MAGNET POWER SUPPLY
PS120-10

(120A, 10V)

Applies to Firmware Version PS2.04 and later.

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SECTION 1. SAFETY

The following general safety precautions must be observed during the operation, service and repair of this instrument.

1.1 Protective Ground

To minimise shock hazard the instrument must be connected to an electrical ground. The ground wire (green/yellow) in the instrument AC power cable must be connected to the installation electrical ground system. Do not use extension cords without a protective earth conductor. Do not disconnect the protective ground inside or outside the instrument. Do not have external circuits connected to the instrument when its protective ground is disconnected.

1.2 Repair and Adjustment

Ensure that the instrument is disconnected from the AC power supply (switching off the front panel POWER switch is not sufficient) before the covers are removed or fuses are replaced, otherwise dangerous voltages are accessible. For fault finding and calibration the AC power supply may require reconnection. This work may only be carried out by skilled personnel who are aware of the hazard involved.

SECTION 2. INTRODUCTION

2.1 Use of this Manual

This manual provides operating and service information for the Oxford Instruments Power Supply Model PS120-10. Sections 1-4 provide essential information and should be read before operating the instrument for the first time. The remainder of the manual provides more detail on specific aspects and may be referred to as required.

2.2 Description of Equipment

The PS120-10 power supply is designed for energising and de-energising superconducting magnets. The supply delivers a maximum current of 120 Amps at a voltage up to +10 Volts for magnet energisation. For de-energisation it is able to absorb energy at -10 Volts. The polarity of the current in the power supply can be switched, allowing magnets to be energised in a forward or reverse direction. A separate output for a switch heater is provided for magnets incorporating superconducting switches. Remote computer control of all power supply functions can be performed via an RS232 interface.

SECTION 3. INSTALLATION

3.1 Supply Connection

A single phase mains supply is required for the power supply. Before connecting the supply, ensure that the voltage label on the unit indicates the correct supply voltage. If the supply voltage is incorrect, refer to section 3.3.

Once the supply is connected, the two pole miniature circuit breaker (MCB) on the rear panel should be left in the "on" or up position. The front panel switch marked ON/OFF is then used to turn the unit on and off.

3.2 Magnet Connections

Connections to the main magnet current terminals are made via the large red and black terminals on the rear panel. A suitable 120 amp rated cable (normally supplied with the magnet), should be used. On no account should these connections be made or broken unless both the voltmeter and the ammeter on the power supply are at zero. When making the connections, the power supply should be switched off to ensure that bank leakage does not cause an output voltage. The small red and black terminals on the rear panel provide connections to the heater of the superconducting switch on the magnet, if fitted.

The power supply magnet terminals are intentionally difficult to remove, but to do so, unscrew to the maximum extent then in one firm movement pull and twist.

3.3 Changing Supply Voltage

The power supply is normally supplied set for the correct supply voltage. If the required change is within the low (100V to 120V) or high (200V to 240V) voltage range, then only the mains voltage assembly must be adjusted and no conversion kit is required. Only steps a, b and e of the procedure described below should be followed.

To change between high (200V to 240V) and low (100V to 120V) voltage ranges, the MCB must be changed and the switch mode power supply (SMPS) adjusted as well as the mains voltage assembly. The whole of the following procedure must be adopted and a conversion kit is required. This consists of a replacement, twin pole, MCB unit and a set of replacement fuses, it is available from the factory.

a) Ensure that the unit is completely disconnected from the supply before starting work. Remove all rear panel connections. A rack mounted power supply should then be removed from the rack. Remove the wrap-round cover.

b) Remove the four screws and the cover from the mains voltage assembly (CBD1600). By adjusting the six links, 1,2,3,4,5 & 6 select the required voltage.

Check that F3, F4 and F6 are correctly rated for this voltage range and change them if necessary. Replace the mains voltage cover.

Mains voltage	Link 1	2	3	4	5	6
100V	A	A	A	A	A	A
120V	B	A	A	B	A	A
200V	A	B	B	A	B	B
220V	B	B	B	A	B	B
240V	B	B	B	B	B	B

The fuse ratings are:

	F1 & F2	F3 & F4	F5
100-120V	6A3 Type T	1A Type T	10mA Type T
200-240V	6A3 Type T	500mA Type T	50mA Type T

c) To gain access to the MCB, which is mounted on the rear panel, remove the two screws at the rear of the analogue PCB and swing the PCB forward. Remove the MCB by releasing the retaining clamp and the four wires connected to it, noting their positions. Connect the replacement MCB in the same arrangement and remount on the rear panel. Replace the analogue PCB.

d) In the middle of the top face of the SMPS is a small panel that covers the mains voltage selector. Remove the retaining screw and panel revealing a link. Move the link to the desired voltage position and replace the panel.

e) Replace the cover on the power supply (return it to its rack) and reconnect at the new supply voltage.

3.4 Cooling Water Connections

The high stability version of the PS120-10 requires connection to a continuous supply of cooling water (see section 9, Specification).

3.5 Serial Data Line Connections

An RS232C bi-directional serial data link from a computer may be connected via the 25 way D-socket labelled RS232 on the rear panel. The unit is configured as a Data Communication Equipment (DCE) and may be connected directly to a computer or a data terminal, configured as a Data Termination Equipment (DTE). If the power supply is to be connected to a computer which is itself configured as a DCE, pins 2 and 3 should be swapped in the interconnecting cable.

Pin connections at the RS232 socket are:

2	Received Data (From Computer)	TxD
3	Transmitted Data (To Computer)	RxD
4	Linked to 5	RTS
5	Linked to 4	CTS
6	+5V when unit is powered up	DSR
7	Signal Ground	GND
8	+5V when unit is powered up	DCD

The pin names refer to the DTE (computer) end.
All other pins are open circuit.

Voltage levels for the transmitted and received data are:

Tx Data High	> +5.5V
Tx Data Low	< -5.5V
Rx Data High Threshold	< +2.6V
Rx Data Low Threshold	> +1.4V
Max Rx Input Voltage	+/-30V

Data protocols are:

Baud Rate	9600
Tx Start Bits	1
Tx Data Bits	8
Tx Stop Bits	2
Rx Start Bits	1
Rx Data Bits	8
Rx Stop Bits	1 or more

For normal ASCII exchanges the 8th data bit is treated as a parity bit. It is always set to "0" on transmitted data. It is ignored on received data.

3.6 IEEE-488 Interface

For use on the General Purpose Interface Bus. (GPIB, HPIB or IEEE-488) an IEEE-488 to RS232 conversion unit is available. This locates externally and is linked by a cable to the RS232 socket on the rear panel. The conversion unit requires a separate mains power supply. Separate operating instructions are supplied with this unit.

3.7 Auto-Run-Down

The auto-run-down mode is activated by contact closure between pins 7 and 14 of the 15 way D-type connector on the rear panel (marked "PARALLEL I/O"). For example,

connection to a pair of terminals marked "COM" and "LOW" on an Oxford Instruments HLM2 helium level meter.

3.8 Auxiliary Port Connections

The auxiliary port is a 15 way D-type connector on the rear panel, it is marked "PARALLEL I/O" (which corresponds to SKT1202 on diagram CBD1202 sheet 2/2). It serves two separate functions.

1) It provides an input command to de-energise a superconducting magnet.

2) It provides an output confirming the output current is within a defined range.

The outputs are open-collector transistors (specification as for ULN2803A) and can sink up to 500mA from a supply of up to 25 volts maximum. When driving an inductive load, it is recommended that a diode is connected across the load to absorb the stored energy.

For low power loads, current may be drawn directly from pin 15, which is connected via a diode and fuse, to the internal unregulated 11 volt line. A maximum total current of 500mA may be drawn from this source.

The input lines on the auxiliary socket are suitable for either TTL level inputs or contact closures to +5V. The input device is a 74HC244 and 100 kohm pull-down resistors to 0V are fitted.

Pin connections at this socket are:

1	Output Bit 0	(spare)
9	Output Bit 1	(spare)
2	Output Bit 2	(spare)
10	Output Bit 3	(spare)
3	Output Bit 4	(spare)
11	Output Bit 5	(spare)
4	Output Bit 6	(spare)
12	Output Bit 7	(Safe Current Interlock)
5	Input K4	(spare)
13	Input K5	(spare)
6	Input K6	(spare)
14	Input K7	(Auto-Run-Down)
7	+5V	
15	Driver Protection / +11V unregulated.	
8	0V	

Safe Current Interlock

The safe current interlock is provided for users who require hardware confirmation that the measured power supply current is within a safe current range. The upper and lower current limits are set by the user, see section 8.5.

The "safe" condition is signalled by pin 12. If the current is "safe", the associated output transistor will sink current, otherwise it will be high-impedance. A recommended interlock circuit would consist of 10mA or so being drawn from pin 7 (at +5V) via an opto-coupler.

The safe-current status can also be read using the serial data "X" command. However it is not indicated on the front panel.

Auto-Run-Down

Auto-run-down will automatically de-energise a magnet system. The function is described in section 7.

To activate auto-run-down, pin 14 should be taken to logic 1 (+5V) relative to pin 8 (0V). The recommended means by which to achieve this is by galvanically isolated contact-closure between pins 7 and 14.

SECTION 4. LOCAL OPERATION

4.1 Front Panel Controls

The majority of the operating controls are located on the front panel and are grouped together in logically related boxes.

POWER

The main ON/OFF switch. When off, the red STANDBY lamp is lit, when the instrument is switched on, this lamp extinguishes and the green POWER ON lamp illuminates.

ADJUST

The red RAISE and LOWER buttons provide the main means of adjusting any parameter. They have no effect on their own but are always used in conjunction with one of the other buttons. Whenever a parameter is being adjusted, its current value is shown on the main display. Setting a value involves pressing RAISE or LOWER until the required value is shown. Operation of the RAISE and LOWER controls has been designed to allow large changes to be made relatively quickly whilst at the same time enabling any value to be set exactly. Pressing RAISE or LOWER briefly will cause the value to change by one unit. If the button is held in, the last figure will start to change at about 5 units per second. After 2 seconds, an approximately 10-fold increase in rate will occur, followed after another 2 seconds by a further rate increase and so on. Altogether there are 4 different rates. Whenever RAISE or LOWER is released, the next lower speed will be selected. This allows the user to "home-in" on the required value most ergonomically.

CONTROL

Control of the instrument may either be LOCAL from the front panel, or REMOTE via the RS232 interface. The LOC/REM button may be used to switch between LOCAL and REMOTE. A third mode, Auto-Run-Down, is selectable via a socket on the rear panel.

When LOCK is lit, the instrument is locked into either local or remote control and the LOC/REM button has no effect. At power up, it is locked in LOCAL, since at that time the instrument has no way of knowing if there is a computer connected to the RS232 interface.

When the instrument is in REMOTE but not LOCKed, many of the front panel controls are inoperative. Those controls which only affect the display, will still work but those which could change the operation of the instrument are disabled.

When in REMOTE and LOCKed, the front panel is completely inoperative.

Auto-Run-Down locks out both LOCAL and REMOTE control. This state is indicated when the "control" lights are flashing, see section 7.

SWITCH HEATER

This controls the heater supply for a superconducting switch on the magnet (if fitted). The HEATER ON lamp indicates that the heater is on and the superconducting switch is open, allowing the magnet to be energised. When the lamp is off, the heater is un-powered and the superconducting switch is closed, putting the magnet into persistent mode.

The associated button allows the heater to be switched on and off. In order to prevent inadvertent damage to the magnet system, the switch heater can only be turned on if the power supply current matches the magnet current in both magnitude and polarity (+/- zero amps are considered equal). The magnet current is recorded as the current in the power supply when the magnet was last put persistent. The record is updated whenever the switch heater is de-energised or if voltage limiting occurs.

If there is a mismatch of the currents, then the current that the power supply believes to be in the magnet (magnet current) is displayed for as long as the switch heater button is depressed. This safety feature can be overridden by holding down the switch heater button for a period of four seconds after which the switch heater is energised and the display reverts to displaying demanded current.

NB It is usually necessary to wait several seconds after operating the button before the superconducting switch changes state.

The current flowing through the switch heater may be adjusted to match an individual switch by means of the control on the rear panel. Where the power supply has been supplied with a magnet, the heater current will be set during final system test.

POLARITY

The power supply will automatically switch the polarity of a magnet between forward and reverse fields. When the power supply performs a polarity change it first ensures that the output current is at zero, then a clamp (or short circuit) is placed across the output, the clamp is then released with the magnet polarity in the opposite direction to the original.

The FORWARD and REVERSE lamps indicate that the power supply is providing magnet current in the forward or reverse sense. OUTPUT CLAMPED indicates that the power supply is placing a short circuit across the magnet. The power supply must always be in one of the three mutually exclusive states; Forward, Reverse or Output Clamped.

The CHANGE POLARITY button has no effect when pressed on its own. However, while SET POINT is depressed, pressing CHANGE POLARITY causes the polarity of the Set Point current, or field, to toggle. The sign of SET POINT corresponds to the polarity of the target current, a positive or negative SET POINT indicates a FORWARD or REVERSE target current.

