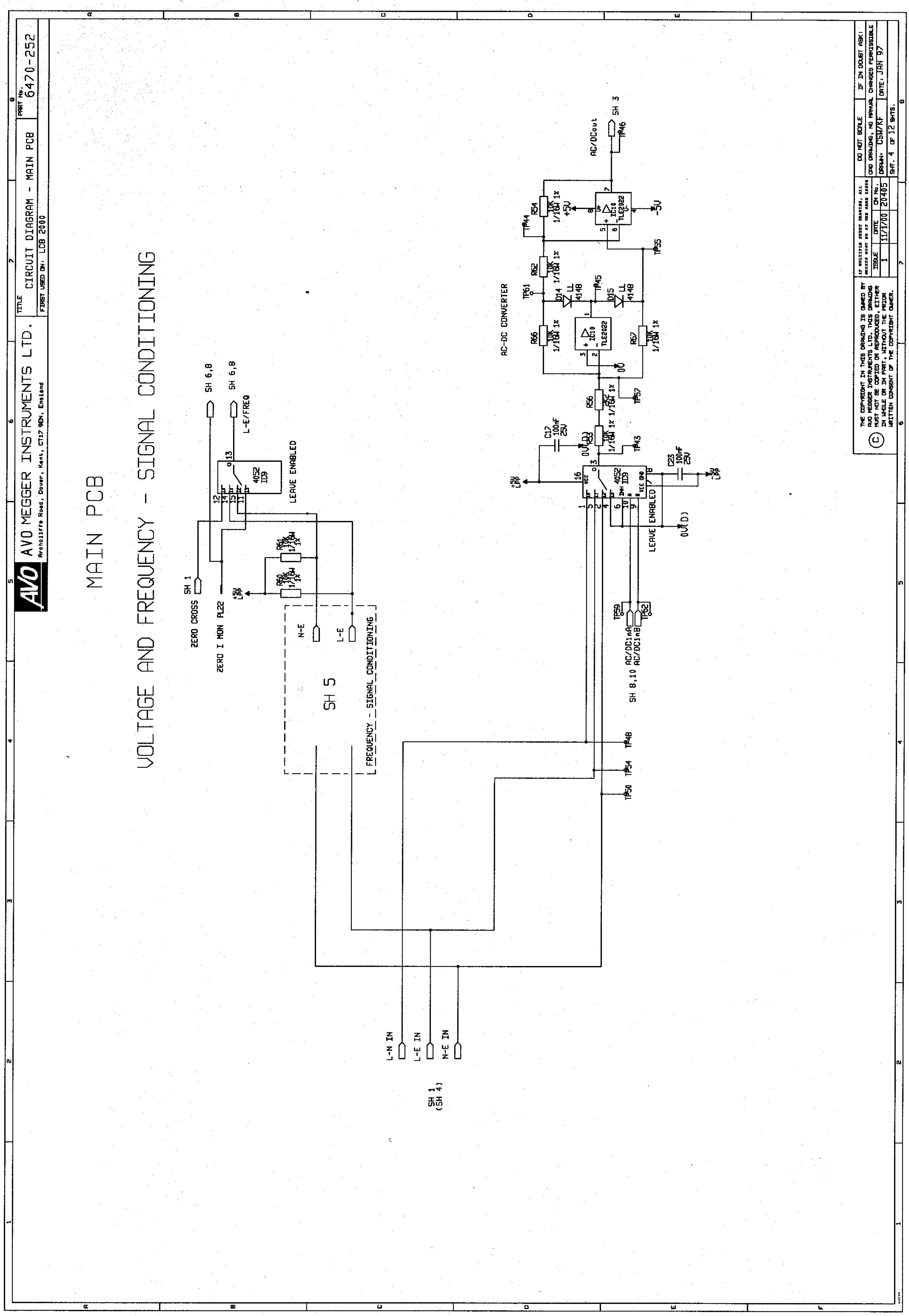
Appendix 7 - Circuit Diagrams

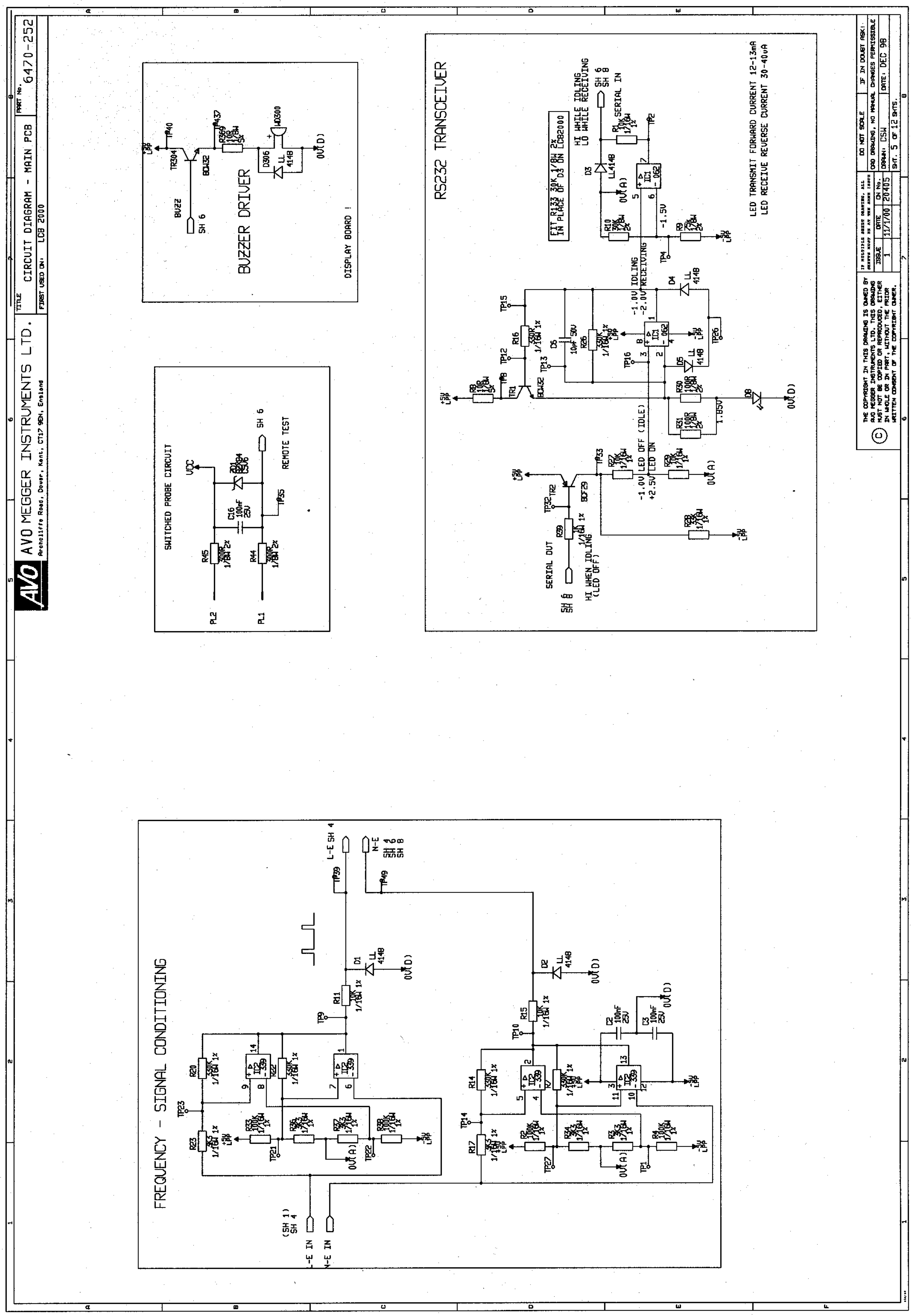
Main and Display Circuit Diagram

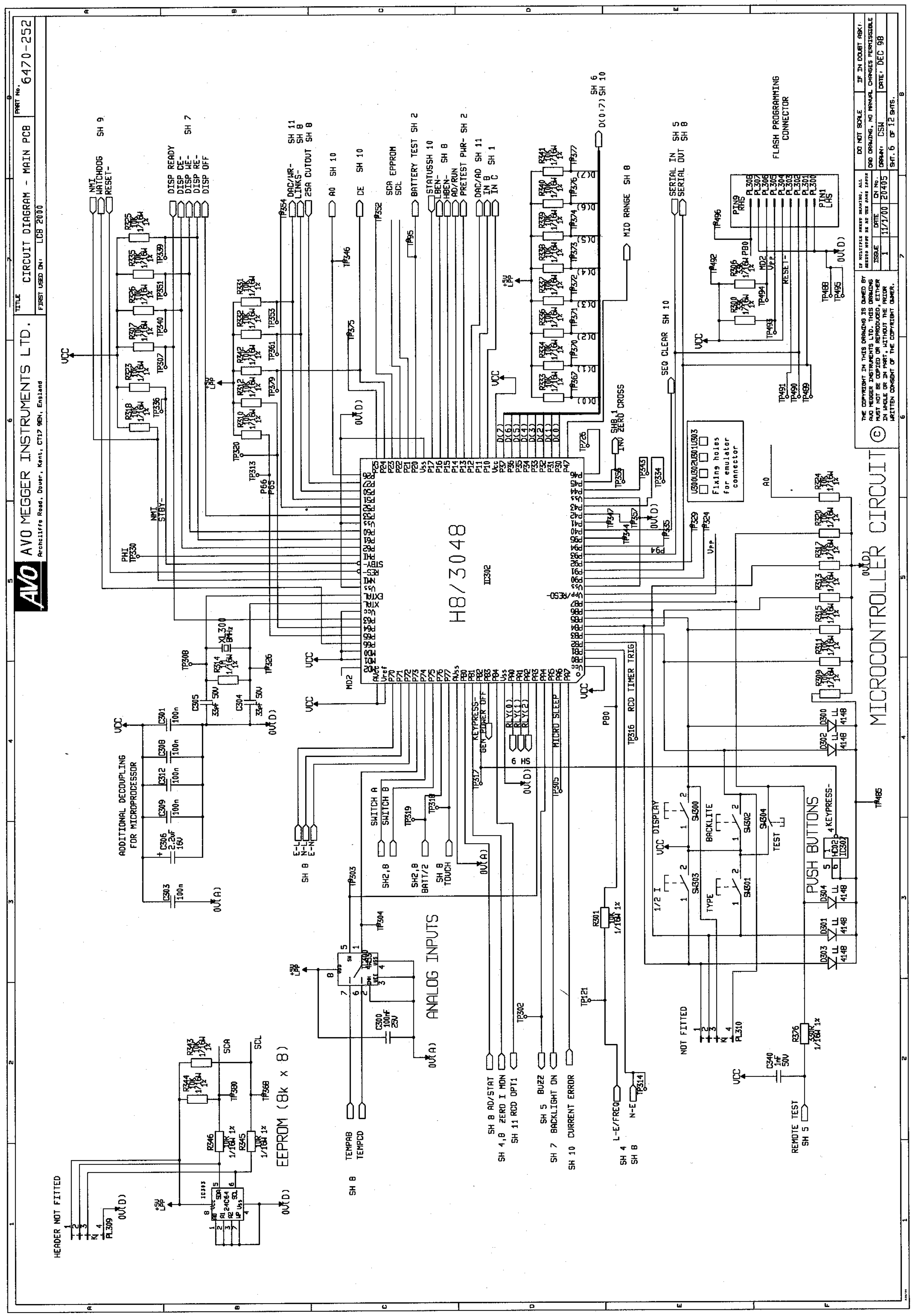

AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
6470-252
INDEX
1 LOOP MEASUREMENT CIRCUITS
2 POWER SUPPLY
3 AD MUX & BROWNOUT DETECT
4 AC-DC CONVERTER
5 FREQ CONDITIONING & RS232
6 PROCESSOR
7 LCD, CONTROLLER AND B/L
9 WATCHDOG & RELAY DRIVERS
10 PLD (ADD I/O & LOOP SEQ)
11 RCD CURRENT CONTROL
12 ISOLATED RS232
INSTRUMENTATION AMPLIFIER
LOADED
UNLOADED
INV ZERO CROSS
ZERO CROSS
ADJUST EARTH SCALE
X3 GAIN
PSD AND AMP
SELECT INPUT
LIMIT TO +/- 5V
TEST PATTERN
FIXING
TOOLING
On A3 edition boards R18 was 68k, R6 10k Changed to aid calibration
DATE: DEC 98
SHT. 1 OF 12 SHTS.

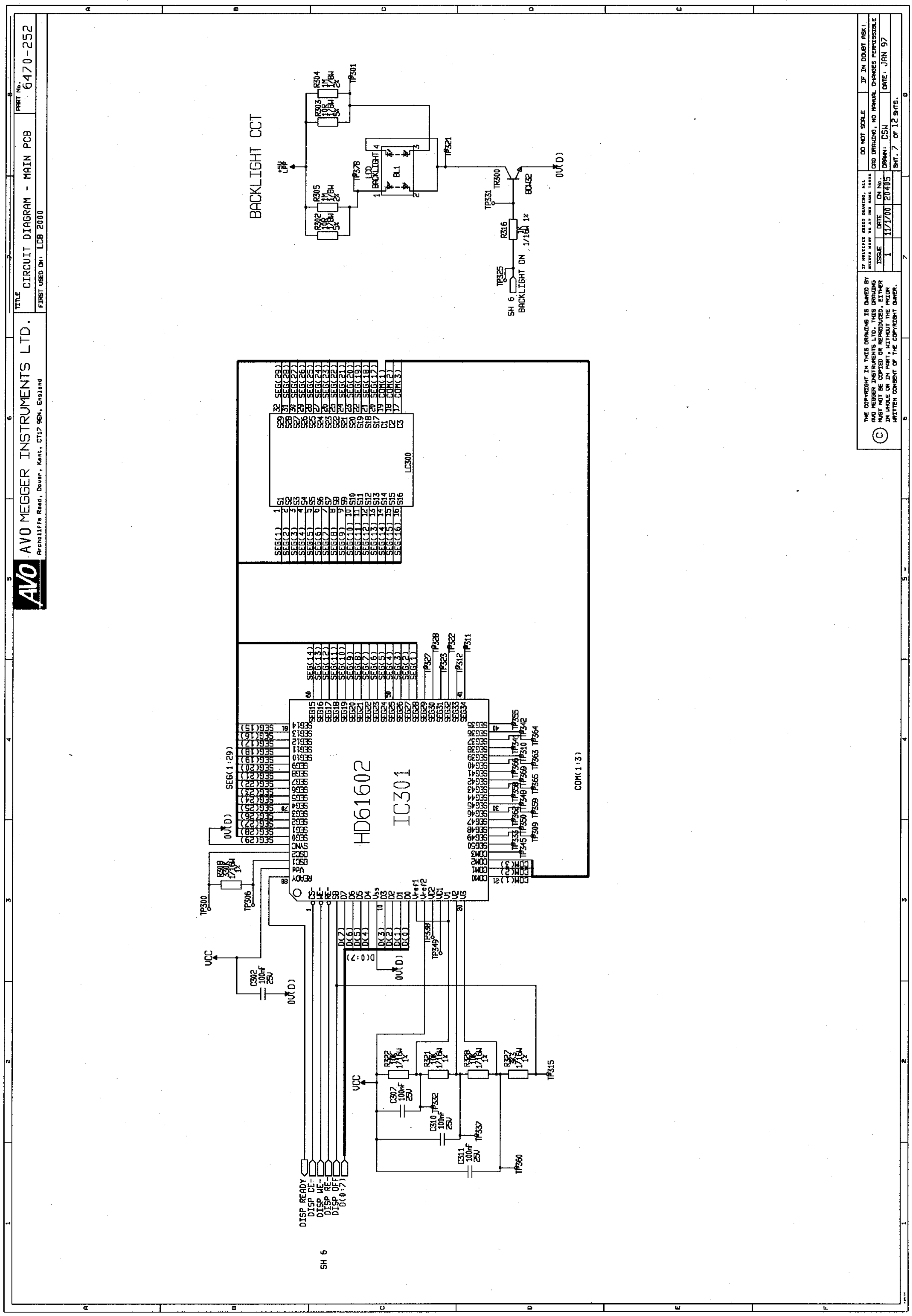

AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - MAIN PCB
6470-252
-5V GENERATOR FOR GENERAL POWER
-5V GENERATOR FOR LPP POWER
BATTERY CHECK
GENERAL POWER SWITCH
RELAY POWER SAVER
PRE-TEST POWER SWITCH
ROTARY SWITCH UNDERSIDE - POWER ON/OFF
ROTARY SWITCH COMPONENT SIDE - RANGE SELECTION
SWITCH MODE 20 VOLT SUPPLY
NO TPs IN GROUND PLANE (EMC)
On A3 boards D19 was a wire link D18 was 1N4007
On A3 boards D16 was 1N4007
SWITCH POSITIONS
TAPPING VOLTAGE

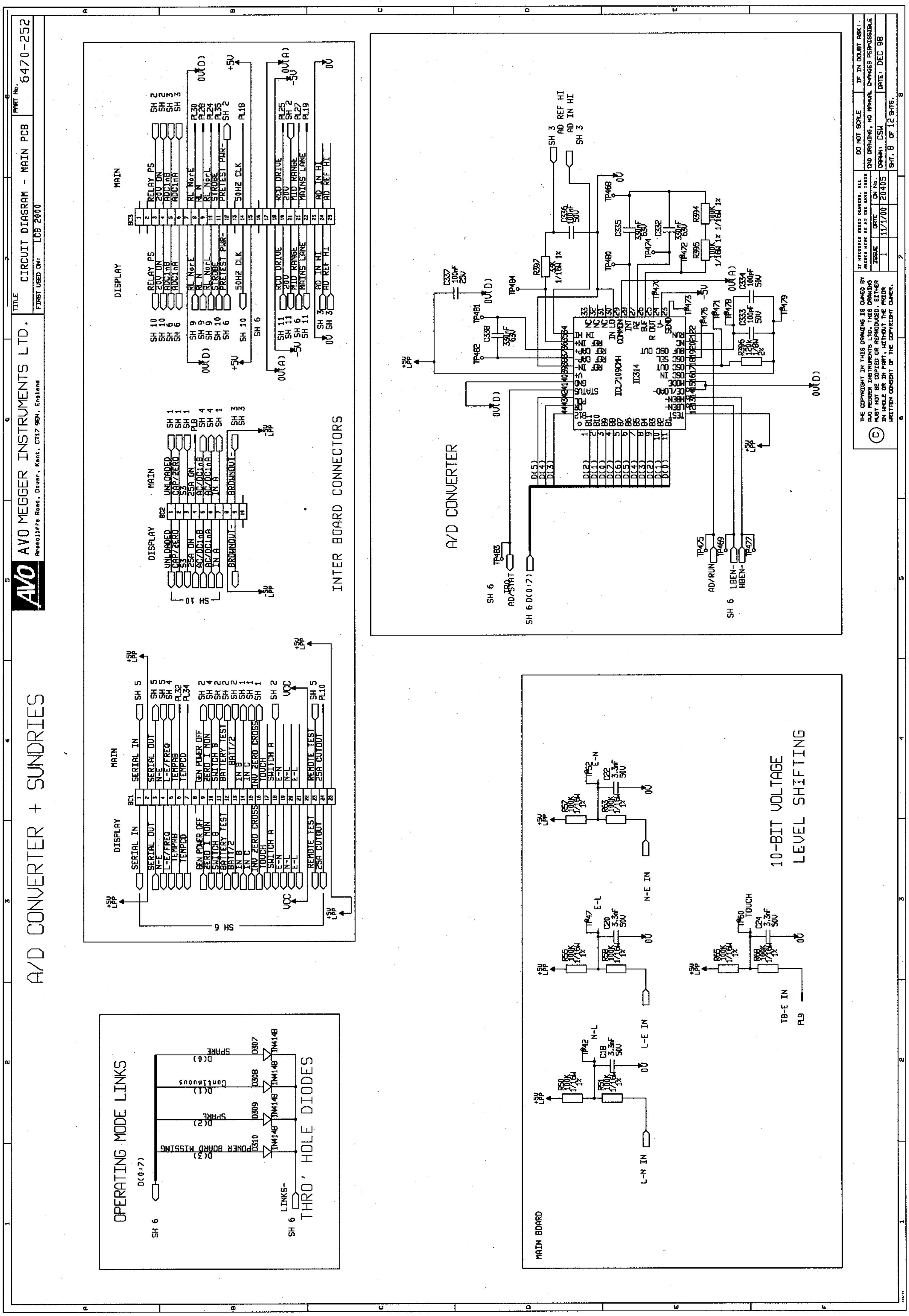

A/D MULTIPLEXING, AND BROWNOUT DETECT
AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
PART No. 6470-252
UNUSED POWER BOARD PINS
PL29
PL31
PL33
PL36
BROWNOUT DETECTOR
ON A3 BOARDS
R77 was 15k
Rxx was not present
BROWNOUT-
SH 8.9
BROWNOUT REF SH 2
0.60V
A/D REFERENCE
2.5V REF
0.987V FOR VOLTAGE MEASUREMENTS
0.254V LOOP RESISTANCE MEASUREMENTS
0.026V NO TRIP RANGES
AD REF HI
TO DISPLAY PCB SH 8
AD IN HI
A/D INPUT
SH 1
SH 4
AC/DCout
GEN POWER OFF
SH 8,10
ADC1nA
ADC1nB
THE COPYRIGHT IN THIS DRAWING IS OWNED BY AVO MEGGER INSTRUMENTS LTD. THIS DRAWING MUST NOT BE COPIED OR REPRODUCED, EITHER IN WHOLE OR IN PART, WITHOUT THE PRIOR WRITTEN CONSENT OF THE COPYRIGHT OWNER.
DO NOT SCALE
IF IN DOUBT ASK!
CAD DRAWING, NO MANUAL CHANGES PERMISSIBLE
DRAWN: CSW/KF
DATE: JAN 97
SHT. 3 OF 12 SHTS.
ISSUE 1
DATE 11/1/00
CN No. 20405

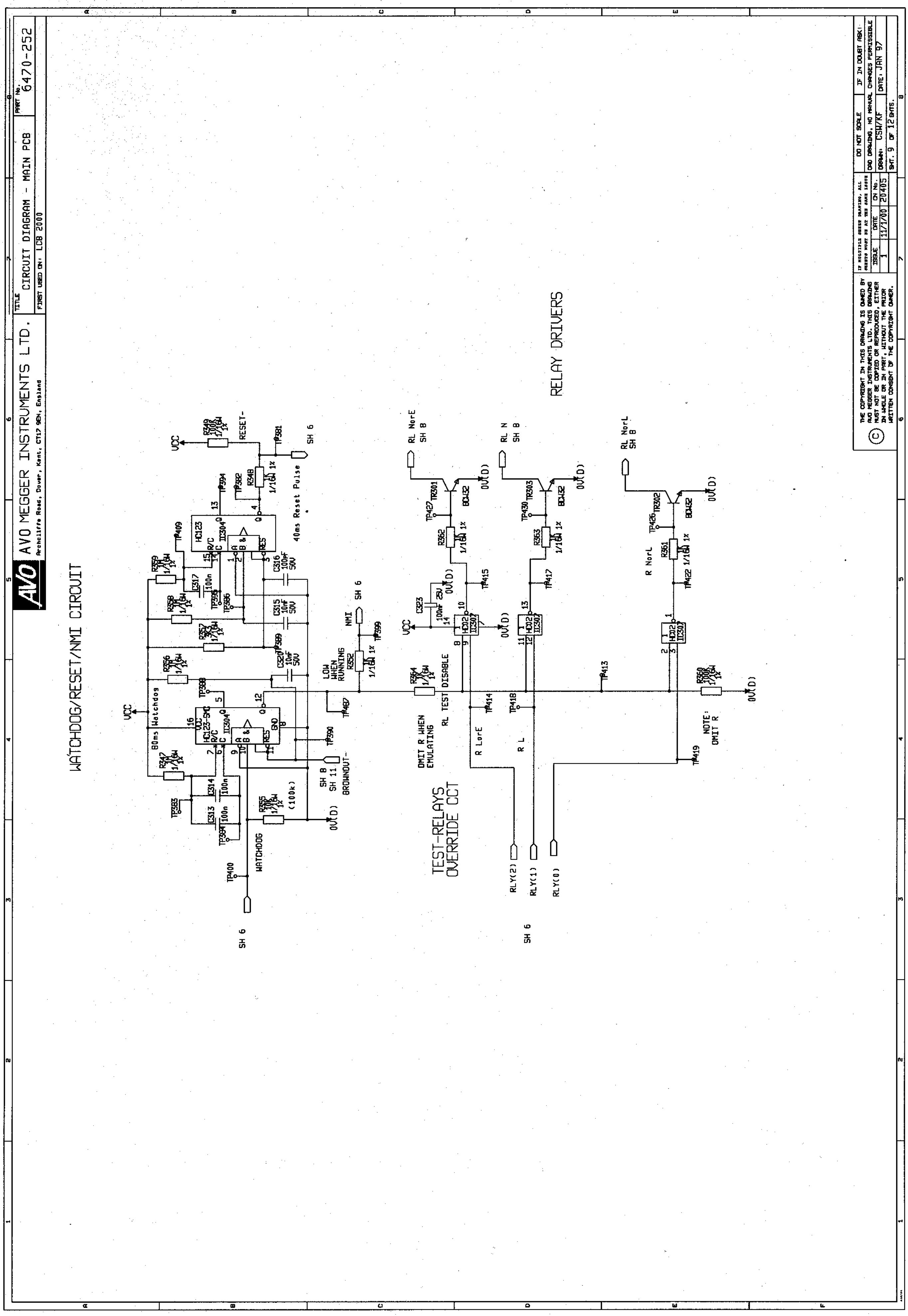

AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
PART No. 6470-252
MAIN PCB
VOLTAGE AND FREQUENCY - SIGNAL CONDITIONING
AC-DC CONVERTER
AC/DCout
SH 3
SH 6,8
L-E/FREQ
LEAVE ENABLED
ZERO CROSS
SH 1
ZERO I MON PL22
FREQUENCY - SIGNAL CONDITIONING
SH 5
N-E
L-E
AC/DCinA
AC/DCinB
SH 8,10
L-N IN
L-E IN
N-E IN
SH 1
(SH 4)
TLE2022
4052
DO NOT SCALE
IF IN DOUBT ASK!
DATE: JAN 97
SHT. 4 OF 12 SHTS.

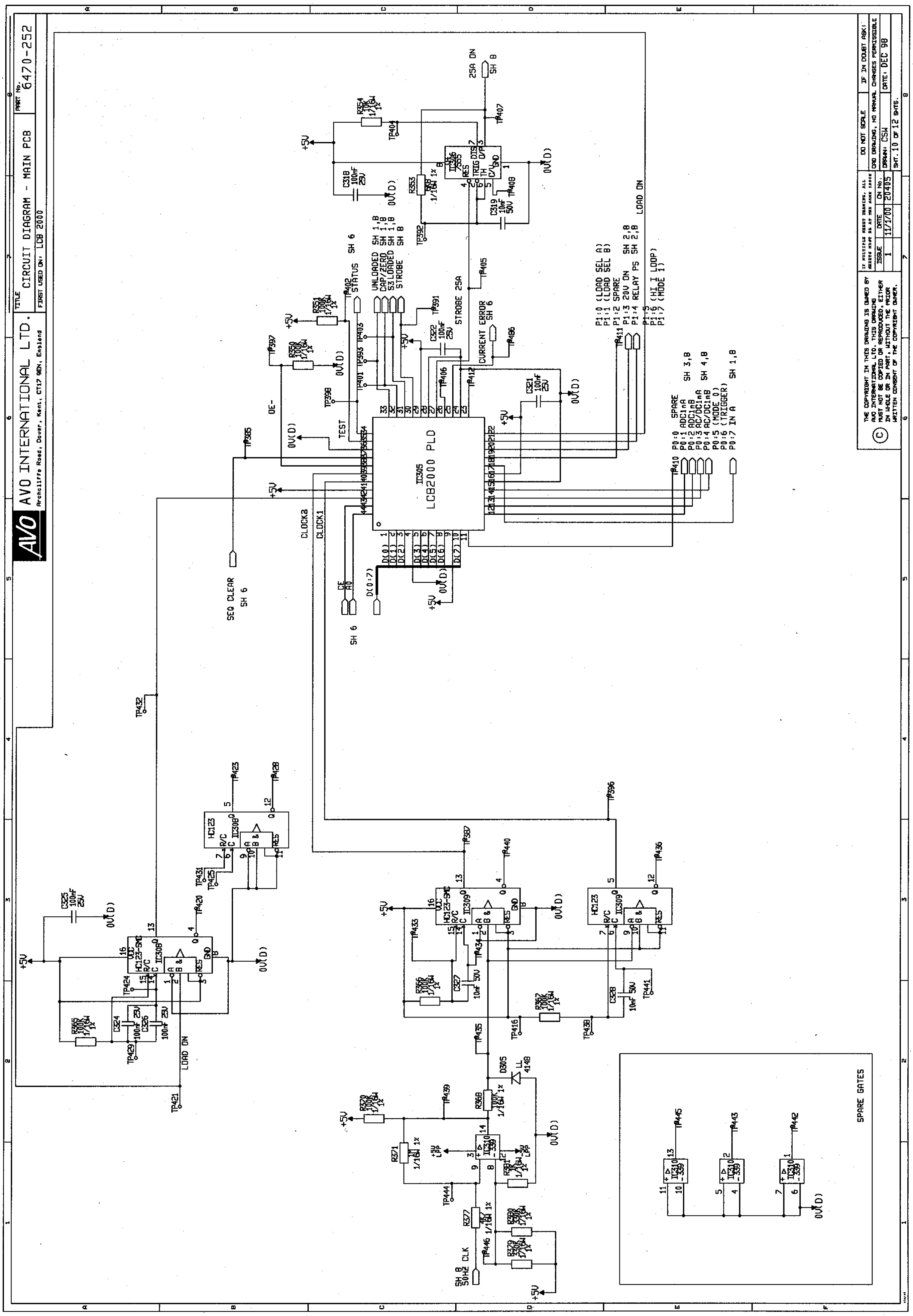

AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
TITLE CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
PART No. 6470-252
BUZZER DRIVER
DISPLAY BOARD !
SWITCHED PROBE CIRCUIT
REMOTE TEST
RS232 TRANSCEIVER
FIT R133 30K 1/8W 2% IN PLACE OF D3 ON LCB2000
HI WHILE IDLING
LO WHILE RECEIVING
SERIAL IN
LED TRANSMIT FORWARD CURRENT 12-13mA
LED RECEIVE REVERSE CURRENT 30-40uA
SERIAL OUT
HI WHEN IDLING (LED OFF)
-1.0V LED OFF (IDLE)
+2.5V LED ON
FREQUENCY - SIGNAL CONDITIONING
L-E SH 4
N-E SH 4 SH 6 SH 8
L-E IN (SH 1) SH 4
N-E IN
DO NOT SCALE
IF IN DOUBT ASK!
DRAWN: CSW
DATE: DEC 98
SHT. 5 OF 12 SHTS.
THE COPYRIGHT IN THIS DRAWING IS OWNED BY AVO MEGGER INSTRUMENTS LTD. THIS DRAWING MUST NOT BE COPIED OR REPRODUCED, EITHER IN WHOLE OR IN PART, WITHOUT THE PRIOR WRITTEN CONSENT OF THE COPYRIGHT OWNER.

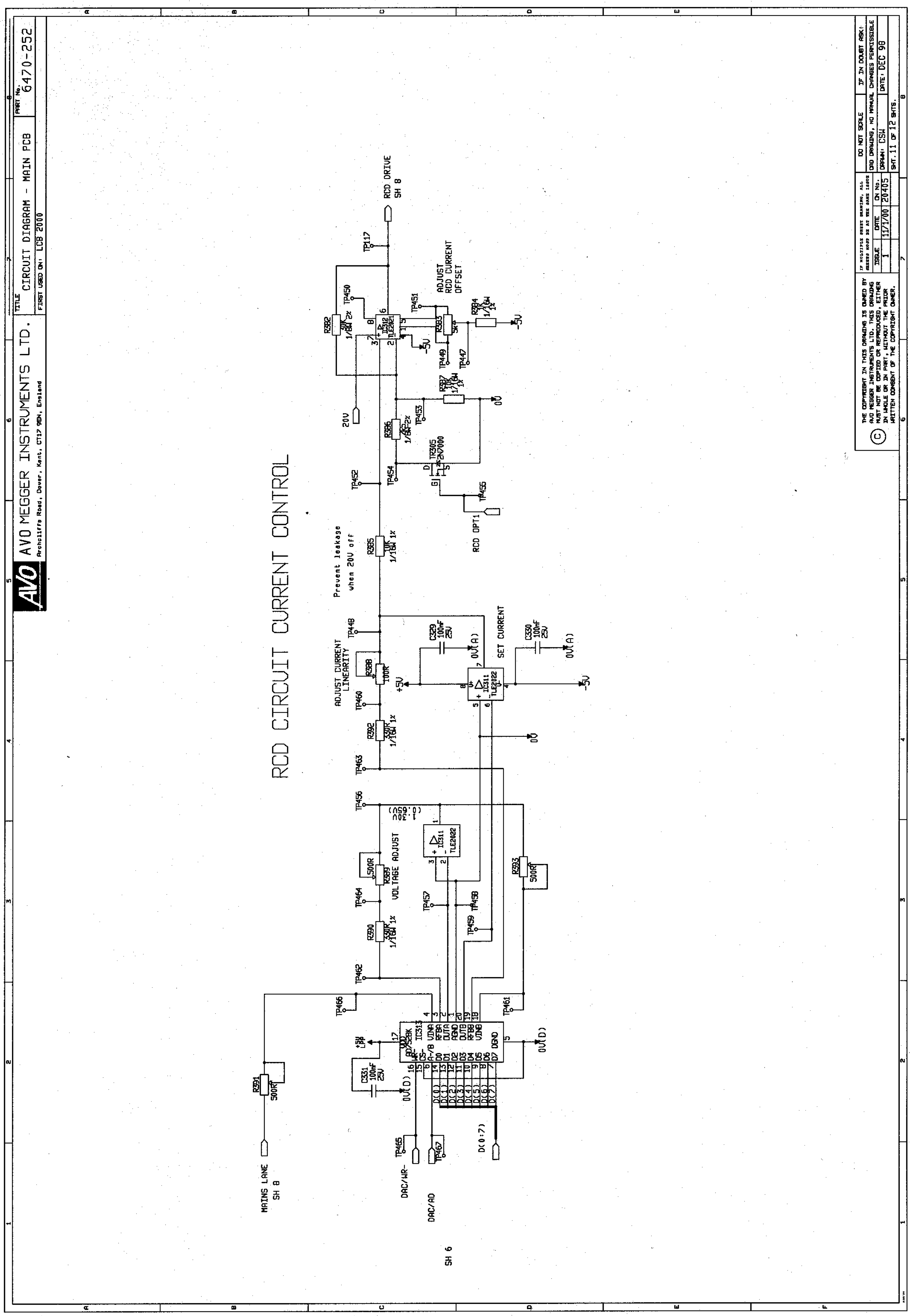

AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - MAIN PCB
6470-252
H8/3048
MICROCONTROLLER CIRCUIT
ANALOG INPUTS
EEPROM (8k x 8)
PUSH BUTTONS
FLASH PROGRAMMING CONNECTOR
ADDITIONAL DECOUPLING FOR MICROPROCESSOR
HEADER NOT FITTED
NOT FITTED

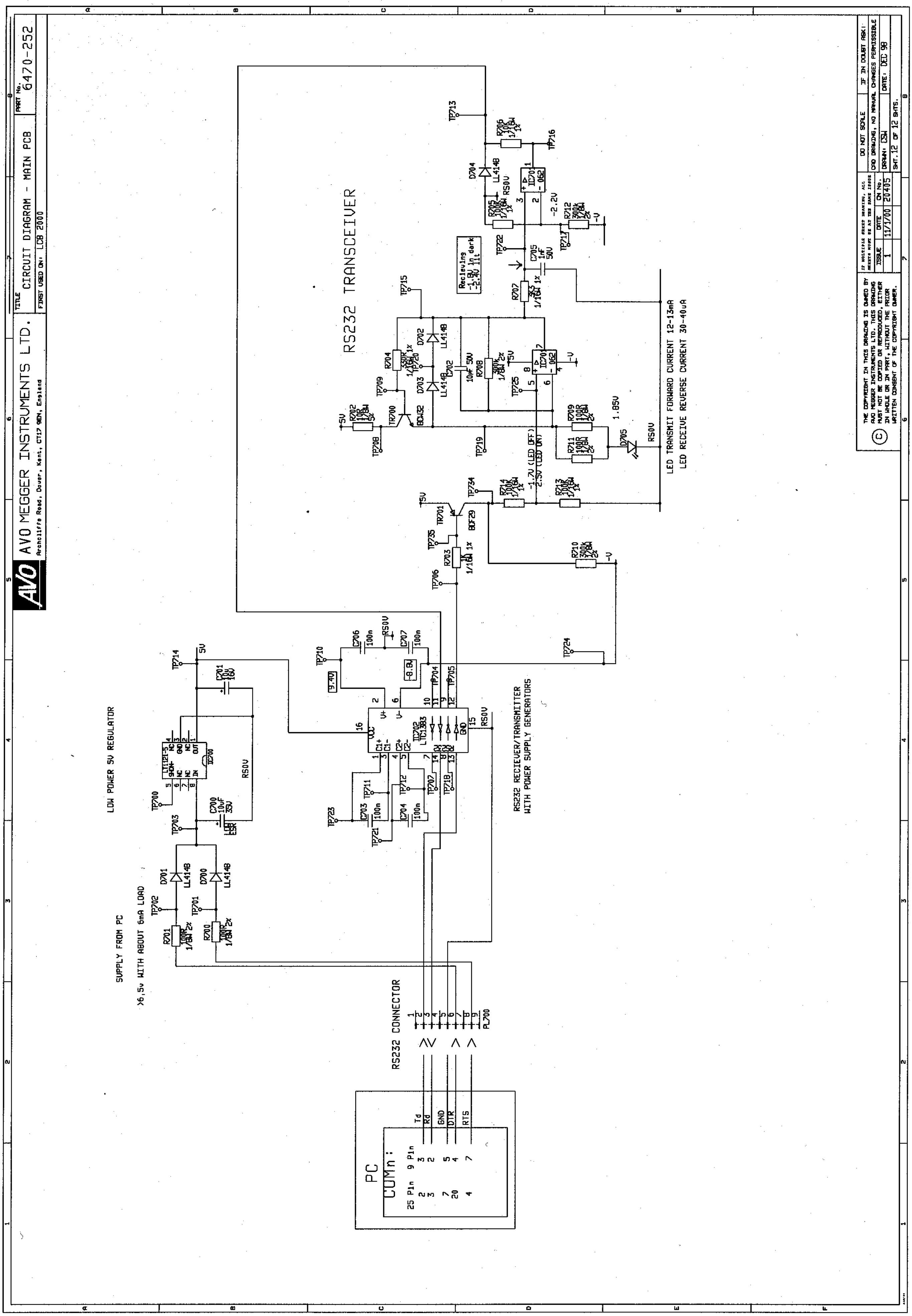

AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - MAIN PCB
6470-252
BACKLIGHT CCT
HD61602
IC301
LC300
BACKLIGHT ON
DISP READY
DISP CE-
DISP WE-
DISP RE-
DISP OFF
D(0:7)


A/D CONVERTER + SUNDRIES
AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - MAIN PCB
6470-252
INTER BOARD CONNECTORS
A/D CONVERTER
OPERATING MODE LINKS
THRO' HOLE DIODES
10-BIT VOLTAGE LEVEL SHIFTING
MAIN BOARD

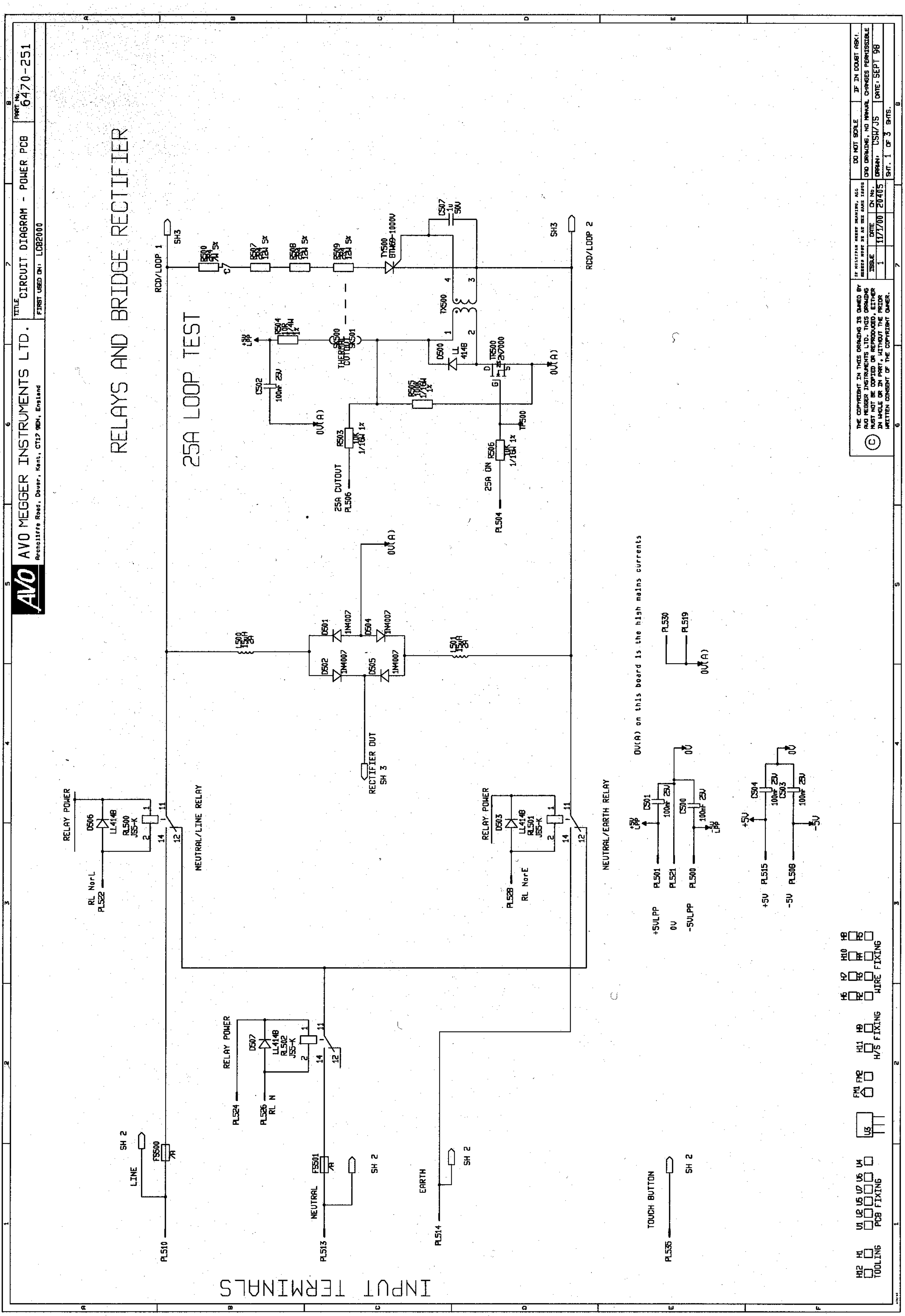

AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
6470-252
WATCHDOG/RESET/NMI CIRCUIT
RELAY DRIVERS
TEST-RELAYS OVERRIDE CCT
DO NOT SCALE
IF IN DOUBT ASK!
DATE: JAN 97
SHT. 9 OF 12 SHTS.