The CHANGE POLARITY button can also be used to enter TEST mode, see section 8.1

SWEEP CONTROL

HOLD, ZERO and SET POINT buttons may be used to control the power supply output current, these states are indicated by three lamps. If none of these lamps are lit then the power supply must be in a fourth state, "Clamped".

Clamped — The magnet is clamped or short circuited. This state is only reached from the front panel when the power supply is turned on (or off). This is a "safe" state for a superconducting magnet, for example in an emergency it can be used to run a magnet to zero, although as the stored energy of the magnet is dissipated only by the lead resistance this is a rather slow method for de-energising a magnet.

When the power supply is clamped, HOLD is the only state that can be entered.

HOLD — Unclamping a magnet. The power supply will connect to the magnet in the SET POINT direction. However, if the power supply senses a significant current flowing through the magnet leads, this will override and the clamp will open in the same direction as the measured current.

Stopping a sweep. The power supply output current and polarity will remain at the same values indefinitely.

A number of secondary functions are performed by HOLD, these are:-

i) The "Hot" and "Quenched" states are cleared.

ii) With a finger on HOLD, pressing (display) SET POINT will cause the last recorded "Trip Current" or "Trip Field" to be displayed, see section 4.2.

iii) With a finger on HOLD, pressing RAISE or LOWER will cause "FASt" or "trAin" to be displayed and toggles between two maximum magnet sweep rate profiles. Fast is the power up state and is restored whenever the power supply is clamped. Train is intended for magnets that may need training after they have been warmed and for that period must then be run at lower sweep rates. The limiting rates are variables, see section 8.5.

ZERO — Causes a sweep towards zero current or field.

SET POINT — Causes the power supply to sweep towards the set point current or field.

The rate at which a sweep will proceed depends on what the power supply is "looking at". If there is no superconducting switch fitted or there is but the switch heater is energised, then the power supply assumes it is passing current through a magnet and

output changes are made in "sweep mode". If, however, there is a superconducting switch fitted and it is not being heated, then the power supply assumes it is passing current through a superconducting switch and output changes are made in "immediate mode".

If the perceived load is a switch, then the (immediate mode) sweep rate is at a fast rate which is usually 240 amps/minute but can be less, see section 8.5. If the load is magnetic then the (sweep mode) sweep rate will be at that defined by the SET RATE button in the "DISPLAY" box unless the rate exceeds and is limited by the maximum magnet sweep rate, see RATE LIMITING.

N.B. if voltage limiting should occur at any point, the power supply will "catch" the magnet and drop the power supply into the HOLD state, see section 4.2.

QUENCH

Indicates that the power supply has detected a sudden decrease in the output current. This is a very unusual event and should it occur it is quite likely to be caused by a magnet quench. For some magnets there is a possibility that a small winding may quench but not the bulk of the magnet, the small part absorbs most of the magnet's stored energy and causes damage to the wire. Secondly, damage may occur to a persistent magnet switch heater if power is continuously dissipated therein while there is no liquid helium left to cool it.

For these reasons a "QUENCH" will cause the power supply to take control. The power supply will sweep quickly to zero amps within +1V, -10V voltage limits. About a minute after the magnet has settled at zero current, the power supply will clamp the output and turn off the switch heater. When a quench is detected, the power supply current will be recorded as the "Trip Current", displayed with a finger on HOLD and pressing (display) SET POINT.

To clear the QUENCH state and regain control at any time, the operator should press the HOLD button.

RATE LIMITING

This lamp indicates that the power supply output current is no longer being swept at the rate defined by SET RATE but is under the control of a preset software limit, the maximum magnet sweep rate. As the power supply only tries to sweep at the SET RATE when looking at a magnet, this warning lamp should not light when driving current into a superconducting switch.

Software sweep rate limits are sometimes installed at the factory to protect a magnet from damage caused by sweeping it too fast. To change a limit see section 8.5.

DISPLAY

The main display normally indicates the delivered current in amps or the equivalent field in tesla. Provided the supply is not voltage limiting this will give an accurate indication of the actual power supply output.

When the supply is in voltage limit, see section 4.2, the display will flash to warn the operator that the number displayed is the target current or field rather than the actual output. Under these conditions the analogue meter on the front panel indicates the actual current.

"Hot" MESSAGE — It is possible that the display may read "Hot" instead of a number, this indicates either that the transistor bank has overheated or in the case of a High Stability PS120-10 that the water cooled shunt has overheated. The "Hot" state will cause the power supply to clamp.

The power supply should be left to cool with the power still on (thus powering the fans) or the water turned on! Pressing the HOLD button will restore normal operation but only if the overheated part has cooled down.

Buttons associated with the display allow this to be switched to display other parameters. These are displayed whilst the appropriate button is pressed. As soon as it is released the normal display returns. Whilst SET POINT or SET RATE are pressed, RAISE and LOWER may be used to adjust the parameter concerned, provided the unit is in LOCAL control.

VOLTS AMPS TESLA — The units of the displayed parameter are indicated by these three lamps. In the case of SET RATE, the units are amps/minute or tesla/minute.

CURRENT /FIELD — Causes the display to toggle between displaying the various parameters in amps or an equivalent number of tesla. The relationship between current and field is a linear one, the conversion ratio depends on the magnet and will have been set at the factory. To change the ratio see section 8.5.

OUTPUT VOLTAGE — A positive voltage indicates a resistive load or a magnet being charged, a negative voltage can appear when a magnet is discharged. The sign of the displayed voltage is independent of forward and reverse magnet polarities.

SET POINT — Displays the target point for a sweep either as current or the equivalent field. Using RAISE and LOWER it may be adjusted between 0 and 120.01 amps, or 0 and the maximum magnet current if a current limit has been installed, see section 8.5.

Whilst holding the SET POINT button, the target polarity can be toggled by the CHANGE POLARITY button. The sign of SET POINT corresponds to the polarity of the target current, a positive or negative SET POINT indicates a FORWARD or REVERSE target current.

With a finger on HOLD, pressing (display) SET POINT will cause the last recorded "Trip Current" or "Trip Field" to be displayed, see section 4.2.

SET RATE — Displays the sweep rate in amps per minute or the equivalent tesla per minute. Values between 0.01 and 240.01 amps per minute may be set. Whilst sweeping, the SET RATE may exceed the maximum magnet sweep rate, in which case the sweep rate will be limited and RATE LIMITING will be illuminated. At very high sweep rates the power supply output voltage may be insufficient to enable a magnet to follow the sweep and the power supply will voltage limit, see section 4.2.

N.B. The SET RATE is only observed when in sweep mode, eg the power supply believes it is driving a magnet. If a superconducting switch is fitted and it is persistent, the sweep is in immediate mode and is at the rate limit e.g. 240 amps/minute, or less if the limit has been reduced (see section 8.5).

4.2 Voltage Limiting

Voltage limiting can result from several causes e.g. a magnet being swept too fast, a magnet quench or a superconducting switch breaking open.

Two voltage limits exist, fast hardware voltage limits (usually set to +/- 10 volts), and slow software voltage limits. In normal use, the power supply output voltage will stay within both sets of limits. However, if a limit is exceeded the power supply will go into "catch" mode and stabilise the magnet system by matching the power supply current to the magnet current. Whilst voltage limiting the display will flash as there may be a discrepancy between the actual power supply output current and the displayed current.

Software voltage limits are usually set to be just below the voltage of the magnet protection network. Exceeding this limit means that current must be in the protection network, if the condition persists for more than a preset period (e.g. 2 seconds), the magnet will be "caught". As the power supply continuously monitors the voltage drop due to the magnet lead resistance there is no need to make allowance for this in setting software limits, see section 8.5.

When the power supply first reaches a voltage limit, the power supply output is recorded as the trip current, displayed by pressing HOLD and display SET POINT (see above). When a magnet has been "caught" the power supply is left in its HOLD state and the (persistent) magnet current and polarity are updated (thus an accurate record of magnet

current is kept even if a superconducting switch should heal at a current different from that at which the operator last turned off the switch heater).

4.3 Metering

Analogue meters are mounted on the front panel and will indicate the actual output Current and Voltage of the power supply at all times, even if mains power is lost. They thus provide an important safety feature.

Connections to the magnet should never be broken unless <u>both</u> meters are at zero.

The Output Current scale is marked FORWARD and REVERSE, thus indicating current polarity as well as magnitude . A more accurate digital indication of magnet current may be obtained from digital display on the control unit. However if the power supply should be voltage limiting, the digital display will no longer represent the actual current. Under these circumstances the display will flash, to warn the operator.

The Output Voltage meter is configured such that its polarity matches that of the magnet. Thus the scale is marked CHARGE and DISCHARGE referring to the magnet (rather than referring to the power supply output terminals with names such as PLUS and MINUS).

4.4 First Time Operation

For a first-time test, it is suggested that the power supply be operated into a short circuit, by linking the output terminals together with a shorting bar. Once the operation of the power supply is familiar, the short may be removed and the supply connected to a magnet.

Switch on the miniature circuit breaker mounted on the rear panel of the power supply and marked "ISOLATION". This switch should now be left in the on position, the front panel ON/OFF switch is for every-day use.

The red STANDBY lamp should be lit, indicating that mains power is connected. Switch on the instrument by means of the ON/OFF switch on the front panel, the STANDBY lamp will extinguish and the green POWER ON lamp illuminates.

After about one second a message such as "PS2.02" will appear on the display. This shows the firmware version and indicates that the power supply has completed its self test and initialisation.

The unit will always power up at zero current, with the output clamped and under LOCAL control.

Decide if the power supply output should be expressed as a current or an equivalent field and if necessary change the display using the CURRENT/FIELD button.

Use the SET POINT and SET RATE buttons to check that these values are as required. (Both parameters are retained in non- volatile memory when power is off). Modify the values if required, by pressing RAISE, LOWER and CHANGE POLARITY whilst holding the appropriate SET button pressed.

If sweeping a switched magnet to field, then turn on the heater by pressing the SWITCH HEATER button, wait 15 seconds for the switch to open.

Press the HOLD button, causing the clamp to release and connecting the magnet in the SET POINT direction.

The power supply output may now be controlled by the HOLD, ZERO and SET POINT buttons.

The display on the control unit will indicate the current being delivered by the power supply or the equivalent field, unless a voltage limit is reached, in which case it will flash, whilst indicating the target output.

4.5 Setting Switch Heater Current

When the power supply has been supplied with a magnet, the switch heater current will have been set to an optimum value during final system testing. If this needs adjusting for another magnet, the control on the rear panel marked "SET SWITCH HEATER CURRENT" should be used to vary the heater current. The current may be observed by connecting a milliammeter in series with one of the switch heater leads. The current is normally set to the minimum value at which the switch will open reliably after 10-15 seconds.

SECTION 5. REMOTE OPERATION

5.1 Introduction

The power supply may be remotely operated by means of its RS232 interface. This allows a computer to interrogate the supply and if required, to take control of it.

When in control, the computer has the option of locking out all the front panel controls, or of allowing the front panel LOC/REM control to remain active, so that an operator may restore LOCAL operation if required.

5.2 Communication Protocols

All dialogue with the power supply is in 9600 baud serial form.

Data sent by the power supply is in the form of 1 start bit, 8 data bits and 2 stop bits.

Data sent by the power supply during normal operation has the 8th (parity) bit always set to zero. When receiving normal data, the power supply ignores the parity bit. (In the "Y" and "Z" diagnostic commands, all 8 bits are used for data).

All commands consist of a string of printing ASCII characters, terminated by a Carriage Return character. A Line Feed character may optionally be sent after the Carriage Return but is ignored by the power supply.

Unless the command starts with a "$" (dollar) character, all commands will evoke a response from the power supply. The response will consist of a string of one or more printing ASCII characters and will be terminated by a Carriage Return Character. This may optionally be followed by a Line Feed character.

The response will normally be sent immediately following the command. If a front panel button is pressed when the command is received, the response may be delayed until the button is released.

If the first character of a command is a "$", the command will be obeyed but no response will be sent. (See section 5.5).

None of the RS232 Modem control lines are required by the power supply, though signals are returned on some of the more common ones for maximum compatibility with other equipment.

The power supply will accept a command string at all times. If a computer is unable to accept data from the power supply at the full rate of the 9600 baud interface, the "W" command may be used to instruct the power supply to send more slowly. (See section 6.1).

5.3 Commands and Responses

Commands to the power supply all consist of a single upper-case letter, optionally followed by a numeric parameter, the whole being terminated by a Carriage Return. The response sent by the power supply varies depending on the command. Usually it consists of the command letter received, followed by the value of any data requested. Where a command instructs the power supply to carry out an action rather than to send data, the command letter alone will be returned.

If a command is not recognised, has an illegal parameter or cannot be obeyed for any reason, an error response will be sent. This consists of a "?" (question mark), followed by all or part of the command string in question. To simplify error handling in the computer, the "?" will always be the first character returned.

The most common reason for a command error is attempting to execute a control command whilst the power supply is in LOCAL control. If in doubt, the "X" command may be used to determine the current status.

5.4 Numeric Parameters

All numeric parameters are treated as signed integers and are sent as a string of decimal digits. The range of acceptable numbers is -32768 to +32767. Alternatively, positive numbers in the range 0 to 65535 will be accepted, if preceded by a "#" (hash) symbol. Numbers outside this range will give an error.

For positive numbers, the "+" sign is optional, as are leading zeros. Any spaces, full stops and commas embedded within the number are ignored.

Thus to set a target current of 20.00 amps the preferred command form is:

I2000

The alternative:

I20.00

would be accepted and correctly obeyed, but the alternatives:

I20 and I20.0

would result in set currents of 0.2 amps or 2.0 amps respectively. Hence unless you can be confident that your computer will always send a specific number of decimal places, it is preferable to convert all data to integers.

For example in BASIC, the instruction:

```
LET N = INT(100*CURRENT)
```

might be used.

The same convention is adopted by the power supply in returning numbers to the computer. Thus 23.09 would be returned as +02309.

The convention of sending all numbers as integers has been adopted to maintain compatibility with the maximum number of computers. It avoids any problems caused by the various formats used by different machines, to represent floating point numbers.

5.5 Use with OXFORD ISOBUS

The OXFORD ISOBUS allows a number of instruments to be driven in parallel from a single RS232 port on a computer, using a special cable assembly.

To allow separate instruments to be distinguished, each is allocated a unique address in the range 1 to 9. Depending on the instrument this may be set up in hardware, or held in non-volatile memory. In the case of this power supply the latter option is used.

When operating on ISOBUS an instrument must be able to recognise and respond to commands addressed to it, whilst ignoring commands addressed to other instruments. This is achieved by starting all commands with a special ISOBUS control character.

When more than one powered-up instrument is connected on ISOBUS, no command should be issued which does not have an ISOBUS control character as its first character. Issuing such a command would result in an unintelligible response, as all instruments would reply together. (N.B. This will only result in lost data. No hardware damage will be caused).

Following the control character and its parameter (where required), the rest of the command follows the form described above. The response of the instrument depends on the initial control character in the following manner:

@n (At) addresses the command to instrument number n, where n is a digit in the range 1 to 9. This instrument obeys the command and returns its usual response. All other instruments ignore the command and send no reply.

$ (Dollar) instructs all instruments to send no reply. This is normally used to precede a command being sent to all instruments simultaneously, and prevents a conflict as they all echo the command together.

It may also be used in non-ISOBUS applications if the computer does not wish to receive a response.

It should be used with caution however, since all responses are suppressed, including the "?" error response. Thus the computer has no way of knowing if a command has been received or even if the instrument is connected.

If a command is to be addressed to a specific instrument, but no reply is required, it is permissible to use "$" and "@n" together. The "$" should always come first.

& (Ampersand) instructs an instrument to ignore any following ISOBUS control characters. It is included in the ISOBUS protocol to allow instruments whose command repertoire includes "@", "$", "&" or "!" to be used on ISOBUS. The power supply does not require the use of this command.

!n (Exclamation) instructs the instrument that from now on, its address is to be n. This command is included here since it is relevant to ISOBUS operation. However for obvious reasons, it should not be sent when more than one instrument is powered up and connected to ISOBUS. (It would result in all instruments having the same address!). The command is intended for initial setting up of instruments, one at a time. To avoid inadvertently changing addresses, the "!" command will only be obeyed following a "U" command with a non-zero password. (See section 6).

SECTION 6. COMMAND SYNTAX

For a more detailed explanation of the power supply states, the user should refer to section 4, Local Operation.

Commands fall into 4 categories:

MONITOR COMMANDS	which are always recognised.
CONTROL COMMANDS	which are only recognised when in REMOTE control.
FIELD STEP CONTROL COMMANDS	are commands which allow for direct control in discrete field steps. Only recognised when in REMOTE control.
SYSTEM COMMANDS	which are only recognised after receipt of the correct "UNLOCK KEY".

In the lists which follow "n" & "m" represent decimal digits 0-9.

6.1 Monitor Commands

Cn SET CONTROL (LOCAL/REMOTE/LOCK)

The control command sets the power supply into LOCAL or REMOTE and determines whether the LOC/REM button is LOCKED or active. At power up the power supply defaults to the C0 state. Allowed values are:

C0	LOCAL & LOCKED (Default State)
C1	REMOTE & LOCKED
C2	LOCAL & UNLOCKED
C3	REMOTE & UNLOCKED

Qn DEFINE COMMUNICATIONS PROTOCOL

Defines the communication protocol.
Currently only 8 values of n are significant:

Q0	"Normal" (Default Value)
Q2	Sends <LF> after each <CR>
Q16	Reduced Protocol (mimics PS126)
Q18	Reduced Protocol & <LF> after <CR>
Q48	Aerosonics Protocol (1.38 firmware or later)
Q50	(Aerosonics Protocol & <LF> after <CR>)
Q80	Aerosonics Protocol (1.37 firmware or earlier)
Q82	(Aerosonics Protocol & <LF> after <CR>)

The <LF> option is for use with computers that require an <LF> as an input message terminator. Reduced protocol simplifies the "X" status message (see below), and allows fewer options in the mode command. It is provided to allow some compatibility with the earlier PS126 power supply. The Aerosonics option, Q48, should be used for all VSM systems driven by 1.38 firmware or later. For VSM systems using 1.37 firmware or earlier, select Q80.

N.B. the Q command is volatile, when the power supply is switched off and on, the communication protocol reverts to a default value eg Q0. However, the power supply can be made to default to Reduced or Aerosonics Protocol by changing the "Magnet System Configuration", Test 06 in section 8.4.

Rnn READ PARAMETER nn

The READ command allows the computer to interrogate any of a number of variables. The returned value is always an integer as defined in section 5.4. Allowed values for n are listed below. Variables marked with a "*" are intended as service diagnostics and are unlikely to be of use to the user.

R 0	DEMAND CURRENT TO PSU (OUTPUT CURRENT)	
R 1	MEASURED POWER SUPPLY VOLTAGE	
R 2	MEASURED MAGNET CURRENT	
R 3	UNUSED	
R 4	DEMAND CURRENT (duplicate of R0)	
R 5	SET POINT (TARGET),	CURRENT A
R 6	SWEEP RATE,	CURRENT A/MIN
R 7	DEMAND FIELD (OUTPUT FIELD)	
R 8	SET POINT (TARGET),	FIELD T
R 9	SWEEP RATE,	FIELD T/MIN
R 10 *	LEAD RESISTANCE,	milli Ohm
R 11 *	CHANNEL 1 FREQ/4	
R 12 *	CHANNEL 2 FREQ/4	
R 13 *	CHANNEL 3 FREQ/4	
R 14 *	DACZ (PSU zero correction as a hexadecimal number)	
R 15	SOFTWARE VOLTAGE LIMIT	
R 16	PERSISTENT MAGNET CURRENT	
R 17	TRIP CURRENT	

R 18	PERSISTENT MAGNET FIELD
R 19	TRIP FIELD
R 20 *	IDAC (demand current as a hexadecimal number)
R 21	SAFE CURRENT LIMIT, MOST NEGATIVE
R 22	SAFE CURRENT LIMIT, MOST POSITIVE

Unnnnn UNLOCK FOR "!" AND SYSTEM COMMANDS

The UNLOCK command allows access to the SYSTEM commands. This set of commands is intended for diagnostic and configuration purposes and have the power to erase or modify the contents of the non-volatile memory. The U command must be followed by the correct KEY parameter before these "dangerous" commands may be used.

These commands should only be used after consultation with Oxford Instruments who will advise the correct KEY. (N.B. The Z command can do no harm and does not require a key).

A lower level of key protection is provided for the "L" and "!" commands, to avoid accidental errors. Allowed values of U are:

U0	LOCKED (Power-up Default)
U1	"L" and "!" COMMAND UNLOCKED
Unnnnn	"Y" COMMAND UNLOCKED

V READ VERSION

The VERSION command requires no parameters. It returns a message indicating the instrument type and software version number.

For example: "PS Version 2.02 (c) OXFORD 1991"

Wnnnn SET WAIT INTERVAL BETWEEN CHARACTERS

The WAIT command sets a delay interval before each character is sent from the power supply via the serial interface. This allows the power supply to communicate with a slow computer with no input buffering. The parameter nnnn specifies the delay in milliseconds. It defaults to zero at power-up.

W 0300 means 300 ms

(N.B. the W command does not reduce the rate at which the power supply can accept data from computer.)

X EXAMINE STATUS

The EXAMINE command allows the computer to read the current power supply STATUS. It requires no parameters and will return a message string of the form:

XmnAnCnHnMmnPmn

where the digits "m" & "n" have the following meaning:

Xmn	SYSTEM STATUS	
	m=0	NORMAL
	m=1	QUENCHED
	m=2	OVER HEATED
	m=4	WARMING UP
	n=0	NORMAL
	n=1	ON POSITIVE VOLTAGE LIMIT
	n=2	ON NEGATIVE VOLTAGE LIMIT
	n=4	OUTSIDE NEGATIVE CURRENT LIMIT
	n=8	OUTSIDE POSITIVE CURRENT LIMIT
An	ACTIVITY	(n as for A command)
	n=0	HOLD
	n=1	TO SET POINT
	n=2	TO ZERO
	n=4	CLAMPED
Cn	LOC/REM/LOC STATUS (n as for C command)	
	n=0	LOCAL & LOCKED
	n=1	REMOTE & LOCKED
	n=2	LOCAL & UNLOCKED
	n=3	REMOTE & UNLOCKED
	n=4	AUTO-RUN-DOWN
	n=5	AUTO-RUN-DOWN
	n=6	AUTO-RUN-DOWN
	n=7	AUTO-RUN-DOWN
Hn	SWITCH HEATER	(n as for H command)
	n=0	OFF (switch closed) MAGNET AT ZERO
	n=1	ON (switch open)
	n=2	OFF (switch closed) MAGNET AT FIELD
	n=8	NO SWITCH FITTED

Mmn MODE (m as for M command)

	Display	Mode	Magnet Sweep
m=0	AMPS	IMMEDIATE	FAST
m=1	TESLA	IMMEDIATE	FAST
m=2	AMPS	SWEEP	FAST
m=3	TESLA	SWEEP	FAST
m=4	AMPS	IMMEDIATE	TRAIN
m=5	TESLA	IMMEDIATE	TRAIN
m=6	AMPS	SWEEP	TRAIN
m=7	TESLA	SWEEP	TRAIN
n=0	AT REST		(output constant)
n=1	SWEEPING		(output changing)
n=2	RATE LIMITING		(output changing)
n=3	SWEEPING & RATE LIMITING		(output changing)

The active states "SWEEPING" and "RATE LIMITING" indicate the mode in which the output current is changing.

A changing output in IMMEDIATE mode (e.g. magnet persistent) will be flagged by RATE LIMITING only. In SWEEP mode (e.g. changing the magnet current) only SWEEPING should be flagged, but if the attempted sweep rate exceeds the sweep rate limit, RATE LIMITING will also be indicated.

Pmn POLARITY

	Desired	Magnet	Commanded
m=0	FORWARD	FORWARD	FORWARD
m=1	FORWARD	FORWARD	REVERSE
m=2	FORWARD	REVERSE	FORWARD
m=3	FORWARD	REVERSE	REVERSE
m=4	REVERSE	FORWARD	FORWARD
m=5	REVERSE	FORWARD	REVERSE
m=6	REVERSE	REVERSE	FORWARD
m=7	REVERSE	REVERSE	REVERSE
n=0	OUTPUT CLAMPED(Transition)		
n=1	FORWARD	(Verification)	
n=2	REVERSE	(Verification)	
n=4	OUTPUT CLAMPED(Requested)		

Desired Polarity — is the final or target polarity, it is the polarity of the SET POINT current.

Magnet Polarity — is the polarity of the power supply last time the magnet was left persistent.

Commanded Polarity — is the present polarity of the power supply unless, that is, the output is clamped for any reason.

Forward & Reverse Verification	indicates the actual state of the change-over switch.
Output Clamped Transition/Request	both signals indicate that the power supply is in the clamped state.

X EXAMINE STATUS, REDUCED PROTOCOLS

For Reduced Protocol or Aerosonics Protocol, as selected by the Q16 or Q48 commands respectively, EXAMINE will not transmit the "m" digit for the X, M & P entries. The complete response becomes:

XnAnCnHnMnPn

where "n" has the same meaning as for the normal EXAMINE response, except:

for Reduced Protocol;

Mn	MODE		
	n=0	IMMEDIATE MODE	(ignore SWEEP RATE)
	n=1	SWEEP MODE	(follow SWEEP RATE)

and for Aerosonics Protocol;

Mn	MODE	
	n=1	ALWAYS

6.2 Control Commands

An SET ACTIVITY (HOLD/UP/DOWN/CLAMP)

The ACTIVATE command corresponds to the use of the HOLD, SET POINT and ZERO buttons on the front panel, a fourth state, CLAMP, can also be selected, corresponding to the state in which the PS120-10 powers up. Allowed values for n are:

A0	HOLD
A1	TO SET POINT
A2	TO ZERO
A4	CLAMP (Clamp the power supply output)

When the power supply is in its clamped state, A1 and A2 will not be recognised.