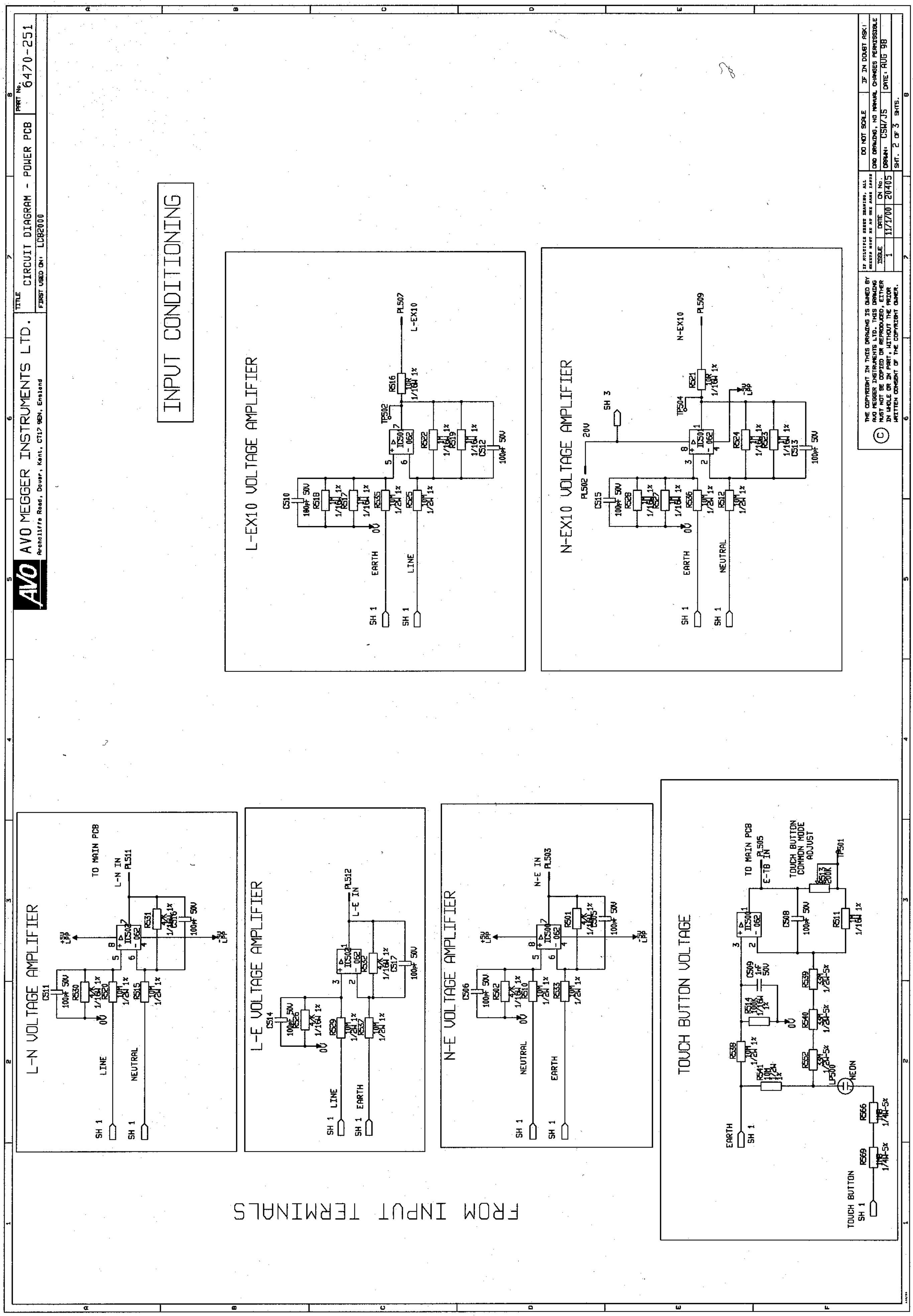

AVO INTERNATIONAL LTD.
CIRCUIT DIAGRAM - MAIN PCB
6470-252
LCB 2000
IC305 LCB2000 PLD
SPARE GATES

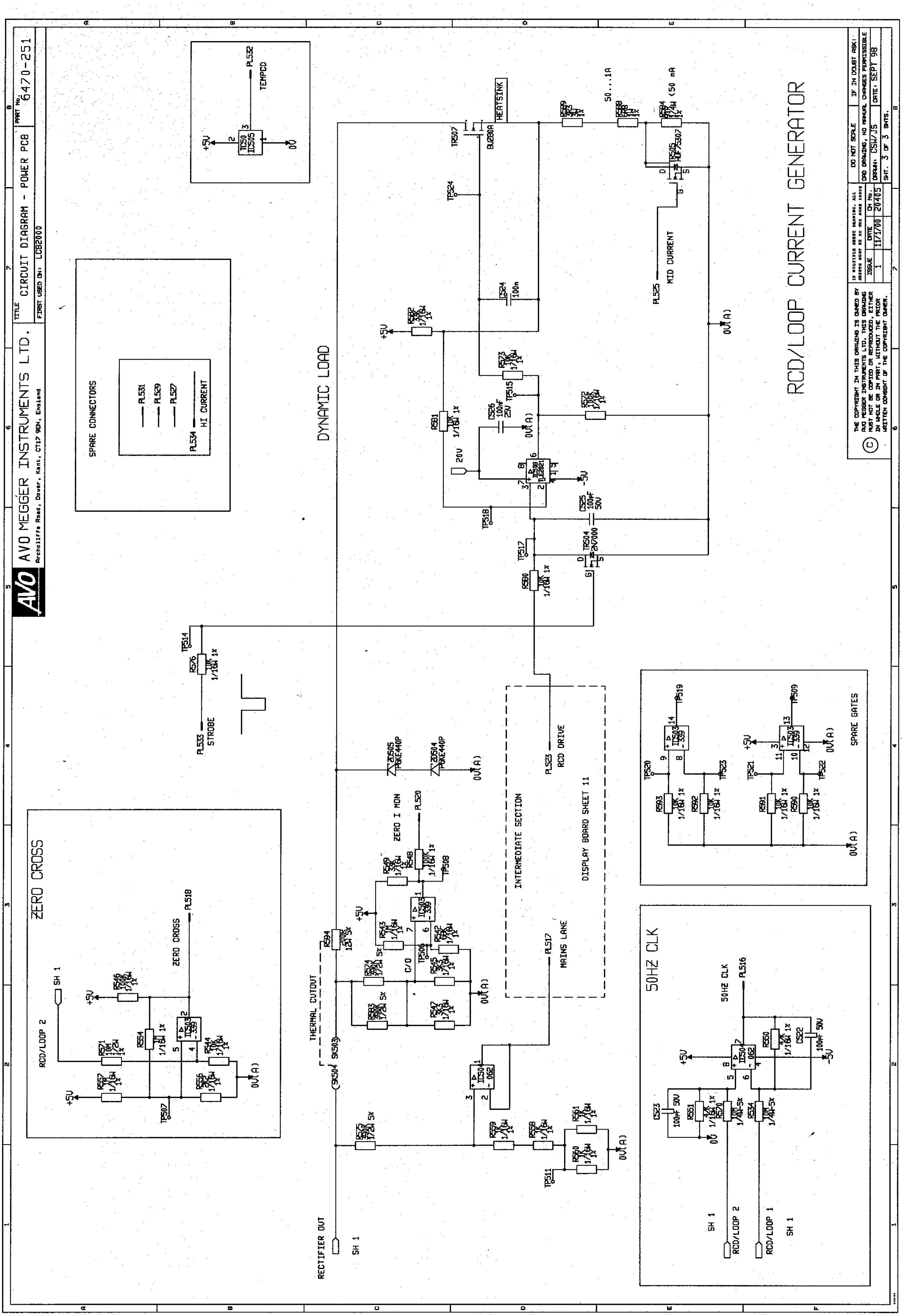

RCD CIRCUIT CURRENT CONTROL
AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
6470-252
RCD DRIVE
SH 8
ADJUST
RCD CURRENT
OFFSET
Prevent leakage
when 20V off
ADJUST CURRENT
LINEARITY
SET CURRENT
VOLTAGE ADJUST
RCD OPT1
MAINS LANE
SH 8
DAC/WR-
DAC/AD
SH 6
D(0:7)
DO NOT SCALE
IF IN DOUBT ASK!
DRAWN: CSW
DATE: DEC 98
SHT.11 OF 12 SHTS.


AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - MAIN PCB
FIRST USED ON: LCB 2000
6470-252
RS232 TRANSCEIVER
LOW POWER 5V REGULATOR
SUPPLY FROM PC
>6,5v WITH ABOUT 6mA LOAD
RS232 RECIEVER/TRANSMITTER
WITH POWER SUPPLY GENERATORS
RS232 CONNECTOR
LED TRANSMIT FORWARD CURRENT 12-13mA
LED RECEIVE REVERSE CURRENT 30-40uA
PC
COMn:
DO NOT SCALE
IF IN DOUBT ASK!

Power Board Circuit Diagram


AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - POWER PCB
PART No. 6470-251
FIRST USED ON: LCB2000
RELAYS AND BRIDGE RECTIFIER
25A LOOP TEST
INPUT TERMINALS
0V(A) on this board is the high mains currents
NEUTRAL/LINE RELAY
NEUTRAL/EARTH RELAY
RECTIFIER OUT
TOUCH BUTTON
LINE
NEUTRAL
EARTH
DO NOT SCALE
IF IN DOUBT ASK!
DATE: SEPT 98


AVO MEGGER INSTRUMENTS LTD.
CIRCUIT DIAGRAM - POWER PCB
6470-251
INPUT CONDITIONING
L-EX10 VOLTAGE AMPLIFIER
N-EX10 VOLTAGE AMPLIFIER
L-N VOLTAGE AMPLIFIER
L-E VOLTAGE AMPLIFIER
N-E VOLTAGE AMPLIFIER
TOUCH BUTTON VOLTAGE
FROM INPUT TERMINALS


AVO MEGGER INSTRUMENTS LTD.
Archcliffe Road, Dover, Kent, CT17 9EN, England
CIRCUIT DIAGRAM - POWER PCB
FIRST USED ON: LCB2000
6470-251
RCD/LOOP CURRENT GENERATOR
DYNAMIC LOAD
SPARE CONNECTORS
ZERO CROSS
50HZ CLK
SPARE GATES
INTERMEDIATE SECTION
DISPLAY BOARD SHEET 11
HEATSINK
THERMAL CUTOUT
RECTIFIER OUT
STROBE
RCD DRIVE
MAINS LANE
ZERO I MON
MID CURRENT
HI CURRENT
TEMPCO
DO NOT SCALE
IF IN DOUBT ASK!
DATE: SEPT 98

Appendix 8 - Circuit Diagram Cross – Reference

LCB2000/2500 Circuit Diagram XREF - Capacitors

Main Board		Display Board		Power Board		RS232 Board	
C1		C300		C500	P1	C700	12
C2	5	C301		C501	P1	C701	12
C3	5	C302		C502	P1	C702	12
C4		C303		C503	P1	C703	12
C5	1	C304	6	C504	P1	C704	12
C6	5	C305	6	C505	P2	C705	12
C7	1	C306	6	C506	P2		
C8		C307	7	C507	P1		
C9	1	C308	6	C508	P2		
C10		C309	6	C509	P2		
C11	1	C310	7	C510	P2		
C12	1	C311	7	C511	P2		
C13		C312	6	C512	P2		
C14		C313	9	C513	P2		
C15	1	C314	9	C514	P2		
C16	5	C315	9	C515	P2		
C17	4	C316	9	C516	P2		
C18		C317	9	C517	P2		
C19	1	C318		C518			
C20		C319	10	C519			
C21	1	C320	9	C520			
C22		C321	10	C521			
C23	4	C322	10	C522	P3		
C24		C323	9	C523	P3		
C25	2	C324	10	C524	P3		
C26	2	C325	10	C525	P3		
C27	2	C326		C526	P3		
C28		C327	10				
C29	3	C328	10				
C30	2	C329	11				
C31		C330					
C32	2	C331					
C33	2	C332	8				
C34	2	C333	8				
C35	3	C334	8				
C36		C335	8				
C37	2	C336	8				
C38	2	C337					
C39	3	C338	8				
C40		C339					
C41	2	C340					
C42	2	C341					
C43	2	C342					
C44	2	C343					
C45	2	C344					
C46	22	C345					
C47	2	C346					

C48	2	C347					
C49	2	C348					
C50		C349					

LCB2000/2500 Circuit Diagram XREF – Diodes, Transistors, ICs, etc

Main Board		Display Board		Power Board		RS232 Board	
D1	5	D306	5	D500	P1	D700	12
D2	5	D307	8 N/F	D501	P1	D701	12
D3	5*	D308	8 N/F	D502	P1	D702	12
D4	5*	D309	8 N/F	D503	P1	D703	12
D5	5*	D310	8 N/F	D504	P1	D704	12
D6	1			D505	P1		
D7	1			D506	P1		
D8	5*			D507	P1		
D9	1						
D10	1			FS500	P1		
D11	1			FS501	P1		
D12	1						
D13	1			L500	P1		
D14	4			L501	P1		
D15	4						
D16	2			RL500	P1		
D17	3			RL501	P1		
D18	2			RL502	P1		
D19	2*						
D20	3						
D21	2						
TR1	5*			TR500	P1		
TR2	5*			TR504	P3		
TR3	2			TR505	P3		
				TR507	P3		
TR7	2						
TR8	2			TX500	P3		
TR9	2						
TR10	2			TY500	P1		
TR11	2						
IC1	5*	IC300	6	IC500	P2	IC700	12
IC2	5	IC301	7	IC501	P2	IC701	12
IC3	1	IC302	6	IC502	P2	IC702	12
IC4	1	IC303	6	IC503	P3		
IC5	1	IC304	9	IC504	P3		
IC6	1	IC305	10	IC505	P3		
IC7	1	IC306	10	IC508	P3		
IC8	1	IC307	6,9				
IC9	4	IC308	10				
IC10	4	IC309	10				
IC11	1,2,3	IC310	10				
IC12	2	IC311	11				
IC13	2	IC312	11				
IC14	3	IC313	11				

IC15	2	IC314	8				
ZD1	5			ZD505	P3		
VR1	2			ZD504	P3		

LCB2000/2500 Circuit Diagram XREF - Resistors

Main Board						Display Board	
R1	5*	R51	8	R101	3	R300	6
R2	4	R52		R102	3	R301	6
R3	4	R53	3	R103	2	R302	7
R4	4	R54	3	R104	3	R303	7
R5	1	R55	8	R105	3	R304	7
R6	1	R56	3	R106	3	R305	7
R7	4	R57	8	R107	2	R306	6
R8	5*	R58	8	R108	2	R307	6
R9	5*	R59		R109	2	R308	7
R10	5*	R60	3	R110	2	R309	6
R11	4	R61	3	R111	2	R310	6
R12	1	R62	3	R112	2	R311	6
R13	1	R63	8	R113	2	R312	6
R14	4	R64		R114	2	R313	6
R15	4	R65	8	R115	2	R314	6
R16	5*	R66	3	R116	2	R315	6
R17	4	R67	3	R117	2	R316	7
R18	1	R68	8	R118	2	R317	6
R19	1	R69	1	R119	2	R318	6
R20	4	R70	3	R120	2	R319	
R21	1	R71	2	R121	2	R320	6
R22	4	R72	2	R122	2	R321	7
R23	4	R73	3	R123	2	R322	7
R24	1	R74	3	R124		R323	6
R25	1	R75	2	R125		R324	6
R26	5*	R76	2	R126		R325	6
R27	5*	R77	3	R127		R326	6
R28	5*	R78		R128		R327	7
R29	5*	R79		R129		R328	7
R30	5*	R80		R130	1	R329	
R31	5*	R81	3	R131	1	R330	
R32	1	R82				R331	6
R33	4	R83				R332	6
R34	4	R84				R333	6
R35	1	R85				R334	6
R36	4	R86	2			R335	6
R37	4	R87	2			R336	6
R38	4	R88	2			R337	6
R39	5*	R89	2			R338	6
R40	1	R90	2			R339	6
R41	1	R91	2			R340	6
R42	1	R92	2			R341	6
R43		R93	2			R342	6
R44	4	R94	3			R343	6
R45	4	R95	3			R344	6
R46	1	R96	3			R345	6
R47	1	R97	3			R346	9
R48	1	R98				R347	9
R49	1	R99	2			R348	9
R50	8	R100	3			R349	10

Display Board		Power Board				RS232 Board	
R350	10	R500	P1	R550	P3	R700	12
R351	8	R501	P2	R551	P3	R701	12
R352	10	R502	P2	R552	P2	R702	12
R353	10	R503	P1	R553	P	R703	12
R354	9	R504	P1	R554	P3	R704	12
R355	9	R505	P1	R555	P	R705	12
R356	9	R506	P1	R556	P3	R706	12
R357	9	R507	P1	R557	P3	R707	12
R358	9	R508	P1	R558	P3	R708	12
R359	9	R509	P1	R559	P3	R709	12
R360	9	R510	P2	R560	P	R710	12
R361	9	R511	P2	R561	P	R711	12
R362	9	R512	P2	R562	P3P	R712	12
R363	9	R513	P2P	R563	P		
R364	9	R514	P2	R564	P		
R365	10	R515	P2	R565	P	**R715**	**3**
R366	10	R516	P2	R566	P2		
R367	10	R517	P2	R567	P		
R368	10	R518	P2	R568	P		
R369	5	R519	P2	R569	P2		
R370	10	R520	P2	R570	P3		
R371	10	R521	P2	R571	P3		
R372		R522	P2	R572	P3		
R373		R523	P2	R573	P3		
R374		R524	P2	R574	P3		
R375		R525	P2	R575	P3		
R376	6	R526	P2	R576	P3		
R377	10	R527	P2	R577	P		
R378		R528	P2	R578	P		
R379	10	R529	P2	R579	P		
R380	10	R530	P2	R580	P3		
R381		R531	P2	R581	P3		
R382	11	R532	P2	R582	P3		
R383	11	R533	P2	R584	P3		
R384	11	R534	P3	R588	P3		
R385	11	R535	P2	R589	P3		
R386	11	R536	P2	R580	P3		
R387		R537	P2	R581	P3		
R388	11	R538	P2	R582	P3		
R389	11	R539	P2	R583	P3		
R390	11	R540	P2	R590	P3		
R391	11	R541	P2	R591	P3		
R392	11	R542	P3	R592	P3		
R393	11	R543	P3	R593	P3		
R394	8	R544	P	R594	P3		
R395	8	R545	P3				
R396	8	R546	P3				
R397	8	R547	P3				
		R548	P3				
		R549	P3				

Appendix 9 - LCB2500 Bill of Materials

Level	Bub	Component		UNIT	QTY
1		6111-377	UK LCB2500 Combinations Tester		
.2	101	6410-972	LCB2500 PLANNING BILL	EA	1
..3	1	6231-649	LCB POWER PCB ASSY	EA	1
...4		6331-768	LCB POWER SM ASSY	EA	1
...4		5440-251	LCB POWER PCB	EA	1
...4		30000-089	IC TEMPERATURE SENSOR LM50CIM3	EA	1
...4		30000-104	IC OP-AMP X2 TL062CPWLE TSSOP8	EA	4
...4		31000-002	DIODE,SM. LL4148 (S/M)	EA	4
...4		31000-016	TRANSISTOR N-TYPE ENCH. FET	EA	1
...4		31000-028	IC COMPARATOR X4 LM339 TSSOP14	EA	1
...4		31000-031	TRANSISTOR MOSFET(N)2.6A 75307	EA	2
...4		32000-004	CAP SMD CER- 100nF 10% 1206	EA	1
...4		32000-027	CAP SMD CER. 1nF 10% 0603	EA	1
...4		32000-029	CAP SMD CER- 100nF -20+80%0603	EA	6
...4		32000-030	CAP SMD CER 100pF 5% 0603	EA	14
...4		33000-031	RES SM. 1K 1% 0.063W	EA	4
...4		33000-033	RES SM. 2K2 1% 0.063W D1	EA	1
...4		33000-034	RES SM. 3K3 1% 0.063W	EA	2
...4		33000-037	RES SM. 10K 1% 0.063W	EA	11
...4		33000-039	RES SM. 33K 1% 0.063W	EA	2
...4		33000-040	RES SM. 47K 1% 0.063W	EA	8
...4		33000-041	RES SM. 68K 1% 0.063W	EA	1
...4		33000-042	RES SM. 100K 1% 0.063W	EA	5
...4		33000-044	RES SM. 1M 1% 0.063W	EA	12
...4		34000-005	POT SMD 200K 25% 0.15W 4mmSQ	EA	1
...4		35000-004	INDUCTOR 15uH 2A	EA	2
....5		5173-579	PCB BAR CODE LABEL	EA	1
...4	1	25995-013	LABEL(CUSTOM) 6,35X24mm	EA	1
..3		30000-092	IC OP-AMP LOW-POWER TLE2021CD	EA	1
...4		6132-033	LCB POWER PCB KIT	EA	1
...4		5131-376	HEATSINK (TRANSISTOR)	EA	1
...4		17641-670	HEATSINK COMPOUND RS503-357	ML	0.1
...4		18760-013	ADHESIVE/SEALANT 744RTV 310ml	ML	1.2
...4		21810-602	NUT M3 FULL STEEL STL.ZP.	EA	1
...4		21813-304	WASHER M3 CRINKLE BER.Cu	EA	1
...4		25418-217	FUSE CLIP 6.3mm 15A PCB 102071	EA	4
...4		25515-677	NEON LAMP	EA	1
...4		25960-045	HEADER, 36-WAY	EA	0.11
...4		25965-143	CONNECTOR 2x6 WAY 0.1" PITCH	EA	1
...4		25965-144	CONNECTOR 2x10 WAY 0.1"PITCH	EA	1
...4		25980-057	RELAY SPDT 380 VAC 8A JS5-K**	EA	3
...4		25990-005	NEON SOCKET, PC-T1.1/4	EA	1
...4		26836-624	RES'1M8 MG. 5% .5W VR25	EA	2
...4		26836-741	RES"33M0 MG. 5% 0.5W. VR37	EA	3
...4		26836-919	RES"10M0 MG. 5%, 0.25W. VR25	EA	2
...4		26837-115	RES 2R40 5% 7W KF216-4	EA	1
...4		26837-130	RES"10M0 MG 1% 0.5W VR37	EA	13
...4		26837-133	2R4-5%-12W WIRE WOUND RES.	EA	2
...4		26837-134	RES:390K MG 5% 0.5W VR37	EA	3
...4		26837-175	RES 3R3 WW.1% 3W PHIL.PAC03	EA	1
...4		26837-176	RES 6R8 WW 1% 1W PHIL.PAC01	EA	1
Level	**Bub**	**Component**		**UNIT**	**QTY**
...4		26900-001	RES 10R0 1% 0.25W MF MFR4	EA	1
...4		26900-130	RES 91R0 1% 0.25W MF	EA	1
...4		27889-996	CAP FILM' 1.0uF 50Vdc 10% 5R	EA	1
...4		27900-032	TRANSFORMER (PULSE) PCB MOUNT	EA	1