Fnn SET FRONT PANEL TO PARAMETER nn

The FRONT PANEL DISPLAY command sets the display to show one of the internal parameters rather than the normal demanded current or field. "nn" may take the same values as for the "R" command above, with the same significance. Normal display operation may be restored by sending an F0 or F7 command for current or field display respectively, by an M command which automatically sets the correct display for the selected mode or by pressing the CURRENT/FIELD button twice. The command is intended chiefly for use during test and fault diagnosis.

Hn SET SWITCH HEATER (OFF/ON)

The HEATER command activates the switch heater, controlling the superconducting switch, if fitted. Allowed values for n are:

H0	HEATER OFF	(CLOSE SWITCH)
H1	HEATER ON IF PSU=MAGNET	(OPEN SWITCH)
H2	HEATER ON, NO CHECKS	(OPEN SWITCH)

The H1 command will only open the switch if the recorded magnet current and polarity are equal to the present power supply output current and polarity (+/- zero amps are considered equal). The H2 command performs no such check, and will open the switch regardless of any apparent conflict.

N.B. i) After issuing a command it is necessary to wait several seconds for the switch to respond before assuming that it has changed state.

ii) Changing the state of the switch heater will automatically set sweep or immediate mode. Immediate mode is selected only if a superconducting switch is fitted and is closed. Otherwise the control of the power supply

is always in sweep mode. Note that in immediate mode, changes occur at a limiting rate eg. 240 amp/minute, not as an instantaneous step. In sweep mode, changes occur at a rate specified by the S or T command, unless this would exceed the rate limit.

Innnnn SET TARGET CURRENT

The I command sets the SET POINT (target) current to which the power supply will sweep. The parameter nnnnn is the required current in units of 0.01 Amp sent as an integer in accordance with section 5.4 and should be positive. Current polarity is defined by a previous or subsequent P command.

Jnnnnn SET TARGET FIELD

The J command sets the SET POINT (target) field to which the power supply will sweep. The parameter nnnnn is the required field sent as an integer in accordance with section 5.4, eg in units of 0.001 Tesla, the integer should be positive. Field polarity is defined by a previous or subsequent P command.

Mn SET MODE

The MODE command selects CURRENT or FIELD mode for the display, selects SWEEP or IMMEDIATE response to changes in demand and selects FAST or TRAIN maximum sweep rates for the magnet. Usually the user will require only to toggle the display between "Amps" and "Tesla", for which M8 and M9 will suffice.

Mn may take the following values:

	Display	Mode	Magnet Sweep
M0	AMPS	IMMEDIATE	FAST
M1	TESLA	IMMEDIATE	FAST
M2	AMPS	SWEEP	FAST
M3	TESLA	SWEEP	FAST
M4	AMPS	IMMEDIATE	TRAIN
M5	TESLA	IMMEDIATE	TRAIN
M6	AMPS	SWEEP	TRAIN
M7	TESLA	SWEEP	TRAIN
M8	AMPS	Unaffected	Unaffected
M9	TESLA	Unaffected	Unaffected

SWEEP/IMMEDIATE In immediate mode, changes occur at a limiting rate eg. 240 amp/minute, not as an instantaneous step. In sweep mode, changes occur at a rate specified by the S or T command

(the sweep rate), unless this would exceed the rate limit. The limiting rates are variables, see section 8.5.

Normally sweep and immediate modes should be left to the adjudication of the power supply. Immediate mode is selected only if a superconducting switch is fitted and is closed. Otherwise the control of the power supply is always in sweep mode.

FAST/TRAIN

This facility protects the magnet from damage due attempting to sweep too fast. Two maximum magnet sweep rate profiles are allowed. FAST is the power up state and is restored whenever the power supply is clamped. TRAIN is intended for magnets that may need training after they have been warmed and for that period must then be run at lower sweep rates. The limiting rates are variables, see section 8.5.

Mn **SET MODE, REDUCED PROTOCOLS**

For Reduced Protocol, as selected by the Q16 command, Mn has the same meanings as those described in the Reduced Protocol EXAMINE (X) command.

M0	IMMEDIATE MODE	(ignore SWEEP RATE)
M1	SWEEP MODE	(follow SWEEP RATE)

However, if Aerosonics Protocol has been set, eg by the Q48 command, then SWEEP MODE can not be selected by the M command.

M0	IMMEDIATE MODE	(ignore SWEEP RATE)
M1	IMMEDIATE MODE	(ignore SWEEP RATE)

Pn **SET POLARITY (FWD/REV/CHANGE-OVER)**

The POLARITY command sets the desired polarity of the output current. If the activity is set to SET POINT and the polarity is to be changed, the power supply will cause a sweep to zero, change the polarity of the magnet and then sweep up to the set point current. Allowed values for P are:

P0	NO ACTION
P1	SET FORWARD
P2	SET REVERSE
P4	SWAP POLARITY

Snnnnn SET SWEEP RATE (AMPS/MINUTE)

The SWEEP RATE command sets the sweep rate (Amps/Minute) determining the rate at which the power supply will sweep the current in SWEEP mode. The parameter nnnnn is the required sweep rate in units of 0.01 Amp/Min. sent as an integer in accordance with section 5.4. The sweep rate selected will only apply when the power supply is operated in SWEEP mode, eg. when the superconducting switch is open. However it is not necessary for the PSU to be in sweep mode when the S command is issued.

Tnnnnn SET SWEEP RATE (TESLA/MINUTE)

The SWEEP RATE command sets the sweep rate (Tesla/Minute) determining the rate at which the power supply will sweep the magnet field. The parameter nnnnn is the required sweep rate sent as an integer in accordance with section 5.4, eg in units of 0.001 Tesla/Min. The sweep rate selected will only apply when the power supply is operated in SWEEP mode, eg. when the superconducting switch is open. However it is not necessary for the PSU to be in sweep mode when the T command is issued.

rate = 2.4 amp/min 0 → 59
1.2 amp/min 59 → 72
0.6 amp/min 72 → set value

6.3 Field Step Control Commands

For which there are no equivalent front panel commands.

Dn **SET DELTA GAUSS (FOR G, O and B)**

The DELTA command sets the step size to be used by the G, O and B commands. The units of D are gauss or 0.1 millitesla, the maximum value that will be accepted is 25 gauss.

Delta may be redefined at any time but, for obvious reasons, this should only be done with caution if the power supply is delivering current.

Gnnnnn **GOTO FIELD**

The GOTO command is similar to the Jnnnnn command but the units differ. Gnnnnn sets a target field in multiples of DELTA Gauss, that is:

SET POINT = (G)nnnnn * (D)n

The parameter nnnnn should be a positive integer, the field polarity is defined by a previous or subsequent P command.

O **STEP FIELD ON**

The ON command steps the field on by an amount defined by the DELTA command. Attempts to step the field beyond the maximum allowed will result in the value being limited.

B **STEP FIELD BACK**

The BACK command steps the field back by an amount defined by the DELTA command. If this would take the field below zero, the field will be limited at zero.

6.4 System Commands

L LOAD CALIBRATION

The LOAD command allows access via the serial link to part of the power supply calibration menu described in section 8.3. At present only L14 is enabled and allows the measured power supply voltage and current to be nulled. This should obviously only be performed when the voltage and current are known to be at zero and ideally when a short circuit rather than a magnet is connected.

The L commands are non-standard to the extent that they do not echo an "L" until they are complete.

To avoid unintentional use of the L command, these commands will not be obeyed unless a non-zero value of the "U" key has been supplied.

Y LOAD ENTIRE RAM CONTENTS

The Y command allows the entire contents of the RAM memory to be loaded in binary, via the serial interface. It is not intended as a user command and will only be obeyed after a correct "U" password.

Z DUMP ENTIRE RAM CONTENTS

The Z command allows the entire contents of the RAM memory to be dumped in binary, via the serial interface. It is not intended as a user command.

! SET ISOBUS ADDRESS

See section 5.5

SECTION 7. AUTO-RUN-DOWN

Auto-run-down will automatically de-energise a magnet system. It does not provide a particularly fast means of doing so. It is primarily intended for use with a helium level meter as a means of protecting a magnet from damage should the helium level in the magnet cryostat drop too far.

The auto-run-down function is invoked via the rear panel connector marked "PARALLEL I/O". See section 3.8.

While auto-run-down is active, local and remote control are locked out and the lights in the front panel section marked "CONTROL" will flash. The operator may only regain control when the auto-run-down signal is removed.

The following sequence of actions are performed when auto-run-down is active:-

i) If the magnet is persistent, CLAMP the power supply and turn on the switch heater. Wait 20 seconds for the system to stabilise. Then open the clamp.

ii) If the magnet is not persistent or after i), de-energise the magnet in a low-voltage mode e.g. +/- 1 volt.

iii) When the magnet is de-energised, wait 20 seconds to ensure no further activity, then clamp the output and turn off the switch heater (if fitted).

SECTION 8. TEST MODE

8.1 Entry to Test Mode

The power supply performs a basic self test of the microprocessor and memory at switch on, before displaying the firmware version message e.g. "PS2.02". A more detailed hardware test mode is accessed by one of two methods, either press the internal RED button, SW1, on the digital circuit board; or, hold in the CHANGE POLARITY button then press LOC/REM, RAISE and LOWER all at the same time. This will result in the message "tESt", which will shortly be followed by the test menu, consisting of a letter "t" and an integer. Test routines which may be of use to the user are described below.

Selecting a given test involves using RAISE and LOWER to display the test number required, then pressing LOC/REM to activate the test. Note that "t 00" is the correct route for exit.

** WARNING **

A complete memory initialisation may be achieved by pressing the internal RED button whilst holding both RAISE and LOWER pressed. This is a drastic measure which will destroy all the calibration data held in the non-volatile memory and so necessitate a complete re-calibration of the power supply. It should be used only if the memory content is known to be corrupt.

8.2 Test Menu

On entering test mode the message "tESt" is displayed, which will shortly be followed by the test menu, consisting of a letter "t" and an integer; initially, "t 00" will be displayed. RAISE and LOWER may be used to step through the menu options, when the required option is displayed, pressing LOC/REM will select it. The menu is cyclic, so that pressing RAISE when t 07 is displayed, will cycle back to t 00.

The Test Options are:

t 00	RESUME OPERATION (EXIT)
t 01	TEST DISPLAY AND LEDS
t 02	TEST BUTTONS
t 03	DUMP THE CONTENTS OF THE INPUT BUFFER
t 04	SELECT "F" MENU (FRONT PANEL DISPLAY)
t 05	SELECT "P" MENU (POWER SUPPLY CALIBRATION)
t 06	MAGNET SYSTEM CONFIGURATION
t 07	SELECT "S" MENU (SUPERCONDUCTING MAGNET CALIBRATION)

Tests 1,2,3 and 4 are described below. Test 5,6 and 7 are described in sections 8.3 , 8.4 and 8.5 respectively.

Test 01 lights each LED or display segment in turn, then pulls each of the auxiliary output lines low in turn. When the test is complete, the unit returns to the test menu.

Test 02 tests the control buttons. When the test is entered, the display will be blank. If the buttons are pressed, one at a time, each should light a single segment in the upper half of the display. Stuck buttons will give a permanently lit segment. If more than one segment lights for a single button, track shorts are indicated. To leave test 2, POWER must be switched off.

Test 03 dumps the content of the serial input buffer back via the serial output buffer. It may help in diagnosing communication problems.

Test 04, Front Panel Display Select ("F" Menu)
allows the front panel display to be set to indicate one of the internal parameters rather than the normal demand current. This produces the same effect as the "Fnn" command described in section 7, without the need to connect a computer.
When test 4 is selected, the display will show "F 00" RAISE and LOWER may be used to select an option in the range 0 to 31 for front panel display. The options are as given in the list for the "Rnn" command in section 5. When the required option has been selected, pressing LOC/REM will implement it. The power supply will return to normal operation but with the selected parameter on display. To restore a normal display "F 00" or "F 07" should be selected, alternatively press the CURRENT/FIELD button.
Options are:-

F 00	DEMAND CURRENT TO PSU (OUTPUT CURRENT)	
F 01	MEASURED POWER SUPPLY VOLTAGE	
F 02	MEASURED MAGNET CURRENT	
F 03	UNUSED	
F 04	DEMAND CURRENT (duplicate of F0)	
F 05	SET POINT (TARGET),	CURRENT A
F 06	SWEEP RATE,	CURRENT A/MIN
F 07	DEMAND FIELD (OUTPUT FIELD)	
F 08	SET POINT (TARGET),	FIELD T
F 09	SWEEP RATE,	FIELD T/MIN
F 10	LEAD RESISTANCE,	milli Ohm
F 11	CHANNEL 1 FREQ/4	
F 12	CHANNEL 2 FREQ/4	
F 13	CHANNEL 3 FREQ/4	
F 14	DACZ (PSU zero correction as a hexadecimal number)	
F 15	SOFTWARE VOLTAGE LIMIT	
F 16	PERSISTENT MAGNET CURRENT	
F 17	TRIP CURRENT	
F 18	PERSISTENT MAGNET FIELD	
F 19	TRIP FIELD	
F 20	IDAC (demand current as a hexadecimal number)	
F 21	SAFE CURRENT LIMIT, MOST NEGATIVE	
F 22	SAFE CURRENT LIMIT, MOST POSITIVE	

8.3 Test 05, Power Supply (Psu) Menu

The "Psu" menu provides access to a set of operations designed to be carried out when initially setting up a power supply. The majority will not be needed thereafter unless hardware changes are made.

"Psu" is entered from test 5 in the Test Menu, resulting in "PSU" being briefly displayed followed by "P" and an integer. RAISE and LOWER may be used to step through the menu and LOC/REM used to choose an option.

The table which follows lists the available options.

P 00	RESTART NORMAL OPERATION (Power-up restart)
P 01	NOT USED
P 02	DEFINE POWER SUPPLY CURRENT RANGE
P 03	ADJUST PSU ZERO CORRECTION
P 04	NOT USED
P 05	NOT USED
P 06	NOT USED
P 07	NOT USED
P 08	NOT USED
P 09	NOT USED
P 10	CALIBRATE PSU VOLTAGE AT NEGATIVE VOLTAGE LIMIT
P 11	CALIBRATE PSU VOLTAGE AT POSITIVE VOLTAGE LIMIT
P 12	AUTO-CALIBRATION OF MEASURED CURRENT
P 13	NOT USED
P 14	AUTO-ZERO POWER SUPPLY
P 15	NOT USED

Psu 02 defines the power supply current range and in the case of the PS120-10 this is always set to 120.00 amps. On entry, RAISE and LOWER may be used to shift the decimal point to the required position. Depress LOC/REM and use RAISE and LOWER to set the number required.

Oxford Instruments advises the user not to change the current range unless a precision high current shunt is available for re-calibration. Note that changing this parameter will also affect all other "Psu" and "Sup" calibrations. Perhaps what is required is Sup 2 ?

Psu 03 allows the power supply zero correction to be manually adjusted. On entry, the present value is displayed as a hexadecimal number, depressing LOC/REM allows this value to be adjusted over a small range.

For the duration of this test, the output of the power supply is unclamped in the forward direction, thus the offset current can be measured between the magnet terminals. An easy way of doing this is to place a 1 kohm resistor across the output, the "OUTPUT VOLTAGE" meter will now display the offset current to the scale of 1 mA/volt.

Psu 10 and Psu 11 calibrate the power supply voltage monitor. Psu 10 calibrates the measured voltage at the negative (hardware) voltage limit, normally about -10 volts. Psu 11 calibrates the measured voltage at the positive (hardware) voltage limit, normally about +10 volts.

These tests require existing connections to the "magnet" and "switch heater" terminals to be removed. A link should be connected between the positive magnet terminal and the positive switch heater terminal. A voltage meter set to read at least +/-10 volts should be connected from the negative to the positive magnet terminals.

On entry to Psu 10 or Psu 11, the power supply will display "PAUSE" as the output voltage sweeps to the (hardware) voltage limit. The display will then change to show the measured output voltage. To alter the calibration, depress LOC/REM and use RAISE and LOWER to set the display to the voltage measured on the external voltage meter. Releasing LOC/REM causes the output voltage to clamp and drop to about 1/10th of its normal value. Pressing the LOC/REM button once more to return to the "Psu" menu.

Exit from Psu 10 and Psu 11 must be via the correct route else corruption of the zero setting of the power supply will result. Pressing LOC/REM at any time will abort the test and return to the Psu menu.

If large adjustments are needed, it will probably be necessary to repeat Psu 10 and Psu 11 until both points are calibrated.

To change the hardware voltage limits, the power supply must be opened up and access obtained to the analogue pcb, CBD1300. To adjust the negative limit, enter Psu 10 as described above and adjust RV2 to set the required limit. To adjust the positive limit, enter Psu 11 as described above and adjust RV3 to set the required limit.

Psu 12 automatically calibrates the measured lead current of the power supply. This test requires existing connections to the "magnet" and "switch heater" terminals to be removed. A link should then be connected between the two magnet terminals.

After entering Psu 12, the calibration is performed automatically but the display indicates something of what is happening:-

i)	Display measured current
ii)	Sweep to the +ve current limit and allow to settle
iii)	Sweep to the -ve current limit and allow to settle
iv)	A gain calculation is now performed
v)	Sweep to zero and allow to settle
vi)	Null measured current
vii)	Display measured current for 2 second
viii)	Exit to "Psu" menu.

This calibration should only be performed when the power supply is "warm", that is, when it has been running for at least 15 minutes.

Psu 14 automatically zeros the voltage and then the current measured by the power supply. This test requires existing connections to the "magnet" and "switch heater" terminals to be removed. A zero ohm link should then be connected between the two magnet terminals.

After entering Psu 14, the zeroing is performed automatically but the display indicates something of what is happening:-

i)	Display measured voltage for 2 second
ii)	Null measured voltage
iii)	Display measured voltage for 2 second
iv)	Display measured current for 2 second
v)	Null measured current
vi)	Display measured current for 2 second
vii)	Exit to "Psu" menu.

This calibration should only be performed when the power supply is "warm", that is, when it has been running for at least 15 minutes.

The error message "driFt Error" will be displayed if the output voltage drifts while zeroing. Ensure that the link is correctly placed.

8.4 Test 06, Magnet System Configuration

Configuration defines what type of magnet system the power supply will be a part of. On entry to test 6, a number in the range 0 to 255 is displayed, this represents "configuration" and may be adjusted by pressing LOC/REM and using RAISE and LOWER, releasing LOC/REM returns to the test menu. The displayed, decimal, number represents an 8-bit binary number, where the bits have the following significance (Bit 0 is LSB):

Bit 0	Superconducting switch fitted.
Bit 1	Reduced communications protocol (mimic PS126).
Bit 2	Aerosonics, VSM system.
Bit 3	Unipolar version of the power supply.
Bit 4	20 volt version of the power supply.

Bits 1 and 2 of "configuration" have a similar function to Bit 4, 5 & 6 of the serial link "Q" command, only they are non-volatile. Corresponding values are:-

Configuration	Q Command
0 (or 1)	Q0 (or Q2)
2 (or 3)	Q16 (or Q18)
4 (or 5)	Q48 (or Q50)
6 (or 7)	Q80 (or Q82)

Bit 3. If a PS120-10 is configured as unipolar at the factory, the orange and yellow wires are disconnected from the reverse contactor coil, ensuring that the power supply can not possibly provide negative current.

The following are the most commonly required configurations:

0	PS120-10	No switch fitted
1	PS120-10	Switch fitted
4	Aerosonics, Post- 1.38 firmware.	
6	Aerosonics, Pre- 1.38 firmware.	
8	PS120-10	Unipolar, no switch fitted.
9	PS120-10	Unipolar, switch fitted.
16	PS120-20	No switch fitted
17	PS120-20	Switch fitted

8.5 Test 07, Superconducting Magnet (Sup) Menu

The "Sup" menu provides access to a set of operations designed to be carried out when initially setting up a power supply. The majority will not be needed thereafter unless hardware changes are made.

"Sup" is entered from test 7 in the Test Menu, resulting in "Sup" being briefly displayed followed by "S" and an integer. RAISE and LOWER may be used to step through the menu and LOC/REM used to choose an option.

The table which follows lists the available options.

S 00	RETURN TO TEST MENU
S 01	DEFINE AMPS/TESLA
S 02	DEFINE POWER SUPPLY CURRENT LIMIT
S 03	DEFINE LOWER (MOST NEGATIVE) SAFE CURRENT
S 04	DEFINE UPPER (MOST POSITIVE) SAFE CURRENT
S 05	DEFINE CURRENT BREAKPOINTS FOR RATE LIMITING
S 06	DEFINE LIMITING RATE FOR LEADS, MAGNET AT ZERO
S 07	DEFINE LIMITING RATE FOR LEADS, MAGNET AT FIELD
S 08	DEFINE LIMITING RATE FOR MAGNET, "FAST" RUN
S 09	DEFINE LIMITING RATE FOR MAGNET, "TRAIN" RUN
S 10	NOT USED
S 11	NOT USED
S 12	NOT USED
S 13	NOT USED
S 14	NOT USED
S 15	SOFTWARE VOLTAGE LIMIT

Sup 01 defines a linear constant relating current and field. On entry, the maximum available current is displayed and may be adjusted by depressing LOC/REM and using RAISE and LOWER. Releasing LOC/REM causes an equivalent field to be displayed, which again can be adjusted. Initially, RAISE and LOWER may be used to shift the decimal point to the required position, then press LOC/REM and use RAISE and LOWER to set the number required. For accuracy, the "amps" and "tesla" entered should be large, convenient numbers.

The error messages "rAtE Error" or "dPt Error" will be displayed if some of the numbers entered are too large for the internal registers. If this should happen reduce the numerical values or change the position of the decimal point for the field display.

Sup 02 defines the power supply current limit. On entry the present limit is displayed and may be adjusted by depressing LOC/REM and using RAISE and LOWER. It will not be possible to set a SET POINT current greater than this limit.

Sup 03 defines the lowest or most negative "safe" power supply current.

Otherwise as Sup 04.

Sup 04 defines the highest or most positive "safe" power supply current.

On entry the present safe current limit is displayed and may be adjusted by depressing LOC/REM and using RAISE and LOWER. If the two current limits are set to overlap then the error message "LAP Error" will be displayed.

If the measured current is outside these limits, the safe current output signal will not be given, see section 3.8.

Sup 05 defines the current breakpoints marking the end of each maximum rate of change segment. Sup 5 should be used in conjunction with Sup 6,7,8 and 9; "b n" marks in the breakpoint (b) table the transition from rate r=n to r=n+1.

On entry, "b 00" is displayed, select a particular breakpoint from 0 to 15 using RAISE and LOWER, then press and release LOC/REM to display this breakpoint current, depressing LOC/REM a second time allows the user to adjust the selected current with RAISE and LOWER, releasing LOC/REM returns to the "b" menu.

"b 00" is fixed at 0 amps and "b 15" is fixed at full output current, pressing LOC/REM whilst either of these breakpoints are displayed will cause a return to the "Sup" menu.

Sup 06 should be used to set the power supply's maximum rate of change of current when the magnet system has a superconducting switch fitted, and the magnet is persistent at zero field.

Otherwise as Sup 09.

Sup 07 should be used to set the power supply's maximum rate of change of current when the magnet system has a superconducting switch fitted, and the magnet is persistent at a non-zero field.

Otherwise as Sup 09.

Sup 08 should be used to set the power supply's maximum rate of change of current when running current into a normal, trained, magnet. Sup 8 defines the rates observed when "FAST" magnet sweep rate limits are selected.

Otherwise as Sup 09.

Sup 09 should be used to set the power supply's maximum rate of change of current when running current into a magnet that requires "training" after having been warmed. Sup 9 defines the rates observed when "TRAIN" magnet sweep rates are selected.

Sup 6, 7, 8 & 9 define the maximum rate of change in amps/minute for each maximum rate segment as defined in Sup 5; "r n" records in the rate (r) table the maximum rate of change between breakpoints b=n-1 and b=n.

On entry, "r 00" is displayed, RAISE and LOWER may be used to step to a particular segment from 0 to 15, press and release LOC/REM to display this maximum rate of change in amps/minute, depressing LOC/REM a second time allows the user to adjust the selected rate with RAISE and LOWER to a maximum value of 240.01 amps/minute, releasing LOC/REM returns to the "r" menu.

Pressing LOC/REM whilst "r 00" is displayed will cause a return to the "Sup" menu.

Sup 15 defines the characteristics of the software voltage limits. Two parameters can be set, the voltage at which limiting should occur and the period for which the limit must be exceeded before any limiting action is taken.

On entry, the software voltage limit is displayed and may be adjusted by depressing LOC/REM and using RAISE and LOWER. Positive and negative voltage limits are set to the same value. By continuously monitoring the resistivity of the magnet system, the power supply is able to take into account the voltage drop along the current leads. Thus the software voltage limit should be set to just less than the voltage at which the magnet protection circuit would start to conduct.

When LOC/REM is released the display will read "SPELL" for a second then a time period, the "dwell spell", will be displayed. If the output voltage should continuously exceed the software voltage limit for this period, then the power supply will be tripped into a "catch" mode (see section 4.2). The dwell spell is defined in units of 1/4 second and can be adjusted by depressing LOC/REM and using RAISE AND LOWER. Dwell spell can be set to any value between 2 and 254 inclusive (between 1/2 second and about 1 minute), trying to set the dwell spell to < 2 will display the error message "2 Error".

If the dwell spell is set to 255 (the maximum value) this function will be completely disabled. The power supply is usually shipped in this state.