...4		27920-039	ZENER TVS.600W 440V UniDir	EA	2
...4		28940-043	TRANSISTOR BUZ 80A 800V	EA	1
...4		28940-044	SILICON CONTROL RECTFIER 1000V	EA	1
....5		6132-012	THERMAL CUT-OUT ASSY CM & LCB	EA	1
....5	1	18274-838	SLEEVING H/SHRINK 19mm BLACK	MS	0.022
....5	2	28863-352	THERMAL CUT-OUT, 71DEG.C	EA	1
....5	3	17567-246	TAPE POLY S/ADH YEL 7mm 1607	EA	
...4	4	26837-133	2R4-5%-12W WIRE WOUND RES.	EA	1
...4		28863-082	DIODE,1N4007 1A-1000V	EA	4
....5		6132-011	THERMAL CUT-OUT ASSY CM & LCB	EA	1
....5	1	18274-838	SLEEVING H/SHRINK 19mm BLACK	MS	0.022
....5	2	28863-352	THERMAL CUT-OUT, 71DEG.C	EA	1
....5	3	17570-015	TAPE SOLDER RESIST 6mm WIDE	MS	0.3
....5	4	26837-131	RES;200R 5% 12W WW	EA	1
....5	5	25950-046	THERMAL FUSE 2.5A 250V AC 150C	EA	1
...4	6	18274-719	SLEEVING PTFE 1.0mm bore NAT	MS	0.05
...4		25411-854	FUSE, 7A(F)HBC 600V 50A 32mm	EA	2
....5		6140-335	WACL POWER PCB LCB	EA	1
...4	1	13489-326	WIRE 1/0.6 PTFE WHITE TYP C	MS	0.133
....5		5140-938	HEATSHIELD LCB	EA	1
...4	1	5140-939	NOMEX FELT SHT 406x305x3 S/ADH	EA	0.028
..3		21389-047	STUD M3x10LG.CLINCH ZINC	EA	1
...4		5173-579	PCB BAR CODE LABEL	EA	1
.2	1	25995-013	LABEL(CUSTOM) 6,35X24mm	EA	1
..3	2	6231-651	LCB2500 MAIN & DISP. PCB ASSY	EA	1
...4		6430-796	LCB2500 MAIN & DISP. SM ASSY	EA	1
...4		5440-252	LCB MAIN/DISPLAY PCB	EA	1
...4		30000-007	IC ADC 12BIT 3 STATE BINARY OP	EA	1
...4		30000-023	IC MULTIPLEXER ANOLOG 4051	EA	1
...4		30000-024	IC ANOLOG SWITCH 3x2IN-PT 4053	EA	2
...4		30000-066	IC ANALOG SWITCH 2P4W 4052	EA	2
...4		30000-067	IC DAC. DUAL 8 BIT 7528KC	EA	1
...4		30000-068	IC TIMER CMOS 7555	EA	1
...4		30000-073	IC NOR GATE QUAD 2 INPUT 7402	EA	1
...4		30000-076	IC MULTIPX 2CH. TC4W53F	EA	1
...4		30000-084	IC OP-AMP DUAL TLE2022CD	EA	2
...4		30000-085	IC LCD DRIVER HD61602 E	A	1
...4		30000-087	IC OP-AMP AD622AR	EA	1
...4		30000-088	IC DRIVER/RECR.X 2 LTC1383CS	EA	1
...4		30000-092	IC OP-AMP LOW-POWER TLE2021CD	EA	1
...4		30000-102	IC EEPROM 8Kx8 24C64 SO8	EA	1
...4		30000-103	IC CONVERTER +5to-5V MAX860CUA	EA	2
...4		30000-104	IC OP-AMP X2 TL062CPWLE TSSOP8	EA	4
...4		30000-105	IC MONOSTABLE X2 74HC123 TSSOP	EA	3
...4		31000-001	TRANSISTOR -NPN- DRG 6180-396	EA	9
...4		31000-002	DIODE,SM. LL4148 (S/M)	EA	27
...4		31000-004	TRANSISTOR -PNP- DRG 6180-395	EA	3
...4		31000-016	TRANSISTOR N-TYPE ENCH. FET	EA	1
...4		31000-021	DIODE 1A SCHOTTKY MBRS130LT3	EA	1
...4		31000-022	IC MOSFET X 2 0.10HM IRF7306	EA	3
...4		31000-023	IC REGULATOR MW LT1121CS8-5	EA	1
...4		31000-025	IC REGULATOR/SWITCH LT1373CS8	EA	1
...4		31000-028	IC COMPARATOR X4 LM339 TSSOP14	EA	3
Level	**Bub**	**Component**		**UNIT**	**QTY**
...4		31000-029	IC BANDGAP 2.5V1% ZRC250 SOT23	EA	1
...4		32000-004	CAP SMD CER- 100nF 10% 1206	EA	13
...4		32000-022	CAP SMD TANT'- 10uF 20% 7343	EA	5
...4		32000-023	CAP SMD ELEC 10uF 16V 0405	EA	6

...4		32000-025	CAP SMD CER- 10nF 10% 0603	EA	6
...4		32000-026	CAP SMD CER. 3.3nF 10% 0603	EA	4
...4		32000-027	CAP SMD CER. 1nF 10% 0603	EA	2
...4		32000-029	CAP SMD CER- 100nF -20+80%0603	EA	44
...4		32000-030	CAP SMD CER 100pF 5% 0603	EA	3
...4		32000-031	CAP SMD CER 33pF 5% 0603	EA	2
...4		32000-032	CAP SMD CER 10pF 5% 0603	EA	2
...4		32000-033	CAP SMD FILM- 100nF 20% 2220	EA	2
...4		32000-034	CAP SMD FILM- 330nF 20% 2824	EA	3
...4		32000-035	CAP SMD FILM, 1.0uF 20% 2824	EA	2
...4		33000-002	RES SM. 300R 2% 1/8W (S/M)	EA	2
...4		33000-004	RES SM. 30K 2% 1/8W (S/M)	EA	2
...4		33000-007	RES SM. 75K 2% 1/8W (S/M)	EA	1
...4		33000-008	RES SM. 300K 2% 1/8W (S/M)	EA	3
...4		33000-009	RES SM. 1M 2% 1/8W (S/M)	EA	2
...4		33000-013	RES SM. 100R 2% 1/8W (S/M)	EA	6
...4		33000-018	RES SM. 120K 2% 0.125W (S/M)	EA	1
...4		33000-020	RES SM. 7K5 2% 0.125W (S/M)	EA	1
...4		33000-021	RES SM. 10R 5% 0.125W (S/M)	EA	5
...4		33000-027	RES SM. 10R 1% 0.063W	EA	2
...4		33000-029	RES SM. 100R 1% 0.063W	EA	5
...4		33000-030	RES SM. 330R 1% 0.063W	EA	6
...4		33000-031	RES SM. 1K 1% 0.063W	EA	18
...4		33000-033	RES SM. 2K2 1% 0.063W	EA	2
...4		33000-034	RES SM. 3K3 1% 0.063W	EA	12
...4		33000-035	RES SM. 4K7 1% 0.063W	EA	3
...4		33000-036	RES SM. 6K8 1% 0.063W	EA	1
...4		33000-042	RES SM. 100K 1% 0.063W	EA	44
...4		33000-043	RES SM. 330K 1% 0.063W	EA	13
...4		33000-044	RES SM. 1M 1% 0.063W	EA	8
...4		34000-002	POT SMD 5K 25% 0.15W 4mmSQ	EA	1
...4		34000-006	POT SMD 100R 25% 0.15W 4mmSQ	EA	1
...4		34000-011	POT SMD 500R 25% 0.15W 4mmSQ	EA	3
...4		35000-004	INDUCTOR 15uH 2A	EA	1
...4		35000-005	FUSE, 1.25A RESETTABLE SMD	EA	1
...4		35000-006	CRYSTAL SMD 8MHZ 32SMX	EA	1
...4		5131-373	CONNECTOR 10 WAY (UNFORMED)	EA	1
...4		5131-374	CONNECTOR 25 WAY (UNFORMED)	EA	2
....5		5173-579	PCB BAR CODE LABEL	EA	1
...4	1	25995-013	LABEL(CUSTOM) 6,35X24mm D145	EA	1
...4		32000-013	CAP SMD TANT' 2.2uF 20% 1206	EA	1
...4		32000-037	CAP SMD ELEC 100uF 20% 0807	EA	1
....5		6139-143	LCB2000/2500 uP PROGRAMMED	EA	1
....5	1	30000-086	IC MICROPROCESSER HD64F3048F16	EA	1
....6	2	5172-536	LABEL FOR E-PROMS	EA	1
....5	1	17570-035	LABEL YELLOW S/ADH 31.8 x 9.5	EA	1
...4	3	17565-559	LABEL STATIC WARNING (SYMBOL)	EA	1
...4		6139-147	LCB PROGRAMMED DEVICE	EA	1
...4		31300-002	DIODE SMD, 1A 50V GF1A	EA	2
...4		31400-002	ZENER 0.3W 5% 5.6V SOT23 BZX84	EA	1
...4		33000-037	RES SM. 10K 1% 0.063W	EA	57
...4		33000-038	RES SM. 22K 1% 0.063W	EA	3
...4		33000-041	RES SM. 68K 1% 0.063W	EA	1
Level	**Bub**	**Component**		**UNIT**	**QTY**
...4		34000-010	POT SMD 50K 25% 0.15W 4mmSQ	EA	2
...4		33000-040	RES SM. 47K 1% 0.063W	EA	2
..3		33000-039	RES SM. 33K 1% 0.063W	EA	12
...4		6132-028	LCB2500 MAIN PCB KIT	EA	1

...4		25960-045	HEADER, 36-WAY	EA	0.39
...4		6280-327	LCD LCB2000/2500	EA	1
...4		21810-601	NUT M3 FULL STEEL N.P	EA	1
...4		21813-304	WASHER M3 CRINKLE BER.Cu	EA	1
...4		25960-096	PLUG "D" 9 WAY RIGHT ANGLED	EA	1
...4		28900-099	VOLT. REGULATOR 5 VOLT	EA	1
...4		6180-418	BACKLIGHT BMM/LCB	EA	1
...4		10005-240	KAPTON DISC 30mm DIA	EA	1
...4		25975-107	SWITCH PUSH TACTILE SPNO PCB	EA	1
...4		5131-381	HEATSINK (TRANSISTOR) 2mm THK	EA	1
...4		27920-047	TRANSDUCER EM SEALED	EA	1
...4		21389-047	STUD M3x10LG.CLINCH ZINC	EA	1
...4		25960-066	72 PIN DIL HEADER	EA	0.5
..3		28920-087	LED HIGH BRIGHTNESS 38 DEG	EA	2
...4		5173-579	PCB BAR CODE LABEL	EA	1
.2	1	25995-013	LABEL(CUSTOM) 6,35X24mm	EA	1
.2	3	5410-298	FRONT COVER	EA	1
.2	4	5410-300	REAR COVER LCB (DEEP)	EA	1
.2	5	5410-301	BATTERY COVER	EA	1
.2	6	5310-410	RANGE KNOB	EA	1
.2	7	5210-428	KEYPAD LCB2500	EA	1
.2	8	5110-503	WINDOW (4 BUTTON)	EA	1
.2	9	18760-010	CORD SILICON SPONGE 2mm DIA.	MS	1.03
.2	10	5151-533	CAPTIVE SCREW	EA	2
.2	11	9000-015	PLASTIC BAG 3" X 3.25 SEALEASI	EA	1
.2	12	21264-229	SCREW PLASTITE No4 .25" PAN Hd	EA	1
.2	13	22420-053	SCREWLOCK ASSY(EA=2)	EA	1
..3	14	6280-321	FIXED SOCKET ASSY (5 PIN)	EA	1
..3	1	5210-418	PLUG (AVO 5 PIN)	EA	
.2	2	5152-273	PLUG CONTACT	EA	
.2	15	5152-266	EARTH CONTACT	EA	1
.2	16	21813-304	WASHER M3 CRINKLE BER.Cu	EA	2
.2	17	21810-602	NUT M3 FULL STEEL STL.ZP.	EA	2
.2	18	22420-056	SPACER 4LG SNAP FIT NYLON	EA	6
.2	19	22410-006	BATTERY HOLDER 6xAA C/W	EA	1
.2	20	25511-841	BATTERY, 1.5V, DURACELL MN1500	EA	6
..3	21	5140-926	INSULATOR (PCB)	EA	1
.2	1	18900-043	POLYESTER SHT 406x305x0.175mm	EA	0.333
.2	22	5140-927	GASKET - RS232 FLANGE	EA	1
.2	23	22420-084	SPACER 10LG SNAP FIT NYLON	EA	5
.2	24	5210-361	SWITCH BOTTOM **	EA	1
.2	25	5310-357	INDEX SPIDER/SWITCH TOP**	EA	1
.2	26	5160-324	SPRING (ROTARY SWITCH)	EA	2
.2	27	24126-123	O RING 8mm I/D 1.5mm SECTION	EA	1
.2	28	5131-378	CONTACT DISC	EA	2
.2	29	17685-002	CONTACT GREASE 35ML SYRINGE	ML	0.06
.2	30	17641-672	GREASE SILICONE BASED MS44	GM	
.2	31	21128-008	PIN SPRING DOWEL 2x8mm	EA	2
.2	32	25274-417	CABLE TIE 100x2.5mm T18R	EA	8
.2	36	6220-619	TEST LEAD 3 WIRE	EA	1
..3	37	5173-730	TEST LEAD LABEL - 3 WIRE	EA	1
..3	1	18900-044	POLY SHT 406 X 305X.125mm MATT	EA	0.13
..3	2	17525-018	TAPE DS/ADH 305mm 3M-467	MS	0.025
Level	**Bub**	**Component**		**UNIT**	**QTY**
..3	3	17490-009	INK LABEL LIGHT GREY CM56614	GM	0.28
..3	4	17490-011	INK LABEL RED CM56616	GM	0.13
..3	5	17490-014	INK LABEL DARK GREY CM56613	GM	0.28
.2	6	17490-008	INK THINNER PLASTIPAK ZE5985LT	LT	0.000

.2	38	6220-529	PROBE TEST RED	EA	1
.2	39	6220-530	PROBE TEST BLACK	EA	1
.2	40	6280-283	CROCODILE CLIP (RED)	EA	1
.2	41	6280-284	CROCODILE CLIP (BLACK)	EA	1
.2	42	6280-285	CROCODILE CLIP (GREEN)	EA	1
..3	43	6140-334	WACL LCB	EA	1
..3	1	18274-733	SLEEVING PTFE 2mm NAT.	MS	0.23
..3	2	13489-021	WIRE 7/0.2 PVC ORANGE TYP 2	MS	0.25
..3	3	25257-698	CRIMP RING-TAG M3 17SWG RED	EA	1
.2	4	18274-755	SLEEVING PTFE 3mm CLEAR	MS	0.15
.2	45	21264-227	SCREW PLASTITE No4 .5" PAN Hd	EA	5
.2	46	5140-929	GASKET - RS232 INTERNAL	EA	1
.2	47	5140-930	FOAM STRIP 25x8x3	EA	2
1	48	6180-410	BATTERY CONNECTOR (PP3)	EA	1
1	102	6170-618	WARRANTY BOOK AVO MEGGER	EA	1
.2	103	5270-691	LABEL SET LCB2500	EA	1
.2	1	18900-043	POLYESTER SHT 406x305x0.175mm	EA	0.5
.2	2	17525-018	TAPE DS/ADH 305mm 3M-467	MS	0.2
.2	3	17490-008	INK THINNER PLASTIPAK ZE5985LT	LT	0.002
.2	4	17490-009	INK LABEL LIGHT GREY CM56614	GM	1.125
.2	5	17490-010	INK LABEL YELLOW CM56615	GM	0.5
.2	6	17490-011	INK LABEL RED CM56616	GM	0.5
.2	7	17490-014	INK LABEL DARK GREY CM56613	GM	1.125
.2	8	17490-007	INK LABEL BLUE CM86332	GM	0.5
1	9	5240-366	LABEL SET CUTTING LCB	EA	
.2	104	5172-161	SERIAL NO.LABEL	EA	1
.2	1	5173-068	LABEL BLANK - SERIAL NO. LABEL	EA	1
1	2	18900-037	PRINT THERM TRANSFER BLK 83mm	MS	0.1
.2	105	6220-622	TEST LEAD UK MAINS CM500	EA	1
.2	1	5152-297	SOCKET CONTACT	EA	
.2	2	5210-419	SOCKET (AVO 5 PIN)	EA	
1	3	5210-420	SHROUD (for 5210-419)	EA	
.2	106	5173-727	LABEL TEST LEAD - UK MAINS	EA	1
.2	1	18900-044	POLY SHT 406 X 305X.125mm MATT	EA	0.125
.2	2	17525-018	TAPE DS/ADH 305mm 3M-467	MS	0.025
.2	3	17490-009	INK LABEL LIGHT GREY CM56614	GM	0.281
.2	4	17490-011	INK LABEL RED CM56616	GM	0.125
.2	5	17490-014	INK LABEL DARK GREY CM56613	GM	0.281
1	6	17490-008	INK THINNER PLASTIPAK ZE5985LT	LT	0.000
1	107	6172-306	CERT OF TEST EN61557 (BLUE)	EA	1
1	108	6172-428	USER GUIDE LCB ENGLISH	EA	1
1	109	6420-122	TEST & CARRY CASE LCB	EA	1
1	110	6260-124	PACKING KIT LCB	EA	1
1	111	5270-722	CARTON LABEL SET LCB2500	EA	1
	114	6111-442	DOWNLOAD MANAGER S/WARE CDROM	EA	1

Appendix 10 - Download Specification (LCB2500 only)

Download to a computer

Data will be downloaded in the order in which the tests were carried out. Download is requested by sending ASCII 'S' <CR> to the instrument, which (if it is in the RCL position) will go into remote mode and then transmit the serial number. An 'N' <CR> sequence will obtain the next line of code as detailed below. Sending 'X' <CR> or the user pressing any of the instrument keys will abort the download.

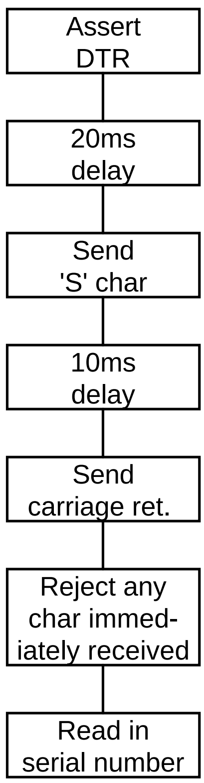
Hardware

The LCB2500 uses an internal optically-isolated serial link. The pc side of the link generates its own supply by utilising the DTR pc output line. Therefore, this must be permanently asserted (i.e. positive voltage) during communication. To allow the supply to be generated, a delay of approximately 20ms should occur between DTR being asserted and the first character being sent by the pc.

As no handshaking is used over the serial link it is recommended that there is a delay of, say, 10ms between each character sent. This also allows the internal supply to recover between characters.

A characteristic of the internal optical link used is that each time a character is transmitted to the LCB2500 a spurious character may be reflected back on the receive line. This can be accommodated by ignoring the receive line whilst transmitting a message and rejecting any character received immediately after the message is complete. The LCB2500 makes an allowance for this by delaying each line of information sent by approximately 5ms.

To clarify, to put the LCB2500 into download mode the following steps would be undertaken by the pc : -



Note that there can be up to a 200ms delay between the instrument receiving the carriage return and the transmission of the serial number.

Output Format

The format will be 9600 baud, 2 stop bits, 1 start bit, no parity.
The coded information is in the format developed for the BM80/400, i.e.

```
"<identifier>","<text before number>",<value>,"<units>"<CR><LF>
```

The first field is a unique identifier giving the test type.
The second field gives any text before the result, i.e. >, <, +, -. This field may also be used to give information on the test type.
The third field gives the result as a numeric value.
The fourth field gives the units.

Serial Number

Information

<serial number>

The first line downloaded will always be the serial number and is sent when the instrument goes into remote mode (i.e. after receiving S<CR>).

Format

```
"LCB2500 yyy...yyy"<CR><LF>
```

where
`yyy...yyy` is an identifier unique to the instrument.

The total number of characters within the quotes can be up to 20.

NB the instrument name may be five to nine characters depending the variant. It is always separated from the serial number by a space.

Distribution Board Number

Information

<distribution board number>

Format

```
"DB","",nn,""<CR><LF>
```

where
nn is in the range 1 - 99

The distribution board number is downloaded in sequence and all results subsequently downloaded relate to that distribution board. Subsequent distribution board numbers will be downloaded each time a new number is chosen.
Note that a distribution board number does not have to be selected by the user, so it is possible to have results that do not relate to any distribution board.

Circuit Number

Information

<circuit number>

The first line of each test result downloaded is always the circuit number.

Format

```
"C","",circuit number,""<CR><LF>
```

where
`circuit number` is in the range 1 to 99

Circuit 14 is used in the examples below.

In the examples below, the `<CR><LF>` characters at the end of each line have been omitted for clarity.

Loop resistance and short circuit current

Loop L-L, L-N, L-PE and Loop L-PE 0.1Ω

Information

<connection & resistance>
<fault current> (optional, not available for Loop L-PE 0.1Ω)

Format

```
"Lxx","",value,"unit"
"Sxx","",value,"kA"
```

where
`xx` = LN, LL or LE
`unit` = R or k

Example

"C","",14,""	Circuit 14
"LLN","",0.16,"R"	Loop LN 0.16 R
"SLN","",0.240,"kA"	Fault Current LN 0.240 kA

Loop L-PE 0.01Ω

Information

<resistance LE>
<fault current LE>
<resistance LN>
<fault current LN>
<resistance R1>
<resistance R2>
<resistance Rn>

Format

```
"C","",2,""
"LLE","",value,"unit"
"SLE","",value,"kA"
"LLN","",value,"unit"
"SLN","",value,"kA"
"LR1","",value,"unit"
"LR2","",value,"unit"
"LRN","",value,"unit"
```

where
`unit` = R or k

`"C","",2,""`	Circuit 2
`"LLE","",1.05,"R"`	Loop resistance L-PE 1.05R
`"SLE","",0.218,"kA"`	Prospective fault current L-PE 218A
`"LLN","",0.14,"R"`	Loop resistance L-N 0.14R
`"SLN","",1.618,"kA"`	Prospective fault current L-N 1618A
`"LR1","",0.09,"R"`	Loop resistance R1 0.09R
`"LR2","",0.96,"R"`	Loop resistance R2 0.96R
`"LRN","",0.05,"R"`	Loop resistance RN 0.05R

RCD tests
The results available for RCD tests depend upon the test type selected.