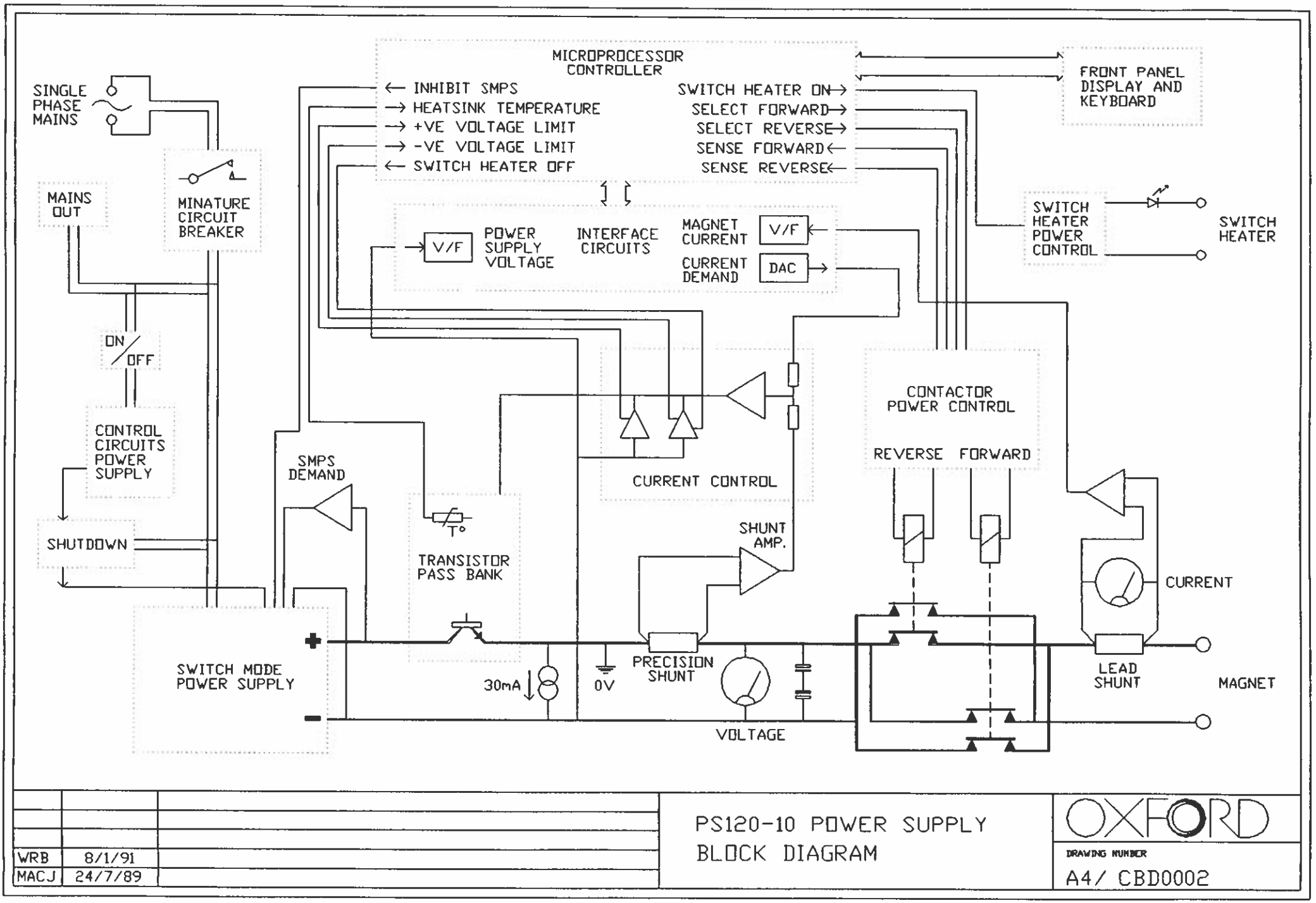
SECTION 9. SPECIFICATION

OUTPUT CURRENT	0-120 Amps DC REVERSIBLE
CURRENT SETABILITY	0.01 Amp
CURRENT STABILITY	
STANDARD	12 mA per hour (100 ppm)
HIGH STABILITY	3 mA per hour (25 ppm)
CURRENT SWEEP	Digitally Generated
SWEEP RATE	0.01 Amp/min to 240 Amp/min in units of 0.01 Amp/min
STEP SIZE	1.8 mA approx.
VOLTAGE COMPLIANCE	+10 Volts to -10 Volts
CURRENT NOISE/RIPPLE	Less than 0.2% of FSD
CURRENT REVERSING	Integral, interlocked to prevent operation except at zero current.
SWITCH HEATER OUTPUT	0-100 mA into 100 Ohms
RS232 INTERFACE	Configured as DCE
HANDSHAKE	None Required
BAUD RATE	9600 Baud
IEEE-488 INTERFACE	Option, via external convertor.
CONNECTORS	
POWER IN	3 pin "AMP" type CPC series 3
CURRENT OUTPUT	Rear Panel Terminals
SWITCH HEATER OUTPUT	Rear Panel Terminals
RS232	25 way D socket
AMBIENT TEMPERATURE	0-40 degrees C.
COOLING	
STANDARD & HIGH STABILITY	Forced Air
HIGH STABILITY ONLY:	Water
TEMPERATURE STABILITY	+/- 1 deg C in 0 to 40 deg C range
CONSUMPTION	1 litre / minute
MAXIMUM PRESSURE	10 bar

POWER REQUIREMENTS	200-240 V 50/60 Hz or 100-120 V 50/60 Hz
POWER CONSUMPTION MAXIMUM	3.3 kVA
DIMENSIONS FREE-STANDING	Height 223 mm Width 582 mm Depth 530 mm
RACK MOUNT	5U high
WEIGHT	34 Kg

SECTION 10. CIRCUIT DIAGRAMS

CBD0002		Block Diagram	
CBD1102		Key/Display PCB	
CBD1202	(1)	Digital PCB	CPU, Memory and Timing
	(2)	Digital PCB	Input/Output Ports
CBD1302	(1)	Analogue PCB	Current Control
	(2)	Analogue PCB	Analogue/Digital Interface
	(3)	Analogue PCB	Power Control
CBD1402		Pass Bank PCB	
CBD1602		Mains PCB and Wiring	
CBD2100		Front Panel Assembly	
CBD2902		Wiring Loom	

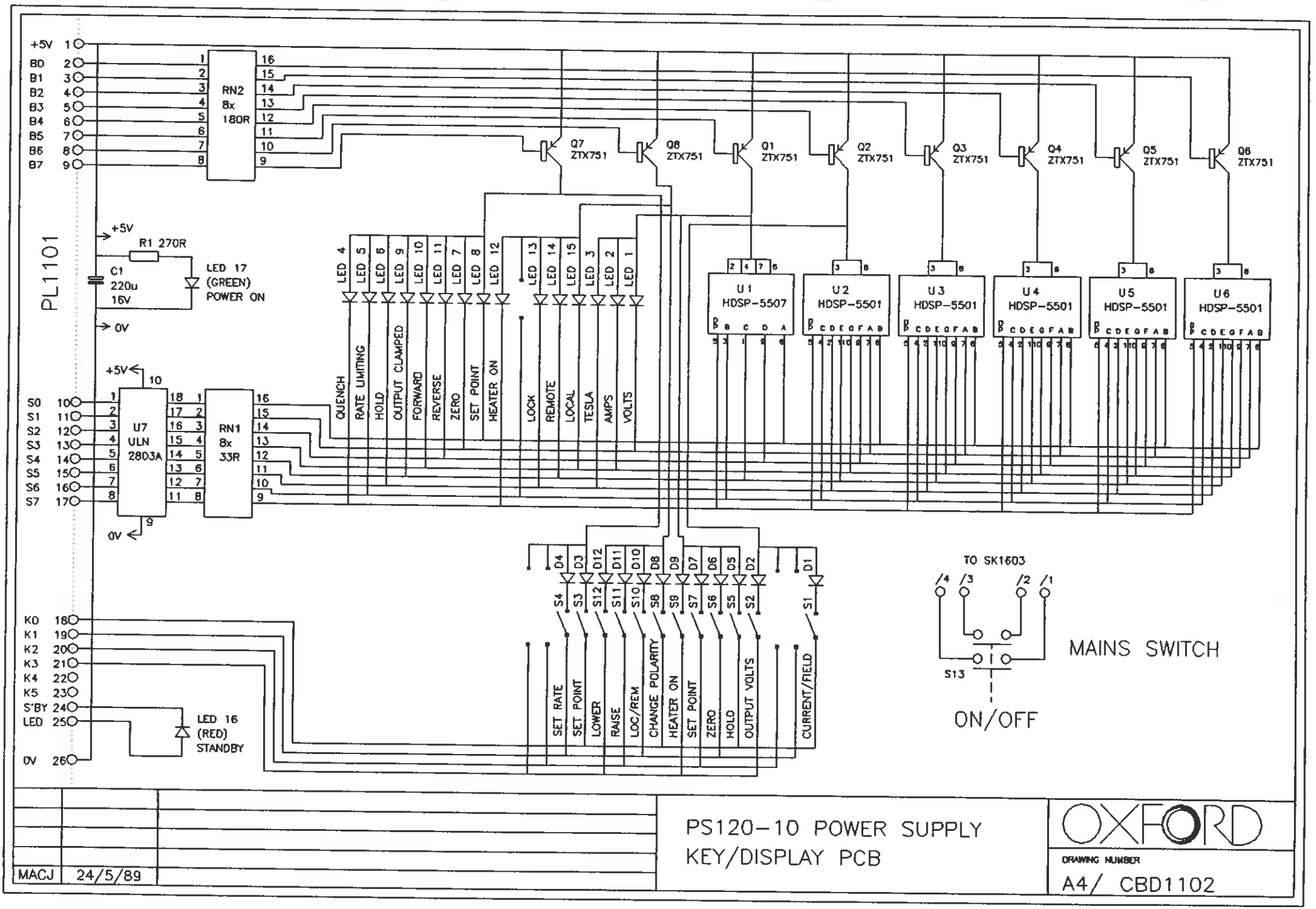


WRB	8/1/91	
MACJ	24/7/89	

PS120-10 POWER SUPPLY
BLOCK DIAGRAM

OXFORD

DRAWING NUMBER
A4/ CBD0002

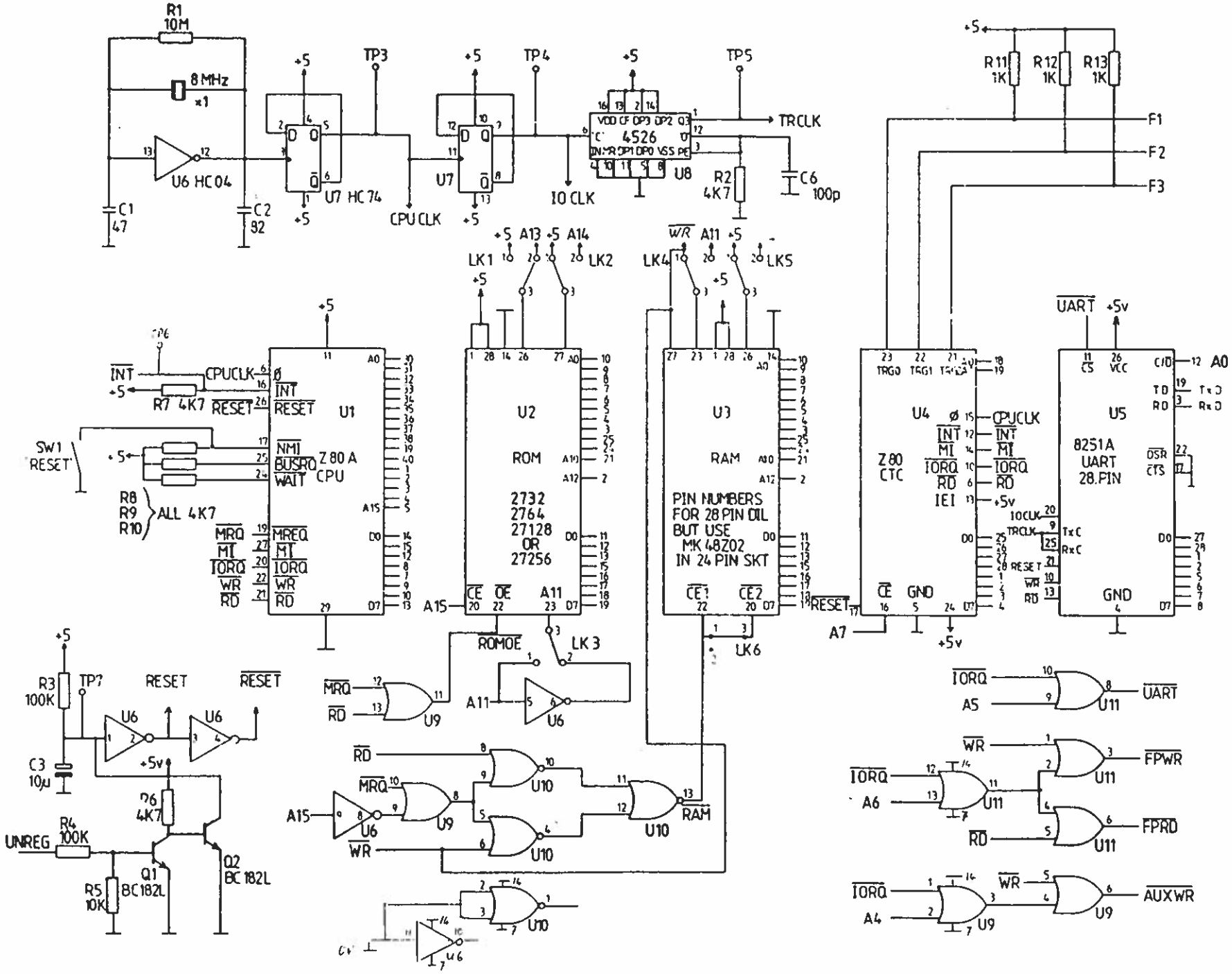


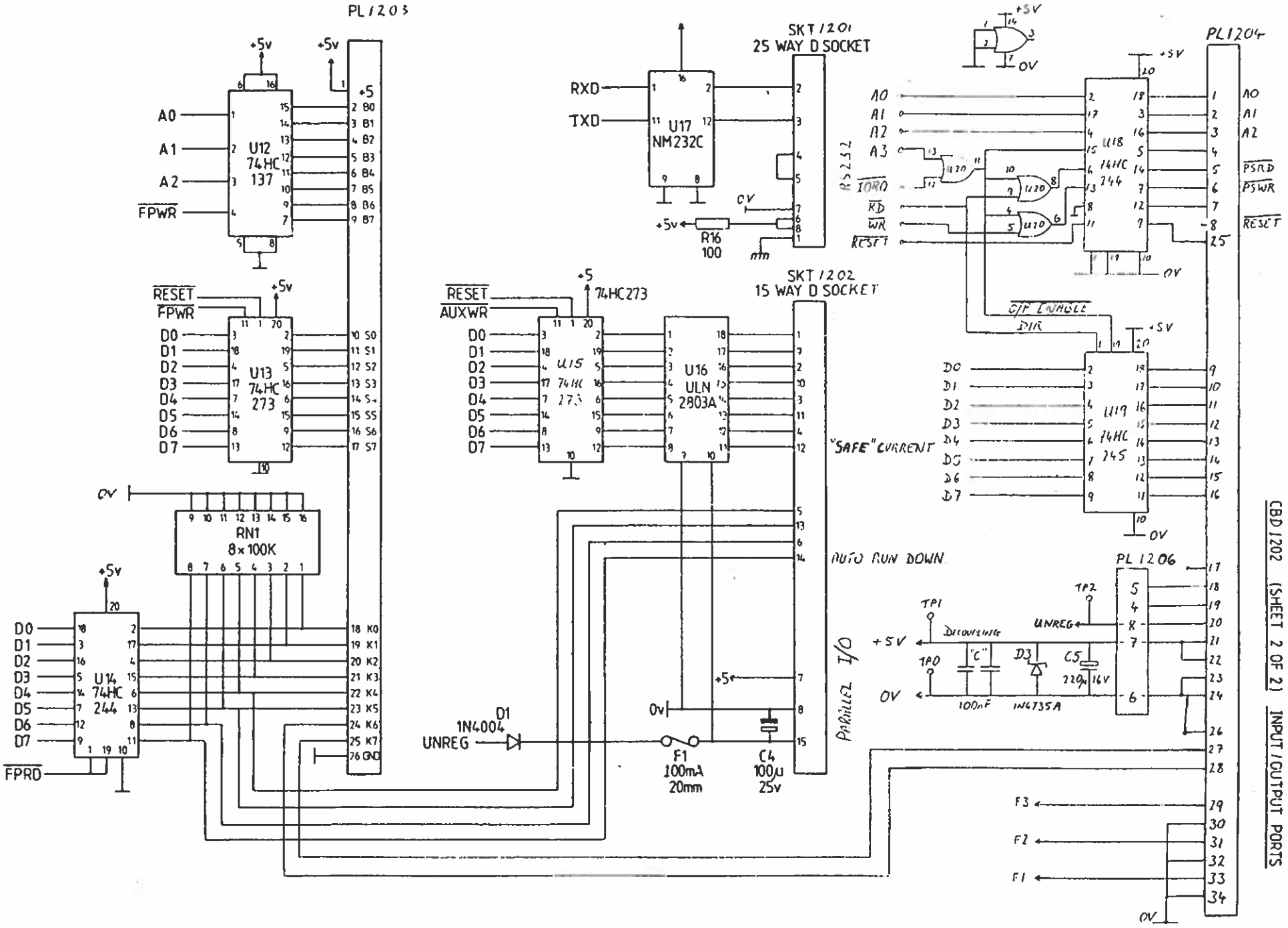
MACJ	24/5/89

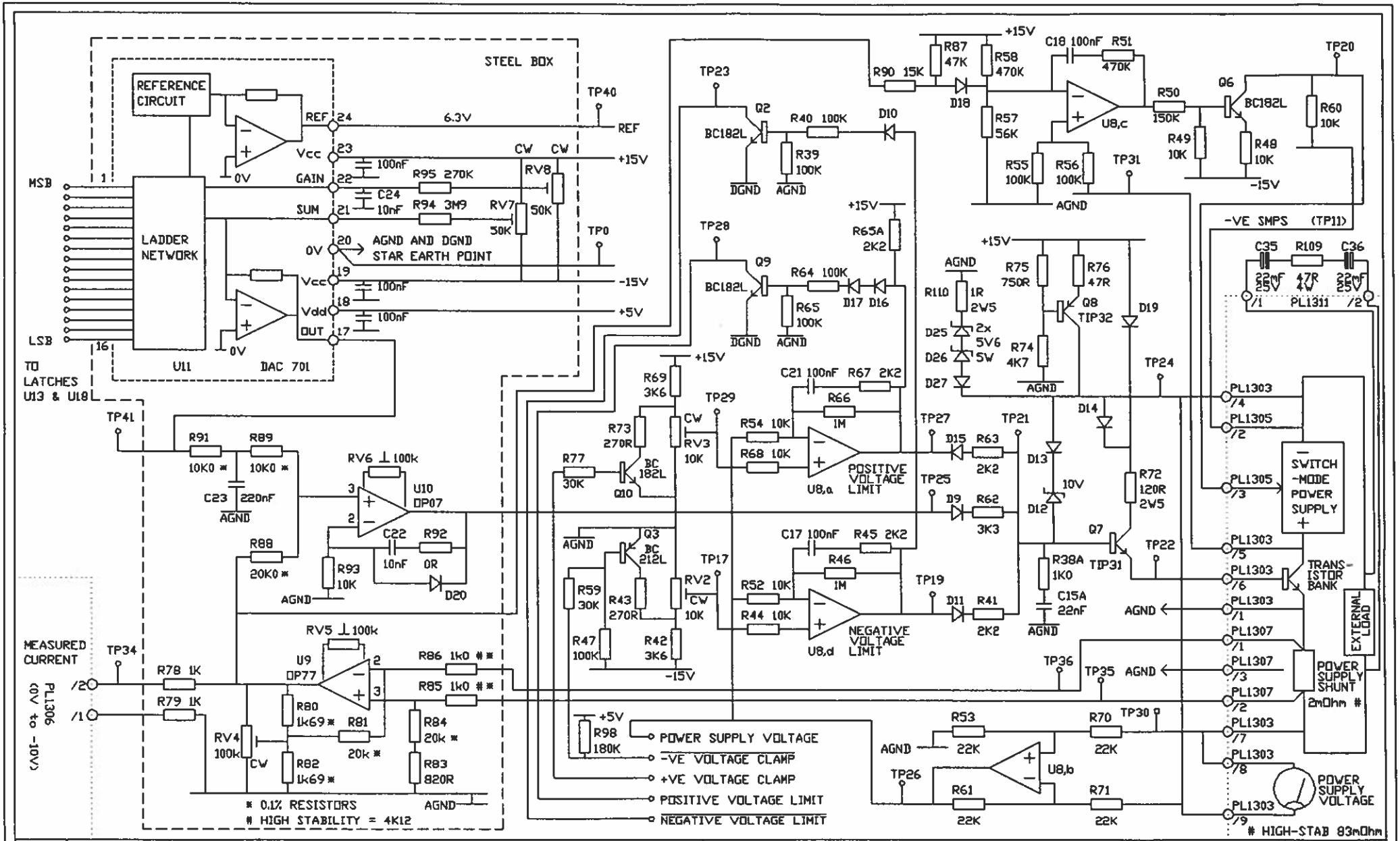
PS120-10 POWER SUPPLY
KEY/DISPLAY PCB

OXFORD

DRAWING NUMBER
A4/ CBD1102


R1
10M
8 MHz
x1
U6 HC04
C1
47
C2
82
U7 HC74
CPU CLK
IO CLK
U8
4526
TRCLK
R2
4K7
C6
100p
TP3
TP4
TP5
R11
1K
R12
1K
R13
1K
F1
F2
F3
LK1
LK2
LK3
LK4
LK5
LK6
U1
Z80A
CPU
U2
ROM
2732
2764
27128
OR
27256
U3
RAM
PIN NUMBERS
FOR 28 PIN DIL
BUT USE
MK 48Z02
IN 24 PIN SKT
U4
Z80
CTC
U5
8251A
UART
28 PIN
R7 4K7
SW1
RESET
R8
R9
R10
ALL 4K7
R3
100K
C3
10µ
R4
100K
R5
10K
R6
4K7
Q1
BC182L
Q2
BC182L
UNREG
ROMOE
RAM
UART
FPWR
FPRD
AUXWR
CBD 1202 (SHEET 1 OF 2)
CPU MEMORY AND TIMING


PL1203
SKT1201
25 WAY D SOCKET
SKT1202
15 WAY D SOCKET
PL1204
PL1206
U12 74HC 137
U13 74HC 273
U14 74HC 244
U15 74HC 273
U16 ULN 2803A
U17 NM232C
U18 74HC 244
U19 74HC 245
RN1 8x100K
74HC273
RS232
"SAFE" CURRENT
AUTO RUN DOWN
PARALLEL I/O
D1 1N4004
F1 100mA 20mm
C4 100µ 25v
R16 100
C5 22µ 16V
100nF
IN4735A
CBD1202 (SHEET 2 OF 2) INPUT/OUTPUT PORTS



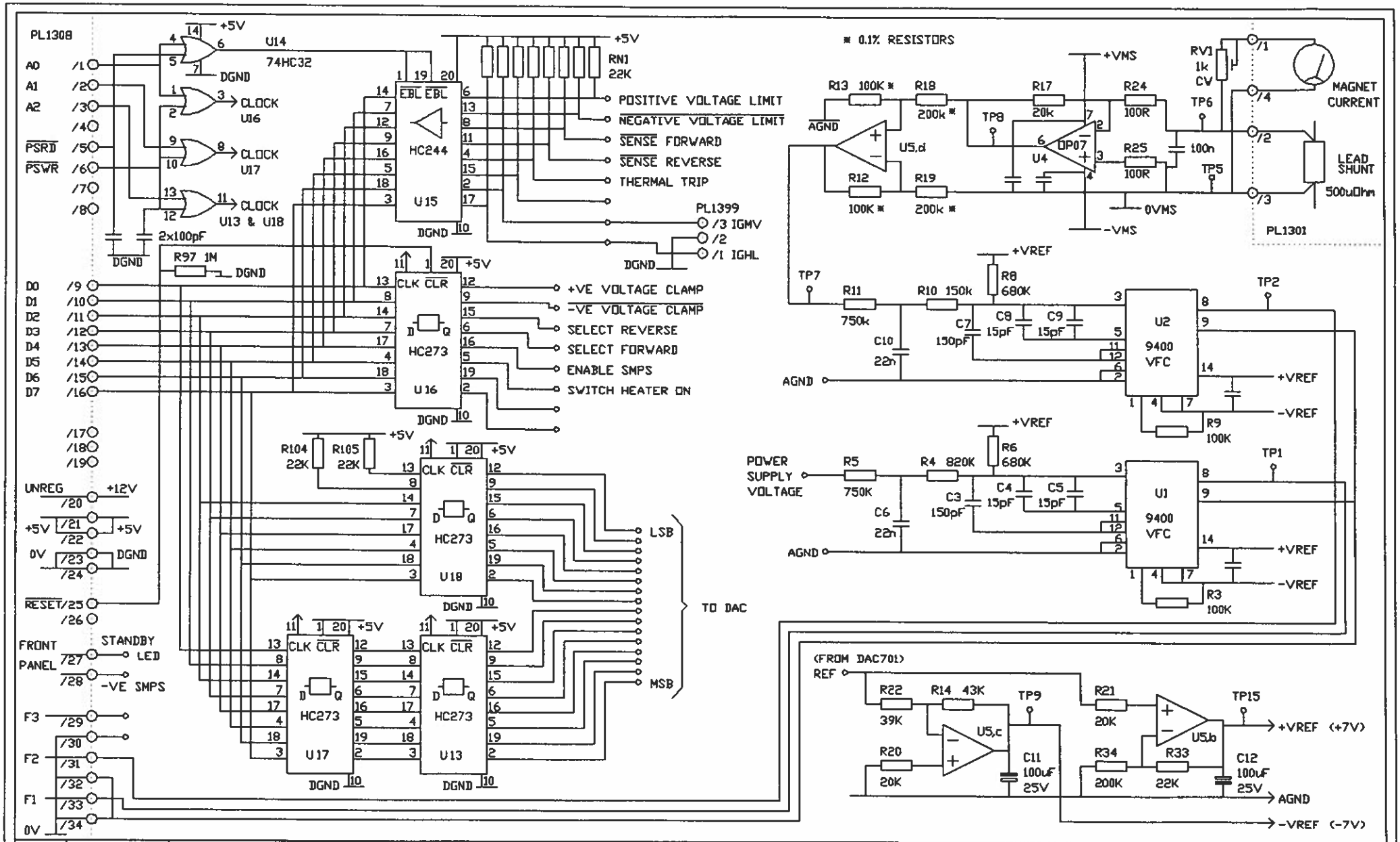
MACJ	25/2/91	
MACJ	9/1/91	ISSUE 4 PCB
MACJ	7/11/89	ISSUE 3 PCB
MACJ	21/9/89	ISSUE 2 PCB.
MACJ	17/7/89	COMPONENTS SHOWN OUTSIDE THE DOTTED LINE ..... ARE NOT ON CBD1300