The general format is :
Line 1, as in all the tests, details the circuit number.
Line 2 details the test type and rated trip current (range 10mA to 1000mA).
Line 3 details the type of RCD tested, i.e.
  the first field will be either "Gen" for general type or "Sel" for selective type
  the second field will be either "Nrm" for normal type or "DCs" for dc sensitive type
Subsequent lines detail the results specific to that test.

Notes :-
1. With the exception of the 150mA 40ms test, the contact voltage and loop resistance are measured unless the probe is used in which case the fault voltage and earth resistance are measured.
2. The rated trip current for the No Trip Test, Trip Test and 5I Overcurrent Trip Test can be continuously variable in the range 10mA to 1000mA (resolution 1mA).

No trip test
Information
  <test type and rated trip current>
  <test duration>
  <RCD type selected>
  <voltage>
  <resistance>

Format
```
"NT","",rated trip current,"mA"
"Dur","",duration,"ms"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
```

where
duration = 2000 for two second test, otherwise ----
type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance

Example
```
"C","",14,""          Circuit 14
"NT","",30,"mA"       No Trip RCD 30mA,
"Dur","",2000,"ms"    2s test
"Gen","Nrm",0,""      general, normal
"CV","",0.4,"V"       contact 0.4V,
"LR","",0.01,"R"      loop 0.01 R
```

Trip test

Information

<Test type and rated trip current>
<RCD type selected>
<voltage>
<resistance>
<trip time>

Format

```
"TT","",rated trip current,"mA"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
"Tsn","",value,"ms"
```

where
type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance
n = 1 for positive cycle, 2 for negative cycle

Example

```
"C","",14,""          Circuit 14
"TT","",30,"mA"       Trip RCD 30mA,
"Sel","Nrm",0,""      selective, normal,
"FV","",0.4,"V"       fault 0.4V,
"ER","",0.01,"R"      resistance 0.01 R,
"TS2","",7.6,"ms"     negative cycle trip 7.6 ms
```

Example of Variable Rated Current

```
"C","",14,""          Circuit 14
"TT","",27.2,"mA"     Trip RCD 27mA,
"Sel","Nrm",0,""      selective, normal,
"FV","",0.3,"V"       fault 0.3V,
"ER","",0.07,"R"      resistance 0.07 R,
"TS2","",16.3,"ms"    negative cycle trip 16.3 ms
```

Ramp test

Information

<test type and rated trip current>
<RCD type selected>
<voltage>
<resistance>
<trip current>
<trip resistance>

Format

```
"RT","",rated trip current,"mA"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
"TC","",value,"mA"
"TR","",value,"unit"
```

where
type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance
unit = R or k

Example

```
"C","",14,""            Circuit 14
"RT","",100,"mA"        Ramp test RCD 100mA,
"Gen","DCs",0,""        general, d.c. sensitive,
"CV","",0.4,"V"         contact 0.4V,
"LR","",0.01,"R"        loop 0.01 R,
"TC","",98.9,"mA"       trip 98.9 mA
"TR","",233,"R"         trip resistance 233R
```

150mA 40ms Overcurrent Trip Test

Information

<test type and test current>
<RCD type selected>
<trip time>

Format

```
"OT150","",30,"mA"
"type a","type b",0,""
"Tsn","",value,"ms"
```

where
type a = always Gen
type b = currently fixed as Nrm
n = 3 for positive cycle, 4 for negative cycle

Note that the rated current is fixed at 30mA.

Example

```
"C","",14,""            Circuit 14
"OT150","",30,"mA"      Overcurrent test, 150mA, 30mA RCD (fixed)
"Gen","Nrm",0,""        general, normal,
"TS3","",8.4,"ms"       positive cycle trip 8.4 ms
```

5I Overcurrent Trip Test

Information

<Test type and rated trip current>
<RCD type selected>
<voltage>
<resistance>
<trip time>

Format

```
"OT5I","",rated trip current,"mA"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
"Tsn","",value,"ms"
```

where

type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance
n = 3 for positive cycle, 4 for negative cycle

Example

```
"C","",14,""          Circuit 14
"OT5I","",30,"mA"     5I test RCD 30mA,
"Sel","Nrm",0,""      selective, normal,
"FV","",0.6,"V"       fault voltage 0.6V,
"ER","",0.76,"R"      resistance 0.76 R,
"TS4","",9.2,"ms"     negative trip 9.2 ms
```

Auto Trip Test 150mA 40ms

Information

<Test type and rated trip current>
<no trip test duration>
<RCD type selected>
<voltage>
<resistance>
<+ve cycle trip time>
<–ve cycle trip time>
<150mA +ve cycle trip time>
<150mA –ve cycle trip time>

Format

```
"AT150","",30,"mA"
"Dur","",duration,"ms"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
"TS1","",value,"ms"
"TS2","",value,"ms"
"TS3","",value,"ms"
"TS4","",value,"ms"
```

where
duration = 2000 for two second no trip test, otherwise ----
type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance

Note :- it is possible for a faulty rcd to fail to trip during the test sequence. The relevant trip time result line will be in the format

```
"TSn","---",0,"ms"
```

Example

```
"C","",14,""          Circuit 14
```

```
"AT150","",30,"mA"    Auto trip 150mA, 30mA RCD(fixed),
"Dur","",----,"ms"    Standard test
"Sel","DCs",0,""      selective, d.c. sensitive
"FV","",2.4,"V"       fault 1.1 V,
"ER","",0.01,"R"      resistance 0.04 R
"TS1","",17.6,"ms"    +ve trip 17.6 ms,
"TS2","",7.7,"ms"     –ve trip 7.7 ms
"TS3","",4.5,"ms"     +ve trip 150 mA 4.5 ms,
"TS4","---",0,"ms"    -ve trip 150 mA failed
```

Auto Trip Test 5I (rated trip current x 5)

Information

<Test type and rated trip current>
<no trip test duration>
<RCD type selected>
<voltage>
<resistance>
<+ve cycle trip time>
<–ve cycle trip time>
<5I +ve cycle trip time>
<5I –ve cycle trip time>

Format

```
"AT5I","",rated trip current,"mA"
"Dur","",duration,"ms"
"type a","type b",0,""
"xV","",value,"V"
"yR","",value,"R"
"TS1","",value,"ms"
"TS2","",value,"ms"
"TS3","",value,"ms"
"TS4","",value,"ms"
```

where
duration = 2000 for two second no trip test, otherwise ----
type a = Gen or Sel
type b = Nrm or Dcs
x = C for contact voltage, F for fault voltage
y = L for loop resistance, E for earth resistance

Note :- it is possible for a faulty rcd to fail to trip during the test sequence. The relevant trip time result line will be in the format

```
"TSn","---",0,"ms"
```

Example

```
"C","",14,""          Circuit 14
"AT5I","",100,"mA"    Auto trip RCD 100mA,
"Dur","",2000,"ms"    2s test
"Sel","DCs",0,""      selective, d.c. sensitive
"FV","",1.1,"V"       fault 1.1 V,
"ER","",0.04,"R"      resistance 0.04 R
"TS1","",17.6,"ms"    +ve trip 17.6 ms,
"TS2","",7.7,"ms"     –ve trip 7.7 ms
"TS3","",4.5,"ms"     +ve trip 5I 4.5 ms,
"TS4","",5.7,"ms"     -ve trip 5I 5.7 ms
```

End Message

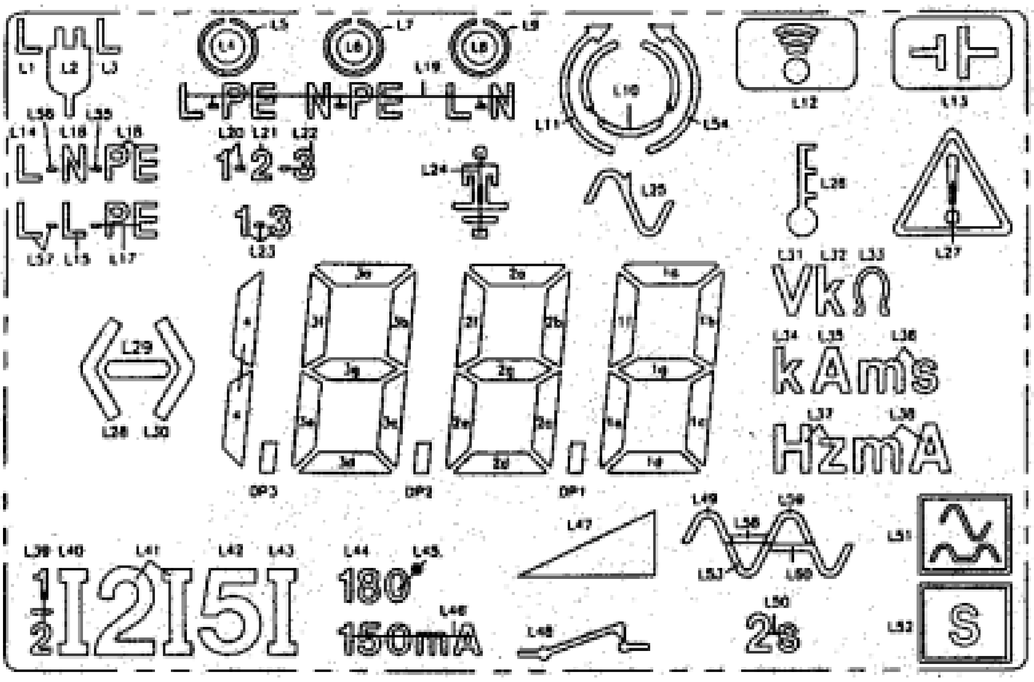
Information

<end message>

Format

```
"C","-",1,""
```

Appendix 11 - LCD Display segments



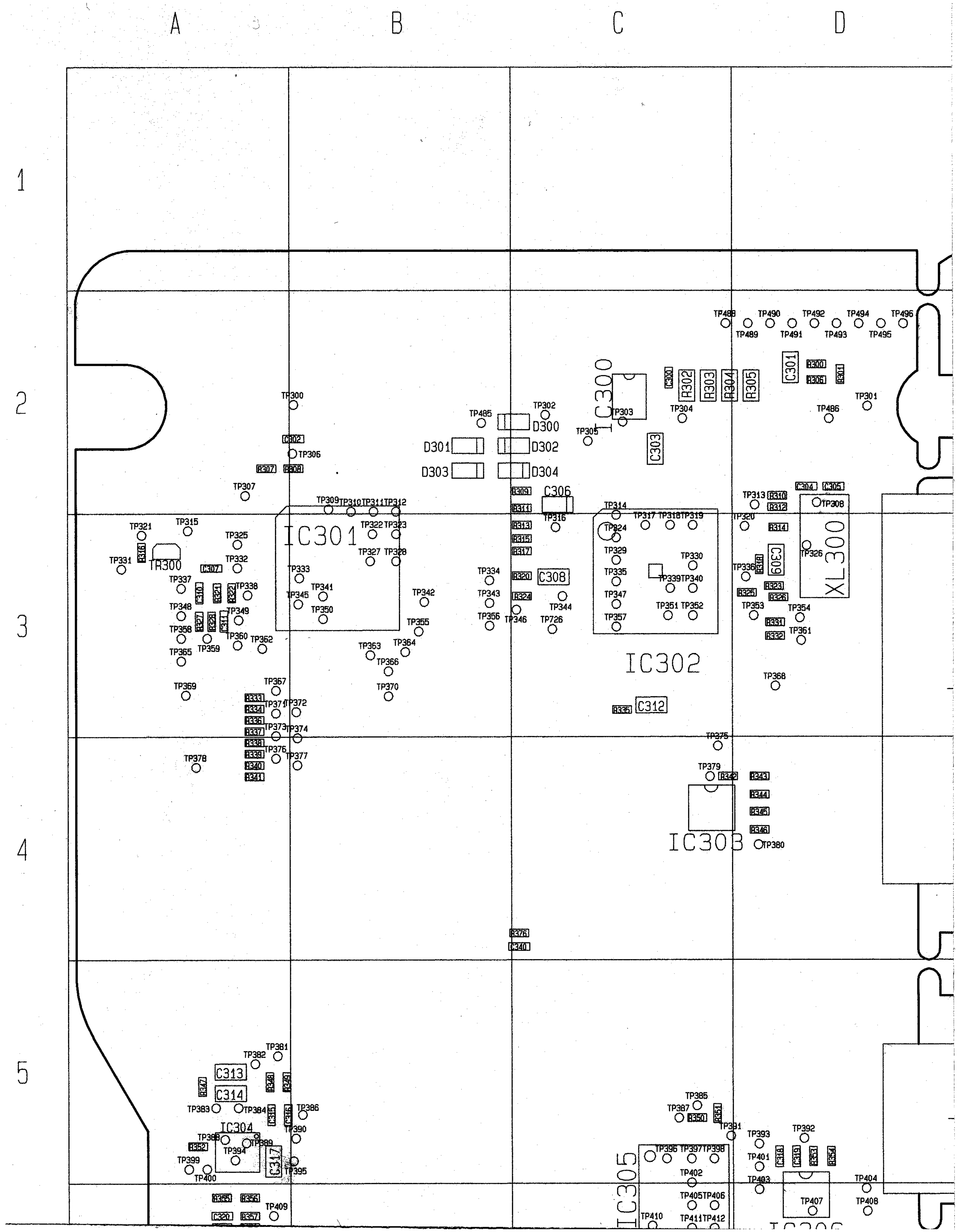
PIN	1	2	3	4	5	6	7	8	9	10
COM1	L39	NC	3f	3a	L24	L46	2f	2a	L25	L48
COM2	L40	L43	3e	3g	3b	L44	2e	2g	2b	L49
COM3	L41	L42	DP3	3d	3c	L45	DP2	2d	2c	L47

PIN	11	12	13	14	15	16	17	18	19	20
COM1	1f	1a	L31	L53	L60	L52	NC	NC	C1	L35
COM2	1e	1g	1b	L58	L59	L51	NC	C2	NC	L34
COM3	DP1	1d	1c	L37	L50	L38	C3	NC	NC	L36

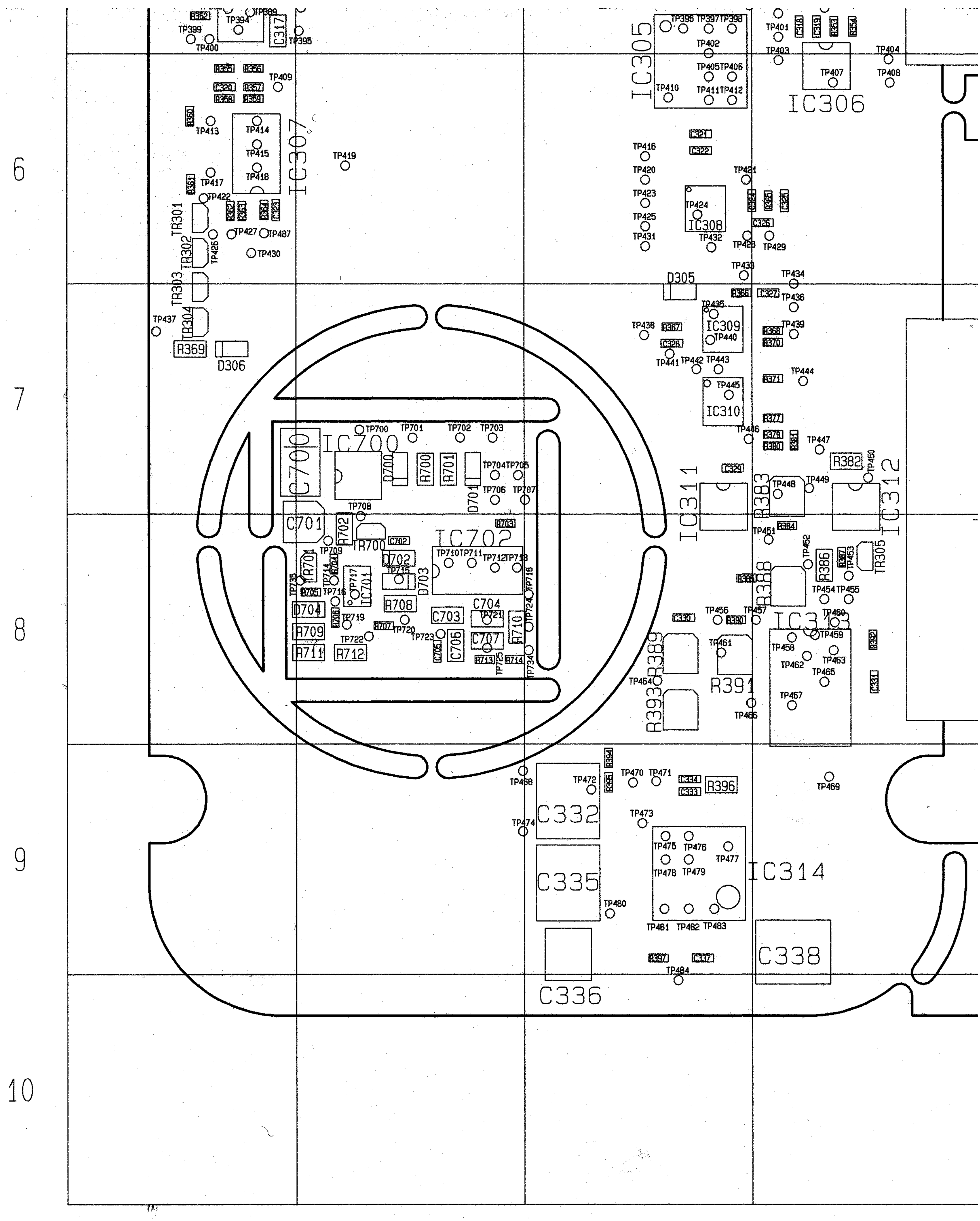
PIN	21	22	23	24	25	26	27	28	29	30
COM1	L13	L12	L11	L8	L6	L4	L19 L5 / L7 L9	4	L29	L3
COM2	L27	L26	L10	L22	NC	NC	L20	L18	L55	L16
COM3	L33	L32	L54	L21	NC	NC	L23	L30	L17	L15

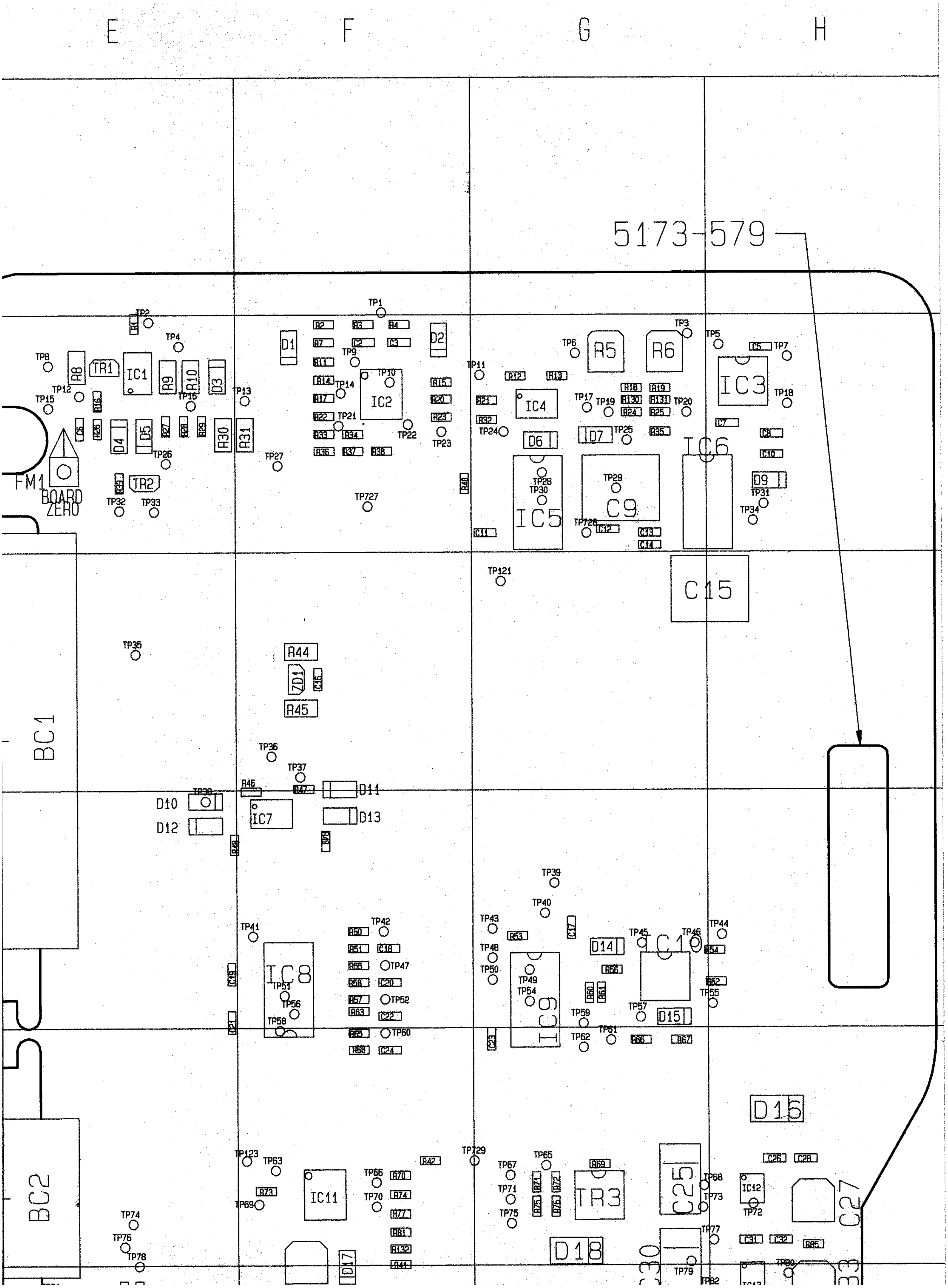
PIN	31	32
COM1	L2	L1
COM2	L56	L14
COM3	L57	L28

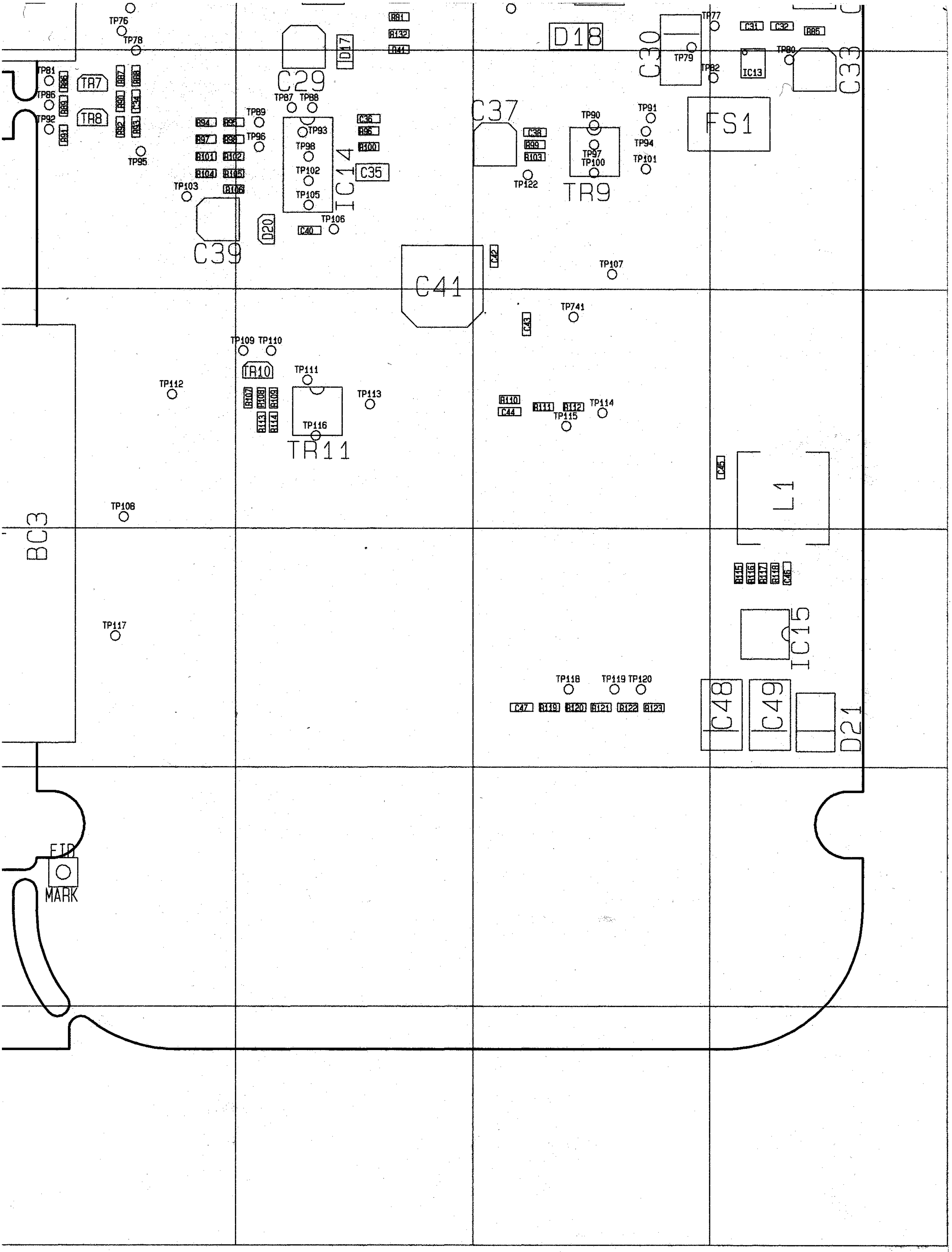
Appendix 12 - SMD PCB Layout



A
B
C
D
1
2
3
4
5
IC300
IC301
IC302
IC303
IC304
IC305
XL300
TR300
D300
D301
D302
D303
D304
C301
C303
C306
C308
C309
C312
C313
C314
C317



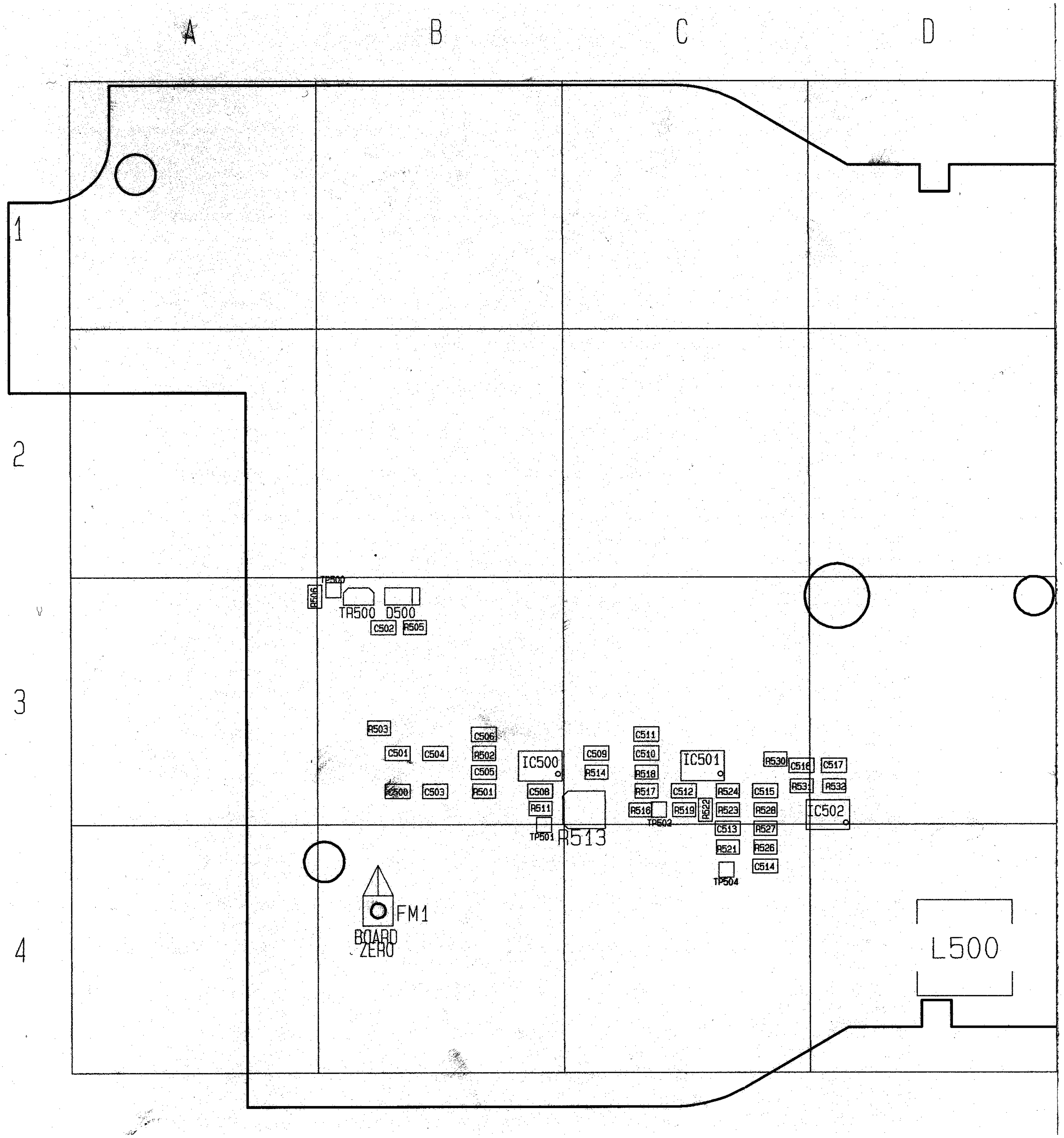

E
F
G
H
5173-579
FM1
BOARD
ZERO
BC1
BC2
IC1
IC2
IC3
IC4
IC5
IC6
IC7
IC8
IC9
IC10
IC11
IC12
TR1
TR2
TR3
R5
R6
R44
R45
D1
D2
D3
D4
D5
D6
D7
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
C9
C15
C25
C27
ZD1

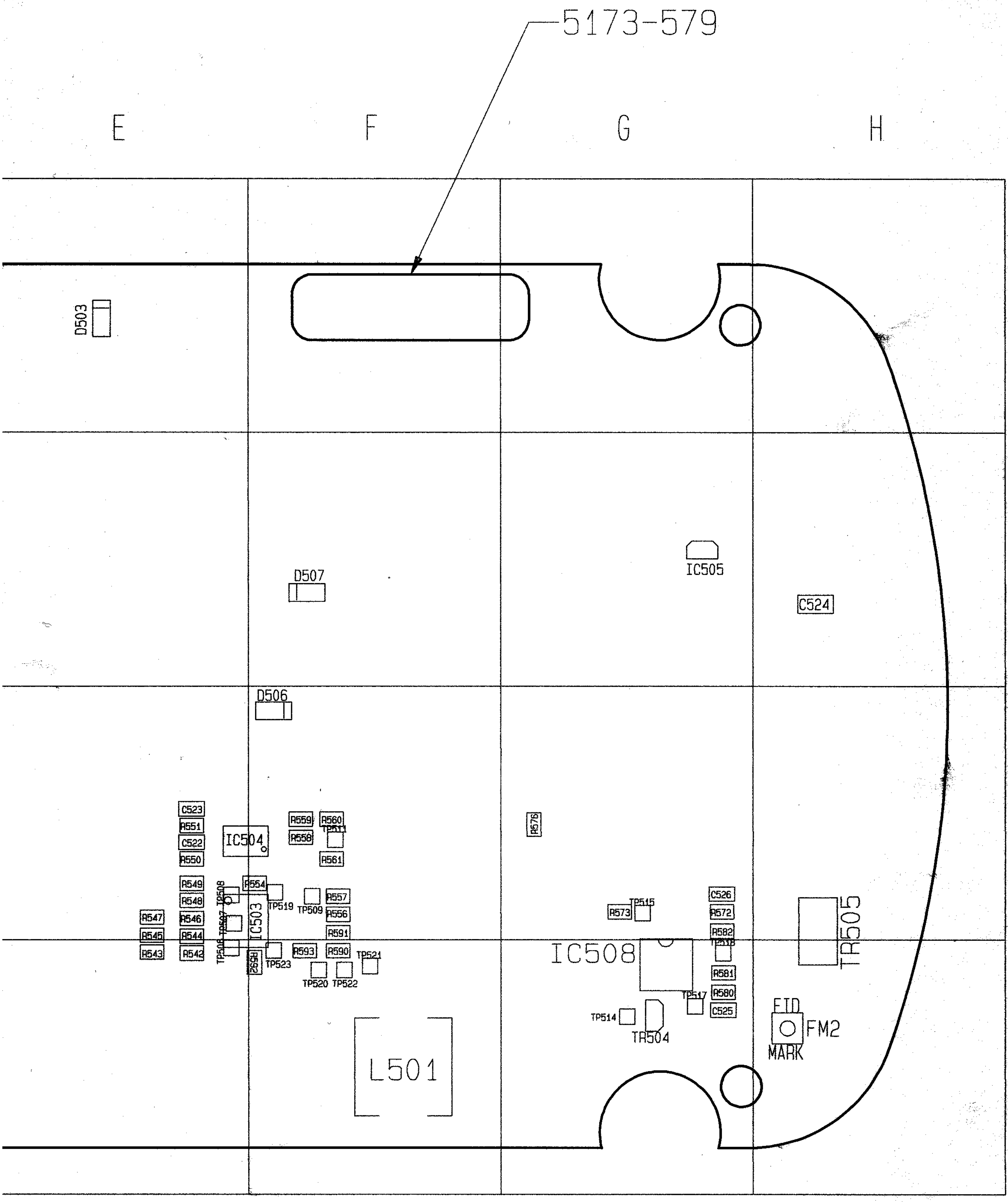

TR7
TR8
C29
D17
D18
C30
C33
FS1
IC13
C37
TR9
IC14
C35
C39
D20
C41
TR10
TR11
BC3
L1
IC15
C48
C49
D21
FID
MARK

REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID
C2	32000-029	F2	C28	32000-029	H5	C303	32000-004	C2	C328	32000-025	C7	D6	31000-002	G2	IC1	30000-104	E2
C3	32000-029	F2	C29	32000-023	F6	C304	32000-031	D2	C329	32000-029	C7	D7	31000-002	G2	IC2	31000-028	F2
C5	32000-029	H2	C30	32000-022	G6	C305	32000-031	D2	C330	32000-029	C8	D9	31000-002	H2	IC3	30000-087	H2
C6	32000-032	E2	C31	32000-029	H5	C306	32000-013	C2	C331	32000-029	D8	D10	31000-002	E4	IC4	30000-104	G2
C7	32000-029	H2	C32	32000-029	H5	C307	32000-029	A3	C332	32000-034	C9	D11	31000-002	F4	IC5	30000-024	G2
C8	32000-029	H2	C33	32000-023	H6	C308	32000-004	C3	C333	32000-030	C9	D12	31000-002	E4	IC6	30000-024	G2
C9	32000-035	G2	C34	32000-029	E6	C309	32000-004	D3	C334	32000-030	C9	D13	31000-002	F4	IC7	30000-104	F4
C10	32000-029	H2	C35	32000-004	F6	C310	32000-029	A3	C335	32000-034	C9	D14	31000-002	G4	IC8	30000-023	F4
C11	32000-029	G2	C36	32000-029	F6	C311	32000-029	A3	C336	32000-033	C10	D15	31000-002	G4	IC9	30000-066	G5
C12	32000-029	G2	C37	32000-023	F6	C312	32000-004	C3	C337	32000-029	C9	D17	31000-002	F6	IC10	30000-084	G4
C13	32000-029	G2	C38	32000-029	G6	C313	32000-004	A5	C338	32000-034	D9	D20	31000-029	F6	IC11	31000-028	F5
C14	32000-029	G2	C39	32000-023	E6	C314	32000-004	A5	C340	32000-027	B4	D21	31000-021	H8	IC12	30000-103	H5
C15	32000-035	G3	C40	32000-029	F6	C315	32000-025	A5	C700	32000-022	B7	D300	31000-002	C2	IC13	30000-103	H6
C16	32000-029	F3	C41	32000-037	F7	C316	32000-030	B5	C701	32000-023	A8	D301	31000-002	B2	IC14	30000-066	F6
C17	32000-029	G4	C42	32000-029	G6	C317	32000-004	A5	C702	32000-032	B8	D302	31000-002	C2	IC15	31000-025	H8
C18	32000-026	F4	C43	32000-029	G7	C318	32000-029	D5	C703	32000-004	B8	D303	31000-002	B2	IC300	30000-076	C2
C19	32000-029	F4	C44	32000-029	G7	C319	32000-025	D5	C704	32000-004	B8	D304	31000-002	C2	IC301	30000-085	A3
C20	32000-026	F4	C45	32000-029	H7	C320	32000-025	A6	C705	32000-027	B8	D305	31000-002	C6	IC303	30000-102	C4
C21	32000-029	E5	C46	32000-025	H8	C321	32000-029	C6	C706	32000-004	B8	D306	31000-002	A7	IC304	30000-105	A5
C22	32000-026	F4	C47	32000-029	G8	C322	32000-029	C6	C707	32000-004	B8	D700	31000-002	B7	IC306	30000-068	D6
C23	32000-029	G5	C48	32000-022	H8	C323	32000-029	A6	D1	31000-002	F2	D701	31000-002	B7	IC307	30000-073	B6
C24	32000-026	F5	C49	32000-022	H8	C324	32000-029	D6	D2	31000-002	F2	D702	31000-002	B8	IC308	30000-105	C6
C25	32000-022	G5	C300	32000-029	C2	C325	32000-029	D6	D3	31000-002	E2	D703	31000-002	B8	IC309	30000-105	C7
C26	32000-029	H5	C301	32000-004	D2	C326	32000-029	D6	D4	31000-002	E2	D704	31000-002	A8	IC310	31000-028	C7
C27	32000-023	H5	C302	32000-029	A2	C327	32000-025	D7	D5	31000-002	E2	FS1	35000-005	G6	IC311	30000-084	C8

REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID
IC312	30000-092	D8	R19	33000-043	G2	R45	33000-002	F3	R73	33000-037	F5	R104	33000-034	E6	R303	33000-021	C2
IC313	30000-067	D8	R20	33000-043	F2	R46	33000-042	F3	R74	33000-031	F5	R105	33000-030	E6	R304	33000-009	D2
IC314	30000-007	C9	R21	33000-042	G2	R47	33000-042	F4	R75	33000-029	G5	R106	33000-033	E6	R305	33000-009	D2
IC700	31000-023	B7	R22	33000-043	F2	R48	33000-042	F4	R76	33000-042	G5	R107	33000-042	F7	R306	33000-039	D2
IC701	30000-104	B8	R23	33000-034	F2	R49	33000-042	F4	R77	33000-038	F5	R108	33000-029	F7	R307	33000-037	A2
IC702	30000-088	B8	R24	33000-041	G2	R50	33000-042	F4	R81	33000-037	F5	R109	33000-042	F7	R308	33000-043	A2
L1	35000-004	H7	R25	33000-043	G2	R51	33000-042	F4	R85	N/F	H5	R110	33000-039	G7	R309	33000-037	C2
R1	33000-037	E2	R26	33000-043	E2	R53	33000-037	G4	R86	33000-042	E6	R111	33000-031	G7	R310	33000-037	D2
R2	33000-042	F2	R27	33000-037	E2	R54	33000-037	G4	R87	33000-040	E6	R112	33000-031	G7	R311	33000-037	C2
R3	33000-034	F2	R28	33000-039	E2	R55	33000-042	F4	R88	33000-037	E6	R113	33000-029	F7	R312	33000-037	D2
R4	33000-042	F2	R29	33000-037	E2	R56	33000-033	G4	R89	33000-042	E6	R114	33000-042	F7	R313	33000-037	C3
R5	34000-010	G2	R30	33000-013	E2	R57	33000-042	F4	R90	33000-039	E6	R115	33000-039	H8	R314	33000-044	D3
R6	34000-010	G2	R31	33000-013	F2	R58	33000-042	F4	R91	33000-042	E6	R116	33000-043	H8	R315	33000-037	C3
R7	33000-043	F2	R32	33000-042	G2	R60	33000-037	G4	R92	33000-037	E6	R117	33000-038	H8	R316	33000-031	A3
R8	33000-021	E2	R33	33000-042	F2	R61	33000-037	G4	R93	33000-037	E6	R118	33000-035	H8	R317	33000-037	C3
R9	33000-007	E2	R34	33000-034	F2	R62	33000-037	G4	R94	33000-035	E6	R119	33000-039	G8	R318	33000-037	D3
R10	33000-004	E2	R35	33000-043	G2	R63	33000-042	F4	R95	33000-034	E6	R120	33000-031	G8	R320	33000-037	C3
R11	33000-037	F2	R36	33000-034	F2	R65	33000-042	F5	R96	33000-037	F6	R121	33000-031	G8	R321	33000-037	A3
R12	33000-038	G2	R37	33000-034	F2	R66	33000-037	G5	R97	33000-039	E6	R122	33000-031	G8	R322	33000-037	A3
R13	33000-042	G2	R38	33000-042	F2	R67	33000-037	G5	R98	33000-037	E6	R123	33000-031	G8	R323	33000-037	D3
R14	33000-043	F2	R39	33000-031	E2	R68	33000-042	F5	R99	33000-044	G6	R130	33000-044	G2	R324	33000-037	C3
R15	33000-037	F2	R40	33000-037	F2	R69	N/F	G5	R100	33000-042	F6	R131	33000-043	G2	R325	33000-037	D3
R16	33000-030	E2	R41	33000-042	F5	R70	33000-039	F5	R101	33000-039	E6	R300	33000-039	D2	R326	33000-037	D3
R17	33000-034	F2	R42	33000-042	F5	R71	33000-029	G5	R102	33000-034	E6	R301	33000-037	D2	R327	33000-034	A3
R18	33000-039	G2	R44	33000-002	F3	R72	33000-042	G5	R103	33000-029	G6	R302	33000-021	C2	R328	33000-037	A3

REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID	REF.	PtNo	GRID
R331	33000-037	D3	R356	33000-044	A6	R386	33000-020	D8	R713	33000-042	B8	BC1	5131-385	D3
R332	33000-037	D3	R357	33000-034	A6	R387	33000-037	D8	R714	33000-042	B8	BC2	5131-383	D5
R333	33000-037	A3	R358	33000-044	A6	R388	34000-006	D8	TR1	31000-001	E2	BC3	5131-385	D7
R334	33000-037	A3	R359	33000-044	A6	R389	34000-011	C8	TR2	31000-004	E2			
R335	33000-037	C3	R360	33000-042	A6	R390	33000-030	C8	TR3	31000-022	G5			
R336	33000-037	A3	R361	33000-031	A6	R391	34000-011	C8	TR7	31000-004	E6			
R337	33000-037	A3	R362	33000-031	A6	R392	33000-030	D8	TR8	31000-001	E6			
R338	33000-037	A4	R363	33000-031	A6	R393	34000-011	C8	TR9	31000-022	G6			
R339	33000-037	A4	R364	33000-031	A6	R394	33000-042	C9	TR10	31000-001	F7			
R340	33000-037	A4	R365	33000-042	D6	R395	33000-042	C9	TR11	31000-022	F7			
R341	33000-037	A4	R366	33000-042	C7	R396	33000-018	C9	TR300	31000-001	A3			
R342	33000-037	C4	R367	33000-042	C7	R397	33000-039	C9	TR301	31000-001	A6			
R343	33000-037	D4	R368	33000-042	D7	R700	33000-013	B7	TR302	31000-001	A6			
R344	33000-037	D4	R369	33000-021	A7	R701	33000-013	B7	TR303	31000-001	A7			
R345	33000-027	D4	R370	33000-042	D7	R702	33000-021	B8	TR304	31000-001	A7			
R346	33000-027	D4	R371	33000-044	D7	R703	33000-031	B8	TR305	31000-016	D8			
R347	33000-044	A5	R376	33000-030	B4	R704	33000-030	B8	TR700	31000-001	B8			
R348	33000-031	A5	R377	33000-035	D7	R705	33000-042	B8	TR701	31000-004	B8			
R349	33000-042	A5	R379	33000-043	D7	R706	33000-037	B8	XL300	35000-006	D3			
R350	33000-042	C5	R380	33000-043	D7	R707	33000-034	B8	ZD1	31400-002	F3			
R351	33000-042	C5	R381	33000-031	D7	R708	33000-008	B8	D16	31300-002	H5			
R352	33000-031	A5	R382	33000-004	D7	R709	33000-013	B8	D18	31300-002	G5			
R353	33000-036	D5	R383	34000-002	D8	R710	33000-008	B8	IC302	6139-143	C3			
R354	33000-037	D5	R384	33000-031	D8	R711	33000-013	B8	IC305	6139-147	C5			
R355	33000-037	A6	R385	33000-037	D8	R712	33000-008	B8	R132	33000-040	F5			


A
B
C
D
1
2
3
4
TP500
R506
TR500
D500
C502
R505
R503
C506
C501
C504
R502
IC500
C509
C511
C510
IC501
R530
C516
C517
C505
R514
R518
R531
R532
C500
C503
R501
C508
R517
C512
R524
C515
R511
R516
TP502
R519
R522
R523
R528
IC502
TP501
R513
C513
R527
R521
R526
C514
TP504
FM1
BOARD
ZERO
L500



5173-579
E
F
G
H
D503
D507
IC505
C524
D506
C523
R551
C522
R550
IC504
R559
R560
TP511
R558
R561
R576
R549
R548
R546
R547
R545
R544
R543
R542
R554
TP519
TP509
R557
R556
R591
R590
R593
TP521
TP523
TP520
TP522
IC503
L501
TP515
R573
C526
R572
R582
TP518
IC508
R581
R580
C525
TP517
TP514
TR504
TR505
FID
FM2
MARK

REF.	PtNo	GRID
C500	32000-029	B3
C501	32000-029	B3
C502	32000-029	B3
C503	32000-029	B3
C504	32000-029	B3
C505	32000-030	B3
C506	32000-030	B3
C508	32000-030	B3
C509	32000-027	C3
C510	32000-030	C3
C511	32000-030	C3
C512	32000-030	C3
C513	32000-030	C4
C514	32000-030	C4
C515	32000-030	C3
C516	32000-030	C3
C517	32000-030	D3
C522	32000-030	E3
C523	32000-030	E3
C524	32000-004	H2
C525	32000-030	G4
C526	32000-029	G3
D500	31000-002	B3
D503	31000-002	E1
D506	31000-002	F3

REF.	PtNo	GRID
D507	31000-002	F2
IC500	30000-104	B3
IC501	30000-104	C3
IC502	30000-104	C3
IC503	31000-028	F4
IC504	30000-104	E3
IC505	30000-089	G2
IC508	30000-092	G4
L500	35000-004	D4
L501	35000-004	F4
R501	33000-040	B3
R502	33000-040	B3
R503	33000-037	B3
R505	33000-042	B3
R506	33000-037	B3
R511	33000-044	B3
R513	34000-005	B4
R514	33000-042	C3
R516	33000-027	C3
R517	33000-044	C3
R518	33000-044	C3
R519	33000-044	C3
R521	33000-027	C4
R522	33000-044	C3
R523	33000-044	C3

REF.	PtNo	GRID
R524	33000-044	C3
R526	33000-040	C4
R527	33000-044	C4
R528	33000-044	C3
R530	33000-040	C3
R531	33000-040	C3
R532	33000-040	D3
R542	33000-041	E4
R543	33000-044	E4
R544	33000-037	E3
R545	33000-034	E3
R546	33000-042	E3
R547	33000-034	E3
R548	33000-042	E3
R549	33000-039	E3
R550	33000-040	E3
R551	33000-040	E3
R554	33000-044	E3
R556	33000-033	F3
R557	33000-044	F3
R558	33000-031	F3
R559	33000-031	F3
R560	33000-031	F3
R561	33000-031	F3
R572	33000-042	G3

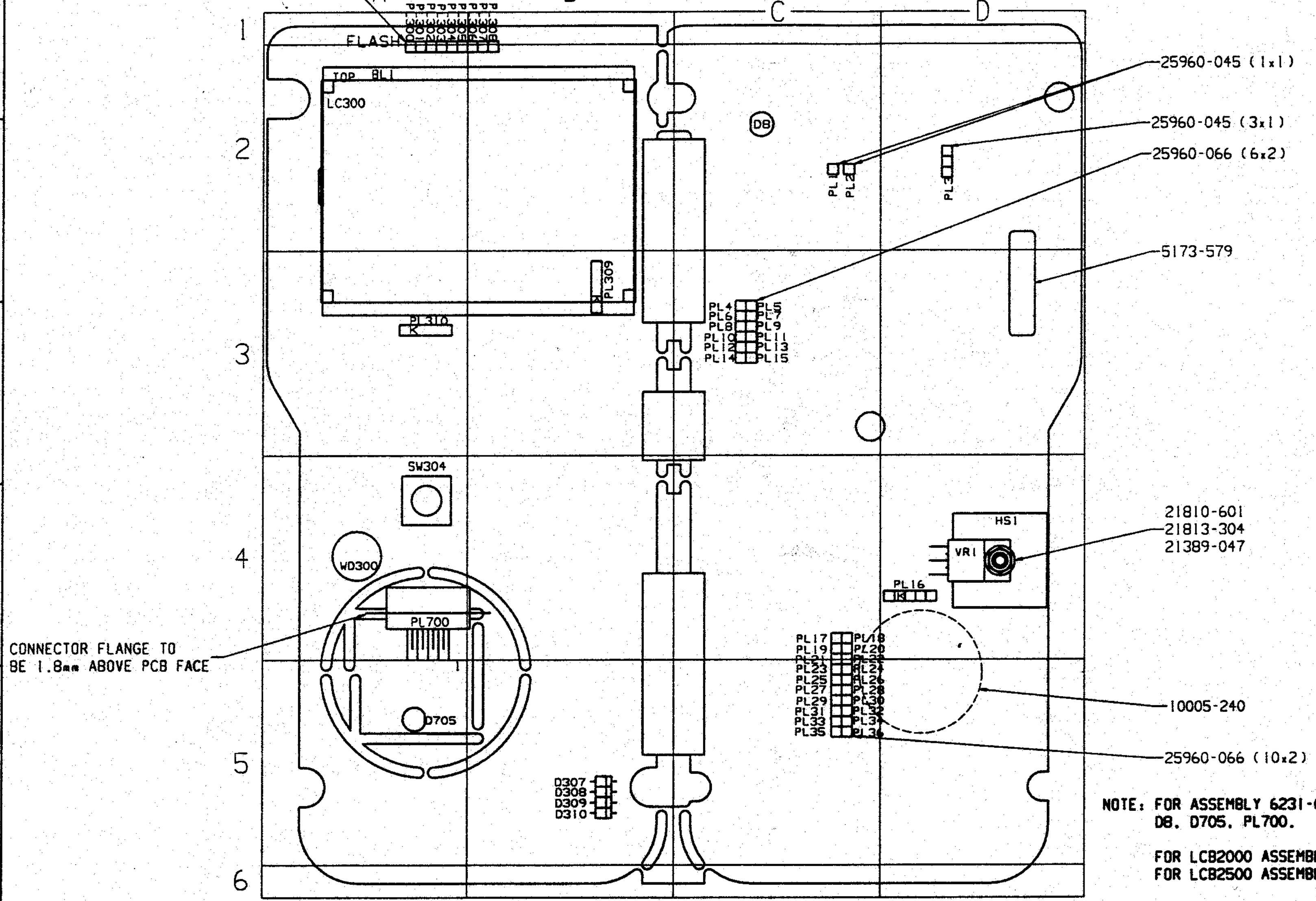
REF.	PtNo	GRID
R573	33000-037	G3
R576	33000-037	G3
R580	33000-037	G4
R581	33000-037	G4
R582	33000-039	G3
R590	33000-037	F4
R591	33000-037	F3
R592	33000-037	F4
R593	33000-037	F4
TR500	31000-016	B3
TR504	31000-016	G4
TR505	31000-031	H4

Appendix 13 - Conventional Assembly

AVO INTERNATIONAL LTD.
Archcliffe Road, Dover, Kent. CT17 9EN. England

TITLE
MAIN & DISPLAY PCB ASSEMBLY
FIRST USED ON: LCB 2000/2500 PROJECT 255

PART No.
6231-650/651



REF.	PtNo	GRID
BL1	6180-418	A2
D8	28920-087	C2
D307	N/F	B5
D308	N/F	B5
D309	N/F	B5
D310	N/F	B5
D705	28920-087	A5
HS1	5131-381	D4
LC300	6280-327	A2
PL16	N/F	D4
PL309	N/F	B3
PL310	N/F	A3
PL700	25960-096	A4
SW304	25975-107	A4
VR1	28900-099	D4
WD300	27920-047	A4

NOTE: FOR ASSEMBLY 6231-650 DO NOT FIT
D8, D705, PL700.

FOR LCB2000 ASSEMBLY 6231-650 USE PCB KIT 6132-027
FOR LCB2500 ASSEMBLY 6231-651 USE PCB KIT 6132-028

CAD DRAWING. NO MANUAL CHANGES PERMISSIBLE

THIS IS A COMPONENT DRAWING AND THE TOLERANCES SHOWN REFER TO THE COMPONENT AND NOT ITS ASSOCIATED TOOLING

DO NOT SCALE | IF IN DOUBT ASK!

DIMENSIONS IN MILLIMETRES
TOLERANCES, UNLESS OTHERWISE STATED:
NOMINAL DIMENSIONS ± 0.5
DIMS. TO 1 DEC. PLACE ± 0.15
ANGULAR DIMENSIONS ± 1°
HOLES TO BS4500 H11

THIRD ANGLE PROJECTION

IF MULTIPLE SHEET DRAWING, ALL SHEETS MUST BE AT THE SAME ISSUE

ISSUE	DATE	CN No.
5	1-03-00	20479
4	19-01-00	20406

DRAWN: S.D.Clark | DATE: 4-01-99
SCALE: 1:1 | SHT. 1 OF 1 SHTS.
MATERIAL: SEE BOM
FINISH:

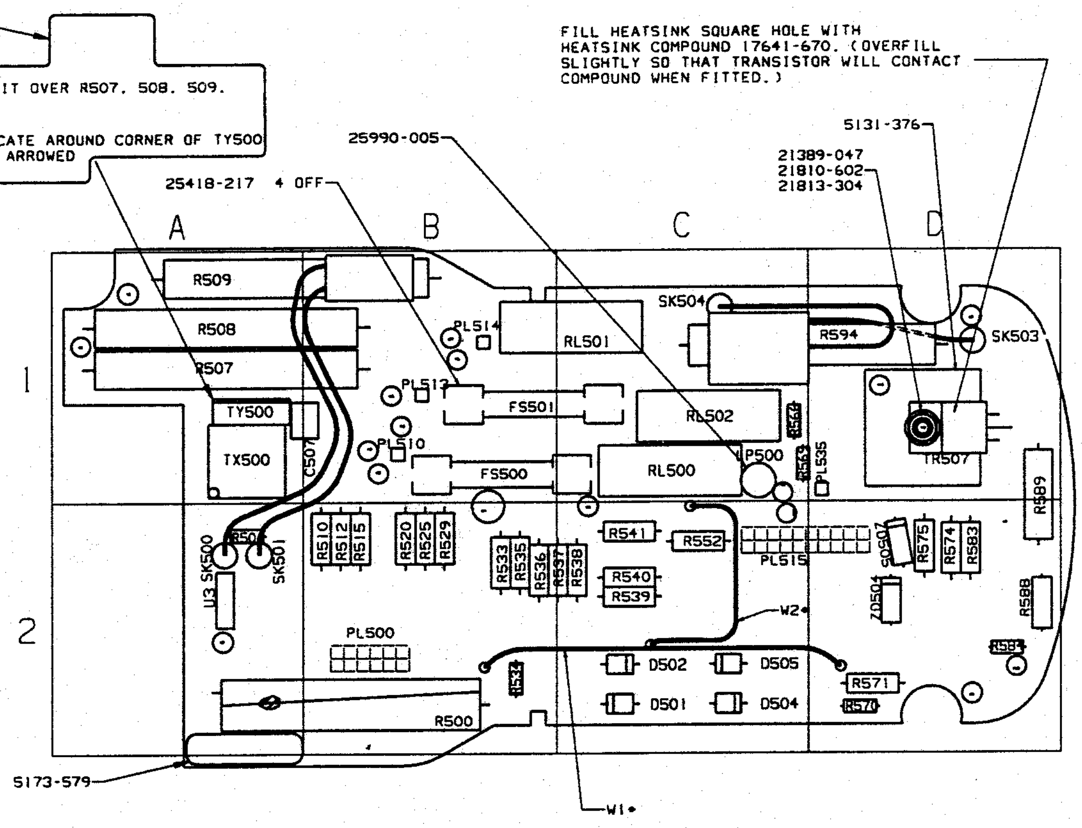
A3/E5

AVO INTERNATIONAL LTD.
Archcliffe Road, Dover, Kent. CT17 9EN. England

TITLE
POWER PCB ASSEMBLY

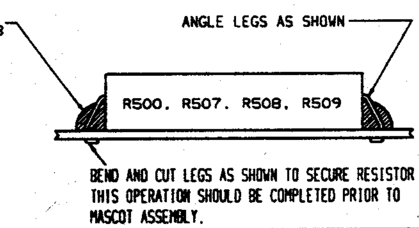
FIRST USED ON: LCB2000

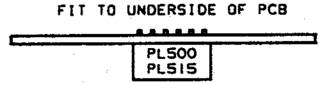
PART No. 6231-649



SEE PCB KIT 6132-033

REF.	PiNo	GRID	REF.	PiNo	GRID	REF.	PiNo	GRID
C507	27889-996	B1	R533	26837-130	B2	SK501	A2	
D501	28863-082	C2	R534	26836-919	B2	SK503	D1	
D502	28863-082	C2	R535	26837-130	B2	SK504	D1	
D504	28863-082	C2	R536	26837-130	B2	TR507	28940-043	D1
D505	28863-082	C2	R537	26837-130	C2	TX500	27900-032	A1
FS500	25411-854	B1	R538	26837-130	C2	TY500	28940-044	A1
FS501	25411-854	B1	R539	26836-741	C2	ZD504	27920-039	D2
LP500	25515-677	C1	R540	26836-741	C2	ZD505	27920-039	D2
PL500	25965-143	B2	R541	26837-130	C2			
PL510	25960-045	B1	R552	26836-741	C2			
PL513	25960-045	B1	R566	26836-624	C1			
PL514	25960-045	B1	R569	26836-624	C1			
PL515	25965-144	C2	R570	26836-919	D2			
PL535	25960-045	D1	R571	26837-130	D2			
R500	26837-115	B2	R574	26837-134	D2			
R504	26900-001	A2	R575	26837-134	D2			
R507	26837-133	A1	R583	26837-134	D2			
R508	26837-133	A1	R584	26900-130	D2			
R509	6132-012	A1	R588	26837-176	D2			
R510	26837-130	B2	R589	26837-175	D2			
R512	26837-130	B2	R594	6132-011	D1			
R515	26837-130	B2	RL500	25980-057	C1			
R520	26837-130	B2	RL501	25980-057	C1			
R525	26837-130	B2	RL502	25980-057	C1			
R529	26837-130	B2	SK500	A2				





* SEE WACL 6140-335

CAD DRAWING, NO MANUAL CHANGES PERMISSIBLE

THIS IS A COMPONENT DRAWING AND THE TOLERANCES SHOWN REFER TO THE COMPONENT AND NOT ITS ASSOCIATED TOOLING

DO NOT SCALE | IF IN DOUBT ASK!

DIMENSIONS IN MILLIMETRES
TOLERANCES, UNLESS OTHERWISE STATED:
NOMINAL DIMENSIONS ± 0.5
DIMS. TO 1 DEC. PLACE ± 0.15
ANGULAR DIMENSIONS ± 1°
HOLES TO BS4500 H11

THIRD ANGLE PROJECTION

IF MULTIPLE SHEET DRAWING, ALL SHEETS MUST BE AT THE SAME ISSUE

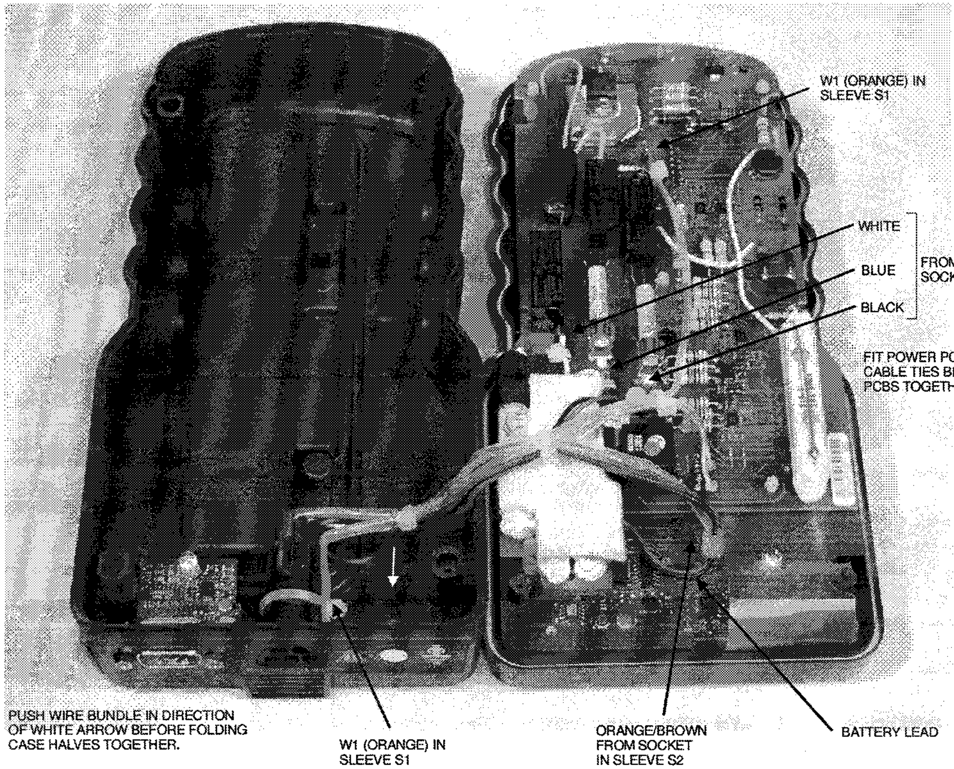
ISSUE	DATE	CN No.
2	25-11-99	20351
3	22-03-00	20510

DRAWN: S.D.Clark | DATE: 3-12-98
SCALE: 1:1 | SHT. 1 OF 1 SHTS.
MATERIAL: SEE BOM
FINISH:

A3/E5

Appendix 14 - Instrument Assembly

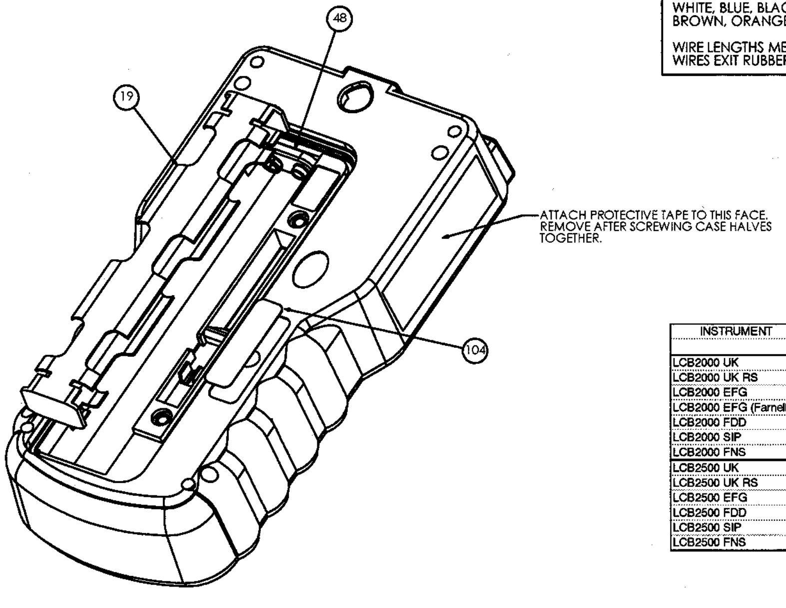
AVO INTERNATIONAL LTD. Archcliffe Road, Dover, Kent CT17 9EN, U.K.	Title: INSTRUMENT ASSEMBLIES	1st Used On: LCB SERIES	Part No.: 6410-971-97; Scale:- 1:1; Sheet 1 of 2

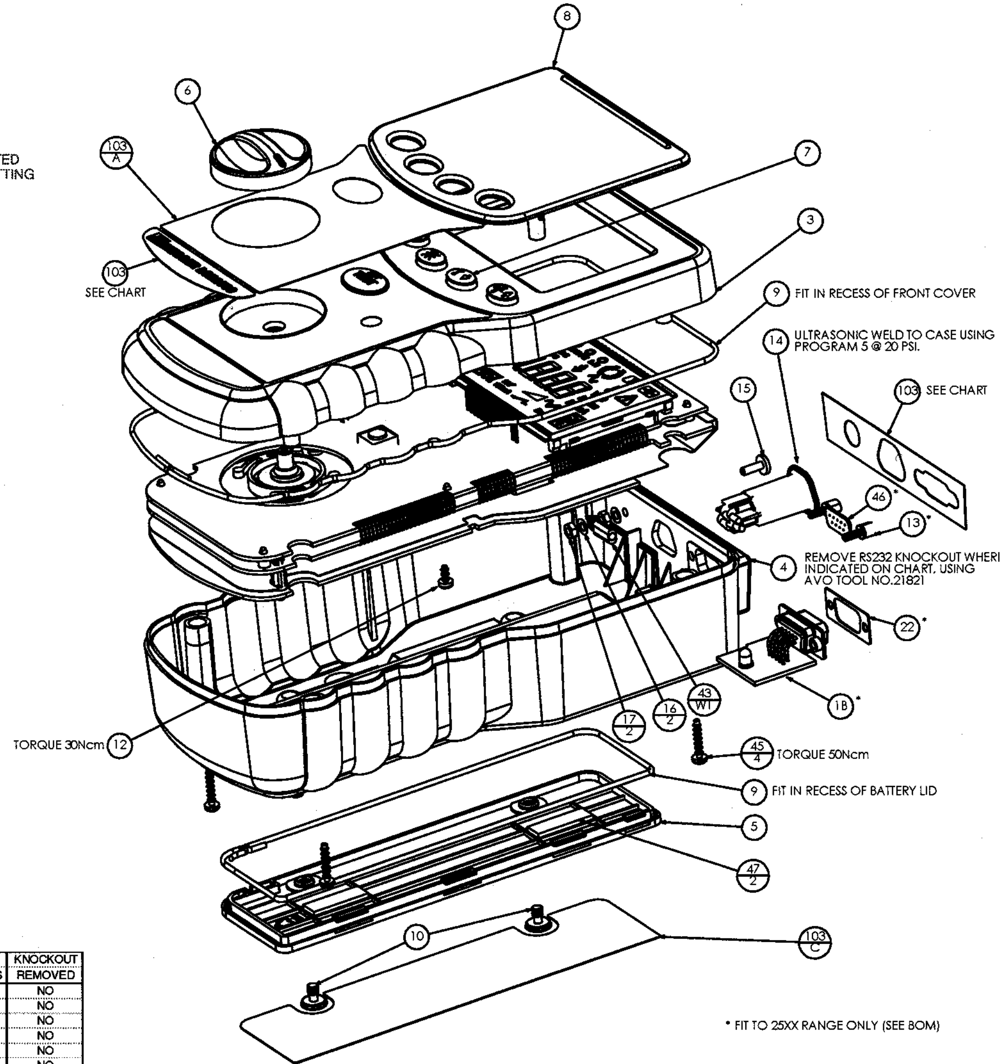


SOCKET WIRE LENGTHS:

WHITE, BLUE, BLACK - 150mm
BROWN, ORANGE - 165mm

WIRE LENGTHS MEASURED FROM WHERE WIRES EXIT RUBBER SLEEVES.





* FIT TO 25XX RANGE ONLY (SEE BOM)

INSTRUMENT	INSTR. NO.	PLANNING BILL	LABEL VARIANTS	KNOCKOUT REMOVED
LCB2000 UK	6111-376	6410-971	B,H.	NO
LCB2000 UK RS	6111-422		C,H.	NO
LCB2000 EFG	6111-439		B,H.	NO
LCB2000 EFG (Farnell)	6111-499		B,H.	NO
LCB2000 FDD	6111-481		B,H.	NO
LCB2000 SIP	6111-482		B,H.	NO
LCB2000 FNS	6111-483		B,H.	NO
LCB2500 UK	6111-377	6410-972	B,G.	YES
LCB2500 UK RS	6111-423		C,G.	YES
LCB2500 EFG	6111-440		B,G.	YES
LCB2500 FDD	6111-484		B,G.	YES
LCB2500 SIP	6111-485		B,G.	YES
LCB2500 FNS	6111-486		B,G.	YES

DO NOT SCALE | IF IN DOUBT, ASK!

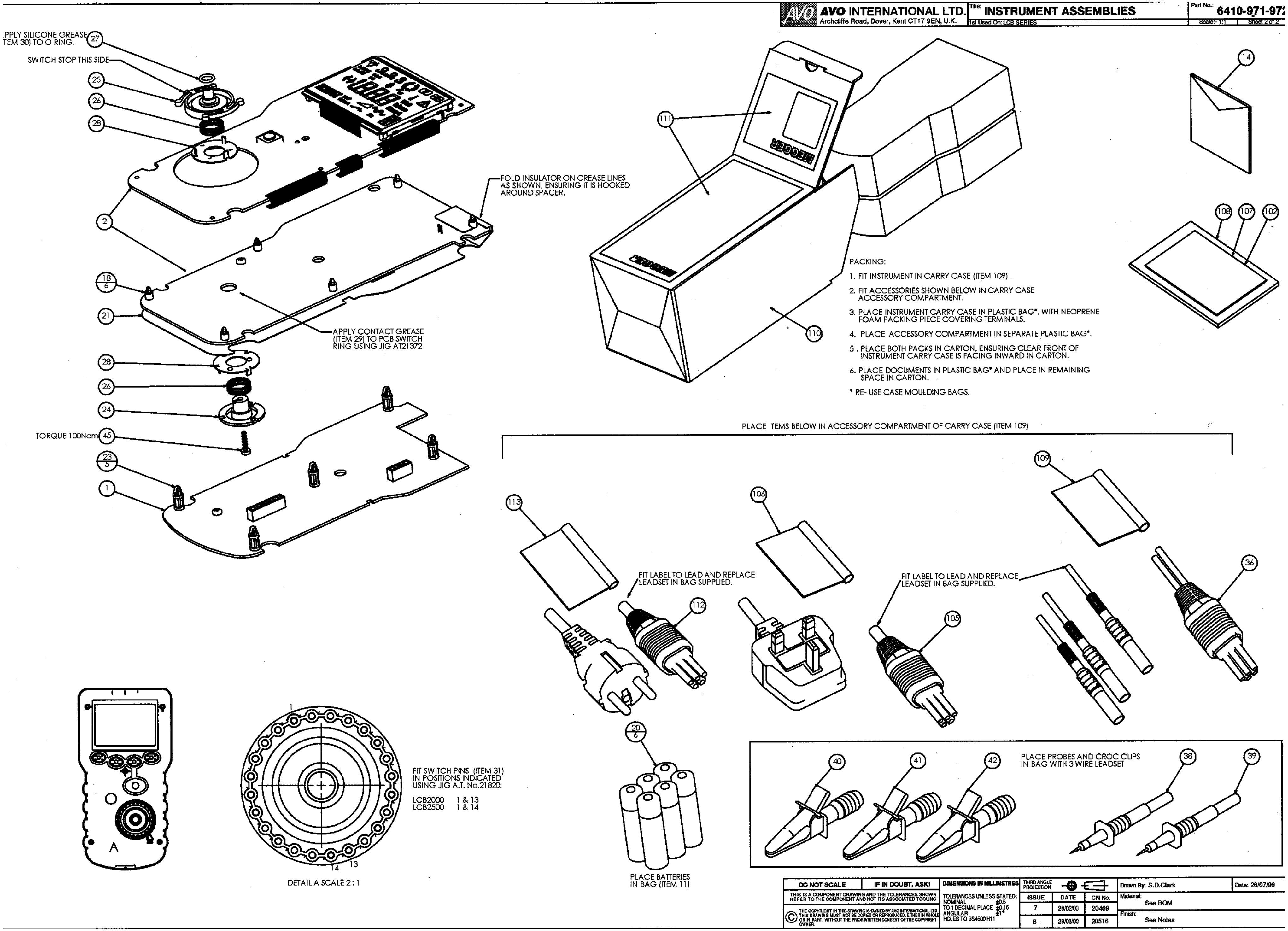
THIS IS A COMPONENT DRAWING AND THE TOLERANCES SHOWN REFER TO THE COMPONENT AND NOT ITS ASSOCIATED TOOLING

DIMENSIONS IN MILLIMETRES
TOLERANCES UNLESS STATED:
NOMINAL ±0.5
TO 1 DECIMAL PLACE ±0.15
ANGULAR ±1°
HOLES TO BS4500 H11

THIRD ANGLE PROJECTION

ISSUE	DATE	CN No:
7	28/02/00	20469
8	29/03/00	20516

Drawn By: S.D.Clark | Date: 26/07/99
Material: See BOM
Finish: See Notes


AVO INTERNATIONAL LTD.
Archcliffe Road, Dover, Kent CT17 9EN, U.K.
Title: INSTRUMENT ASSEMBLIES
1st Used On: LCB SERIES
Part No.: 6410-971-972
Scale:- 1:1
Sheet 2 of 2
.PPLY SILICONE GREASE TEM 30) TO O RING.
SWITCH STOP THIS SIDE
FOLD INSULATOR ON CREASE LINES AS SHOWN, ENSURING IT IS HOOKED AROUND SPACER.
APPLY CONTACT GREASE (ITEM 29) TO PCB SWITCH RING USING JIG AT21372
TORQUE 100Ncm
PACKING:
1. FIT INSTRUMENT IN CARRY CASE (ITEM 109) .
2. FIT ACCESSORIES SHOWN BELOW IN CARRY CASE ACCESSORY COMPARTMENT.
3. PLACE INSTRUMENT CARRY CASE IN PLASTIC BAG*, WITH NEOPRENE FOAM PACKING PIECE COVERING TERMINALS.
4. PLACE ACCESSORY COMPARTMENT IN SEPARATE PLASTIC BAG*.
5 . PLACE BOTH PACKS IN CARTON, ENSURING CLEAR FRONT OF INSTRUMENT CARRY CASE IS FACING INWARD IN CARTON.
6. PLACE DOCUMENTS IN PLASTIC BAG* AND PLACE IN REMAINING SPACE IN CARTON.
* RE- USE CASE MOULDING BAGS.
PLACE ITEMS BELOW IN ACCESSORY COMPARTMENT OF CARRY CASE (ITEM 109)
FIT LABEL TO LEAD AND REPLACE LEADSET IN BAG SUPPLIED.
FIT LABEL TO LEAD AND REPLACE LEADSET IN BAG SUPPLIED.
PLACE BATTERIES IN BAG (ITEM 11)
PLACE PROBES AND CROC CLIPS IN BAG WITH 3 WIRE LEADSET
FIT SWITCH PINS (ITEM 31) IN POSITIONS INDICATED USING JIG A.T. No.21820:
LCB2000 1 & 13
LCB2500 1 & 14
DETAIL A SCALE 2 : 1
DO NOT SCALE
IF IN DOUBT, ASK!
DIMENSIONS IN MILLIMETRES
THIRD ANGLE PROJECTION
Drawn By: S.D.Clark
Date: 26/07/99
THIS IS A COMPONENT DRAWING AND THE TOLERANCES SHOWN REFER TO THE COMPONENT AND NOT ITS ASSOCIATED TOOLING
THE COPYRIGHT IN THIS DRAWING IS OWNED BY AVO INTERNATIONAL LTD. THIS DRAWING MUST NOT BE COPIED OR REPRODUCED, EITHER IN WHOLE OR IN PART, WITHOUT THE PRIOR WRITTEN CONSENT OF THE COPYRIGHT OWNER.
TOLERANCES UNLESS STATED: NOMINAL ±0.5 TO 1 DECIMAL PLACE ±0.15 ANGULAR ±1° HOLES TO BS4500 H11
ISSUE DATE CN No.
7 28/02/00 20469
8 29/03/00 20516
Material: See BOM
Finish: See Notes

Appendix 15 – Design Spec

SUPPLY VOLTAGE MEASUREMENT

25 - 500 V ± 2 % ± 2 digits

SUPPLY FREQUENCY MEASUREMENT

d.c. , 16.0 - 460 Hz ± 0.1 % ± 1 digit

Loop Tests

Loop L-L/L-N (As CM500)

This is a simple high current loop test with a range of 0.01...19.99 ohms. It can be used for measuring the loop resistance between phases on 230V three phase systems. The PFC is calculated and available by pressing the 'display' key after the test. This is calculated using the nominal voltage determined by the setup.
An extension of the LCB is that the PFC can be displayed as XXX A or X.X kA giving extra resolution.

Technical Spec.
Supply Voltage 100 - 480 V, 45 - 65 Hz
Intrinsic Error ± 5% ± 0.03 Ω

The resistance of the circuit is measured and therefore a phase angle of 18° will give an additional error of 5%.

EN61557 Measurement Range 0.25 Ω to 19.99 Ω
Operating Error ± 10% ± 0.06 Ω

PROSPECTIVE FAULT CURRENT (to EN61557-3)

The prospective fault current is calculated from the loop resistance. The intrinsic and operating error are therefore derived from the section above.

EN61557 Measurement Range 1 A to 0.9 kA

Loop L-PE (As CM500)

This is an autorange loop resistance measurement, limited to 280V to earth systems. As it is using a high test current, RCDs will trip.

Technical Spec.
Supply Voltage 100 - 280 V, 45-65 Hz
EN61557 Measurement Range 0.25 Ω to 3.00 kΩ

The resistance of the circuit is measured and therefore a phase angle of 18° will give an additional error of 5%.

Intrinsic and Operating Errors:

Display	Intrinsic	Operating
0.01 - 9.99 Ω	± 4% ± 0.03 Ω	± 10% ± 0.06 Ω
10.0 - 89.9 Ω	± 5% ± 0.5 Ω	± 10% ± 1 Ω
90 - 899 Ω	± 5% ± 5Ω	± 10% ± 10 Ω
900 - 3.00 kΩ	± 5% ± 0.02 kΩ	± 10% ± 0.04 kΩ

Loop L-PE 0.1 Ω (As CM500)

This is the RCD no-trip loop test common with the CM500 modified from the LT7. It is performed at 15mA and therefore will not trip a 30mA RCD and takes about 30-40 s to complete the test. Compared with the traditional high current test, results are sensitive to supply noise, and hence we give a spec. for the variability in the reading. It only requires two wires and therefore can be used where neutral is not distributed (e.g. on a light switch).

Technical Spec.

Display Range 0.1 Ω to 1.99 kΩ

Intrinsic Error up to 200 Ω ± 3% ± 0.3 Ω
over 200 Ω ± 5% ± 5 Ω

Noise Immunity

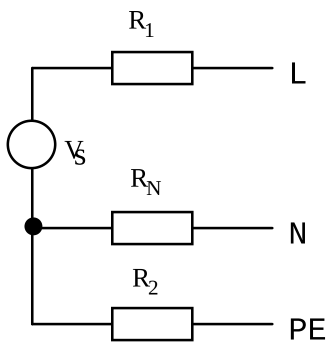
1σ of readings ± 0.3 Ω on a normal domestic supply.

EN61557 Measurement Range 5 Ω to 1.99 kΩ

Operating Error (excluding noise) up to 200 Ω ± 6% ± 1Ω
over 200 Ω ± 10% ± 10 Ω

Loop L-PE 0.01 Ω

This is a new no-trip loop test requiring a connection to line, neutral and earth. A high current test measures the loop resistance Line-Neutral, and this is followed by a measurement of the resistance of the earth conductor to its connection with the neutral. Greater precision in a quicker time is possible using this method; giving a line earth loop impedance measurement in about 10-15s on a normal domestic supply to 0.01 Ω.
If the line-earth resistance is greater than 10 Ω, the '2 wire Loop L-PE 0.1 Ω' test will be used.



Equivalent circuit of a mains supply

As a complete analysis of the loop resistances is carried out, the following results are available:

1. Loop L-PE (what we what most of the time)
2. Fault Current L-PE
3. Loop L-N (result of step 1 -- It's available!)
4. Fault Current L-N
5. R1
6. R2
7. RN (= (Loop L-N - R1))

Note that if neutral is connected to earth, any RCD protecting the circuit will trip.

Technical Spec.

Display Range (Loop L-PE) 0.01 Ω to 10.00 Ω

Intrinsic Error ± 5% ± 0.05 Ω
Operating Error (excluding noise) ± 10% ± 0.10 Ω

Noise Immunity
1σ of readings ± 0.05 Ω on a normal domestic supply.

EN61557 Measurement Range 0.50 Ω to 10.00 Ω

RCD Tests (As CM500)

A comprehensive range of RCD tests is available. At 1/2I the loop resistance and contact voltage may be measured without tripping the RCD, and an optional two second test checks the sensitivity for nuisance tripping as recommended in the IEE guidance notes. At the rated current the time the device takes to trip can be measured with the test current starting on positive or negative going current. The current at which the device trips can be determined using the ramp test. Trip tests may be also done using a pulsed d.c. waveform for d.c. sensitive breakers.
For 10mA and 30mA RCDs an autosequence trip test is available which carries out tests in the sequence 1/2I – 0° – 180° – 5I 0° – 5I 180° or optionally 1/2I – 0° – 180° – 150mA 0° – 150mA 180° for the UK. After each trip the instrument will wait for the supply to be re-connected before automatically starting the next in the sequence. In this way the LCB2000/2500 can be plugged into a convenient socket, the test started and the RCD reset several times without having to walk between the socket and RCD for each test. All test results are available after the test.
As before any test the loop resistance is checked in a single half cycle, all RCD tests can be carried out without a connection to neutral.

Before any test the test type can be selected by use of a key from a list of 1/2I – 0° – 180° – 5I 0° – 5I 180° – Ramp – autosequence. Selective and d.c. sensitive attributes can be selected using another key.

Test currents are limited by the supply voltage.

Supply voltage	a.c. tests	d.c. sensitive tests
>200V	1000 mA	300 mA
>100V	500 mA	150 mA

The maximum test duration of the timed trip tests depends on test type, rated current and if the breaker is selective.

The rated current of the RCD is selected by the switch position from the choice 30, 100, 300, 500 & 1000 mA.
There is also a VAR position which allows the selection of the rated current from 10 to 1A.
Autosequence and ramp tests are only available in this position if the rated current is 10 mA.

There is also a dedicated switch position for the 150 mA 40 ms test.

Technical Spec.
Tests
No Trip (½ $I_{\Delta n}$), Trip ($I_{\Delta n}$), 150 mA Fast Trip, $5I_{\Delta n}$ trip test for 10, 30 and 100 mA RCDs and Ramp.

RCD Types
As well as general purpose RCDs, d.c. sensitive and delayed (selective) types can be tested.

Supply Voltage 100 - 280 V, 45-65 Hz

Variable test current

On the RCD VAR range the test current may be selected from the range 10 mA to 1000 mA.

Two second NO TRIP TEST (Optional)
A test current of $½I_{\Delta n}$ flows for 2s. A tripped RCD shows <1999 ms.

Intrinsic Error (test current)	-8%/-2%
Operating Error (test current)	-10%/+0%

Contact Voltage (measured at $½I_{\Delta n}$)

Intrinsic Error	+5%/+15% ± 0.5 V
EN61557 Measurement Range	10.0 to 99.9V
Operating Error	+20% /-0%

Loop Resistance (measured at $½I_{\Delta n}$)

$I_{\Delta n}$	Intrinsic	Operating
10 – 29	± 8% ± 0.10 kΩ	± 16% ± 0.20 kΩ
30 – 99	± 5% ± 17 Ω	± 10% ± 34 Ω
100 – 299	± 5% ± 5Ω	± 10% ± 10 Ω
300 – 499	± 5% ± 1.7 Ω	± 10% ± 3.4 Ω
500 – 999	± 5% ± 1 Ω	± 10% ± 2 Ω
1000	± 5%± 0.5 Ω	± 10% ± 1 Ω

TRIP TESTS
The maximum possible test current (including the 5I multiplier) is 1000 mA (300 mA for d.c. sensitive RCDs). These limits are halved if the supply voltage is less than 200V.

Trip time measurement

At all currents:

Intrinsic Error (trip time)	± 1% ± 1 ms
Operating Error (trip time)	± 2% ± 2 ms

	$I_{\Delta n}$ Test	**$5I_{\Delta n}$ Test**
Intrinsic Error (test current)	+2%/+8%	
Operating Error (test current)	-0 %/+10%	
Display Ranges	0.1 to 199.9 ms and	0.1 to 39.9 ms and
	(selective) 200 to 1999 ms	(selective) 0.1 to 149.9 ms

150 mA 40 ms Trip Test

Intrinsic Error (test current)	-3 %/+ 3%
Operating Error (test current)	-5 %/+ 5%

Display Range 0.1 to 39.9 ms

TRIP CURRENT MEASUREMENT (RAMP TEST)
Test Current

Intrinsic Error -3 %/+3%
Operating Error -5 %/+5%

plus the increment in the table below

	a.c. sensitive		d.c. sensitive	
$I_{\Delta n}$	Ramp Range	Increment	Ramp Range	Increment
10	5 - 15 mA	1 mA	3 - 15 mA	0.5 mA
30	15 - 50 mA	1 mA	10 - 45 mA	1 mA
100	50 - 150 mA	2 mA	30 - 150 mA	6 mA
300	150 - 300 mA	6 mA	100 – 464 mA	52 mA
500	250 - 500 mA	10 mA	N/A	
1000	500 - 1000 mA	52 mA		

Appendix 16 – Software Versions

V1.1

Changes to calibration mode. –
Auto calibration uses new algorithm and is better.
E12 error when auto-repeating adjustments improved.
Calibration mode re-entered when testing LOOP L-PE 0.1Ω

When instrument powers down (after a period of inactivity) and is awakened by a key-press, results of a test (and setup) are still available. For this to occur, instrument must not be any of the setup menus, saving a result, or in the RCL posistion. Also the switch posisiton must not have changed between power down and wake up.

V1.2

LOOP L-PE 0.1Ω resistance not saved correctly on V1.0 and V1.1

V1.3

Low current loop tests –
'Noise' symbol after a test with a noisy supply is lost during the power-down/wakeup sequence introduced in V1.1.
If the test stops because it has run out of time, the last digit is blanked to show the increased uncertainity in the result.

After a flat battery it was possible to view debug information using the enter key.

Noise symbol shown due to start error in test and calibrate modes removed.

Appendix 17 - PCB Version

Power PCB – 5440-251

There are safety – related modifications to A4 issue PCBs. Ensure these are maintained during repair.

Changes A4-A5

TR507 moved down to allow square heatsink to be used.
A4 boards need a heatsink with the corner cut off

Track re-routed to maintain clearance across R594 and thermal cutout
A4 boards have a wirelink.

Main & Display PCB - 5440-252

Changes A3-A4

VR1 moved to enable square heatsink to be used.
1N4007 diodes changed to surface mount. D19 removed (S/C) (wire – link on A3 boards)
Pads on interboard connector enlarged.
R77 - change value to 22k, add 47k in parallel (15k used on A3 board not standard value)
WD300 - change to sealed buzzer
C19 - change shape to 0603
Move R390 and R385 away from pots and increase distance C35/R100.

Changes A4 – A5

Change main display interboard connector – add holes
Minor component placement
Move flash program connector

Appendix 18 - Known Problems

None