PS120-10 POWER SUPPLY ANALOGUE PCB CURRENT CONTROL

OXFORD

DRAWING NUMBER

A4/CBD1302 1of3



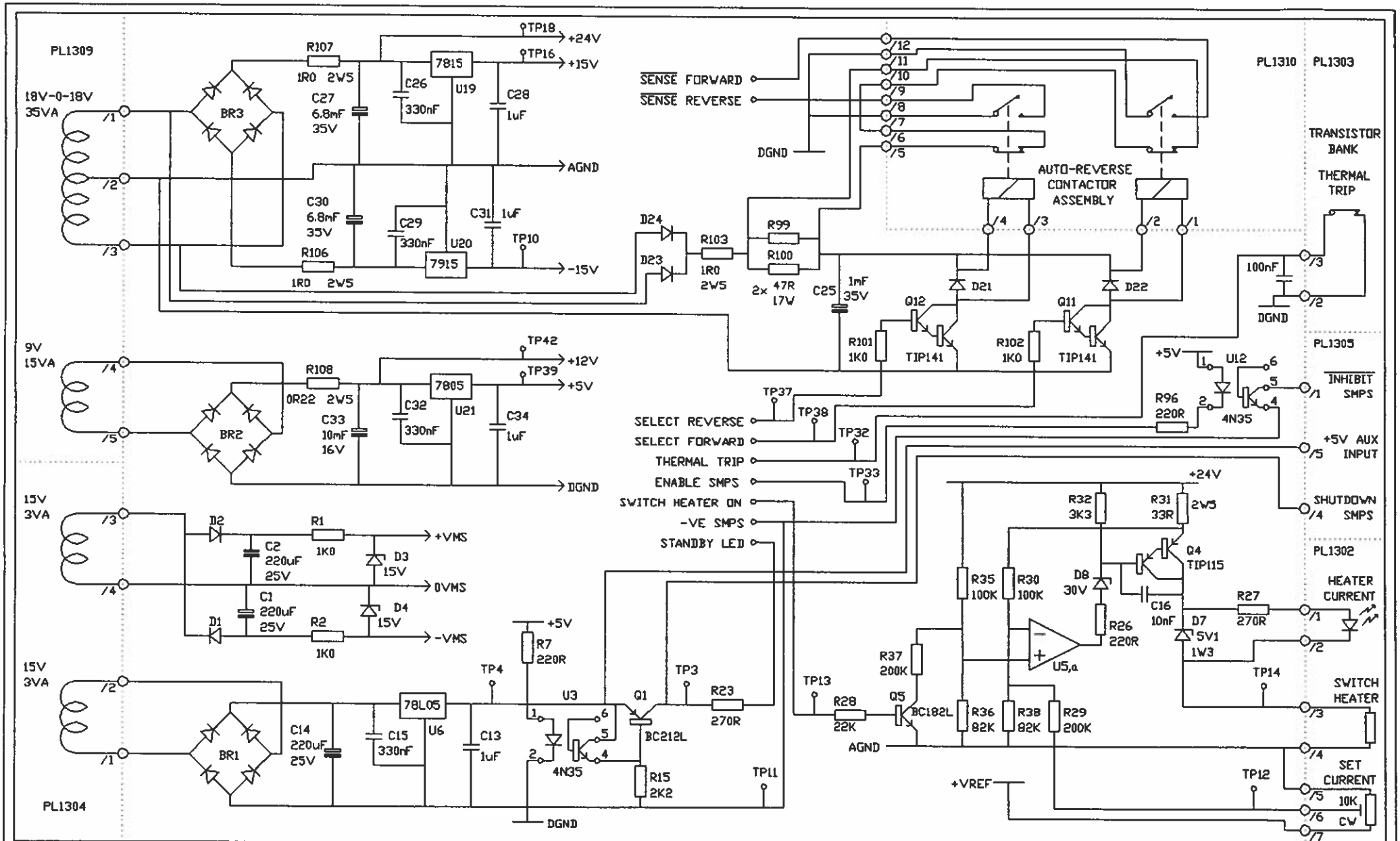
MACJ	25/2/91	
MACJ	7/11/89	ISSUE 3 PCB
MACJ	21/9/89	ISSUE 2 PCB.
MACJ	17/7/89	COMPONENTS SHOWN OUTSIDE THE DOTTED LINE , ... ARE NOT ON CBD1300

PS120-10 POWER SUPPLY
ANALOGUE PCB
ANALOGUE/DIGITAL INTERFACE

OXFORD

DRAWING NUMBER

A4/ CBD1302 2of3



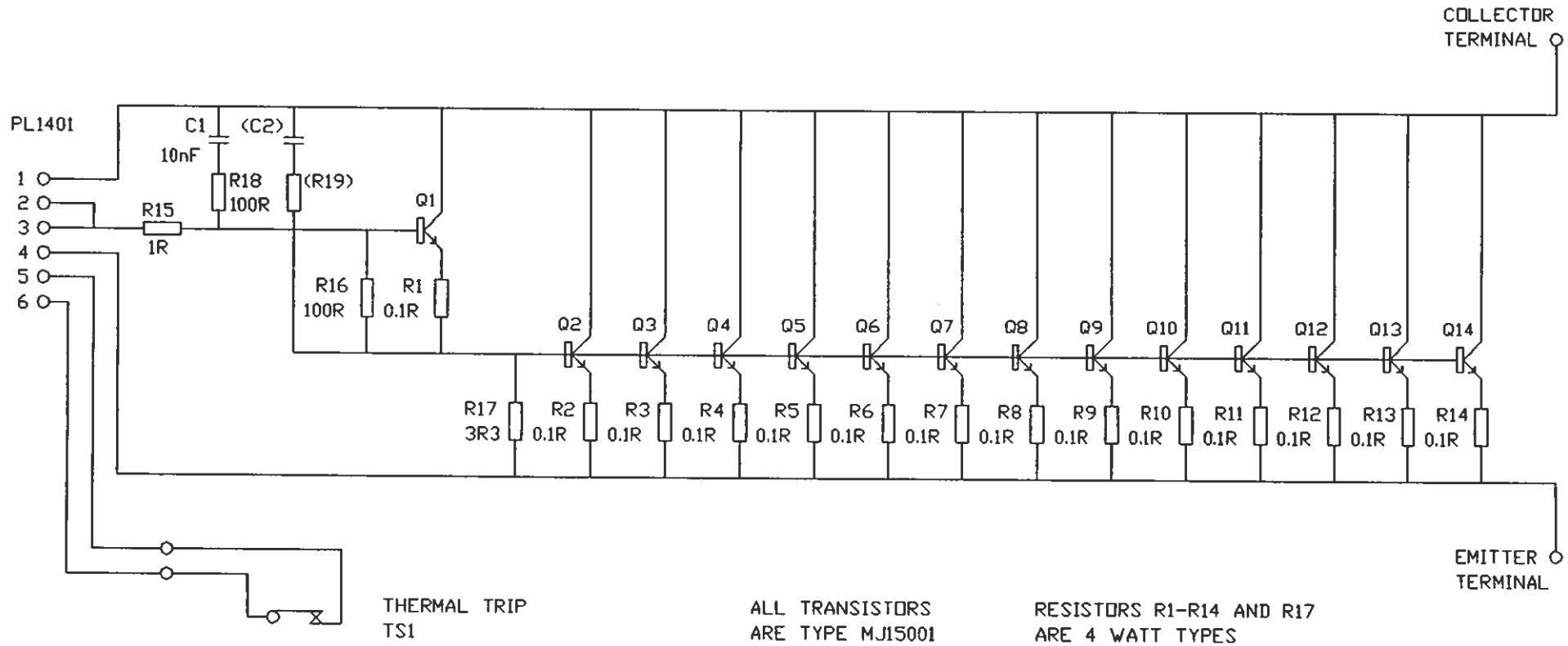
MACJ	21/1/91	ISSUE 4 PCB
MACJ	7/11/89	ISSUE 3 PCB
MACJ	21/9/89	ISSUE 2 PCB.
MACJ	17/7/89	COMPONENTS SHOWN OUTSIDE THE DOTTED LINE , ... ARE NOT ON CBD1300

PS120-10 POWER SUPPLY
ANALOGUE PCB
POWER CONTROL

OXFORD

DRAWING NUMBER

A4/ CBD1302 3of3

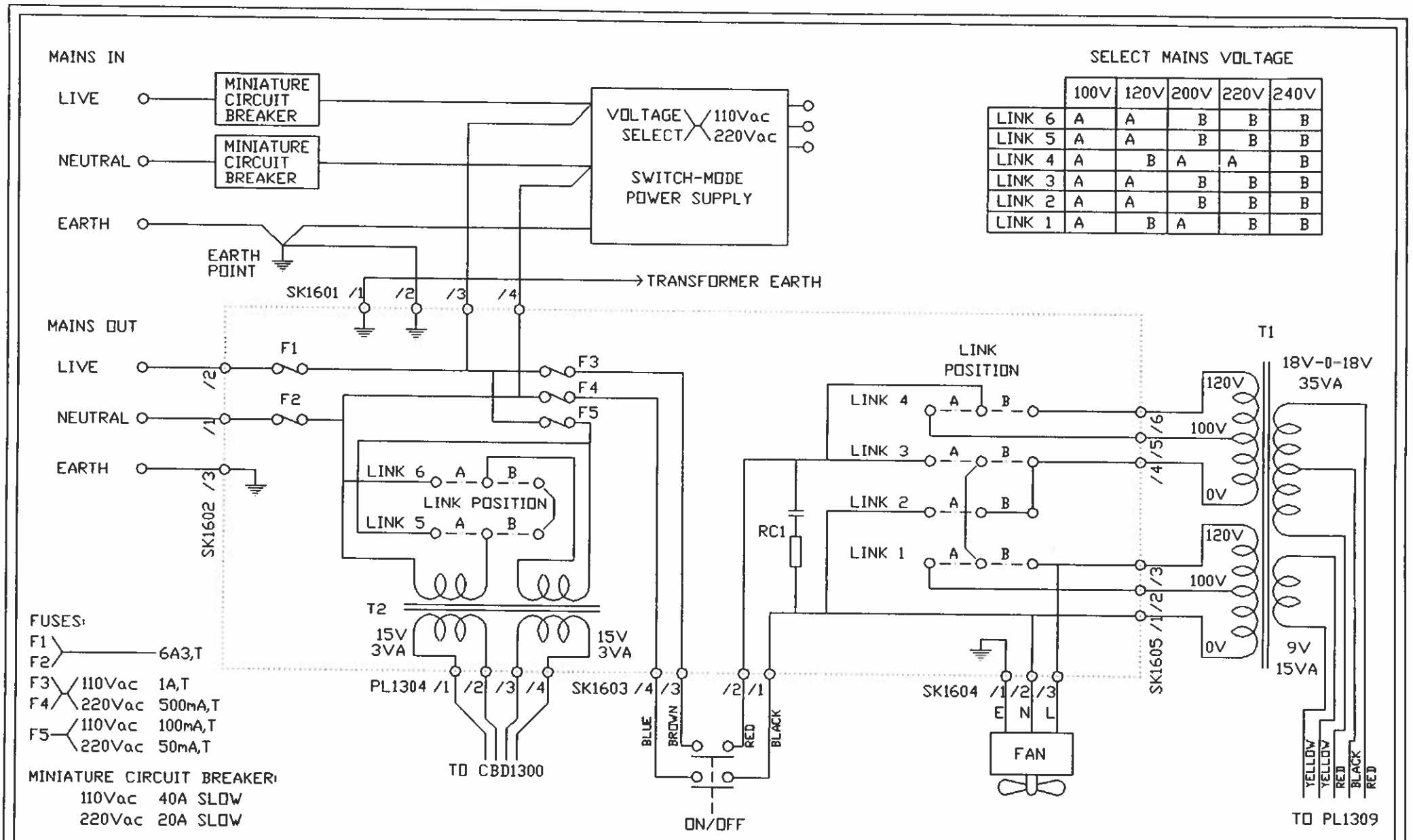


MACJ	24/5/89	

PS120-10 POWER SUPPLY
PASS BANK PCB

OXFORD

DRAWING NUMBER
A4/ CBD1402



SELECT MAINS VOLTAGE

	100V	120V	200V	220V	240V
LINK 6	A	A	B	B	B
LINK 5	A	A	B	B	B
LINK 4	A	B	A	A	B
LINK 3	A	A	B	B	B
LINK 2	A	A	B	B	B
LINK 1	A	B	A	B	B

FUSES:
F1, F2 — 6A3,T
F3, F4 — 110Vac 1A,T; 220Vac 500mA,T
F5 — 110Vac 100mA,T; 220Vac 50mA,T

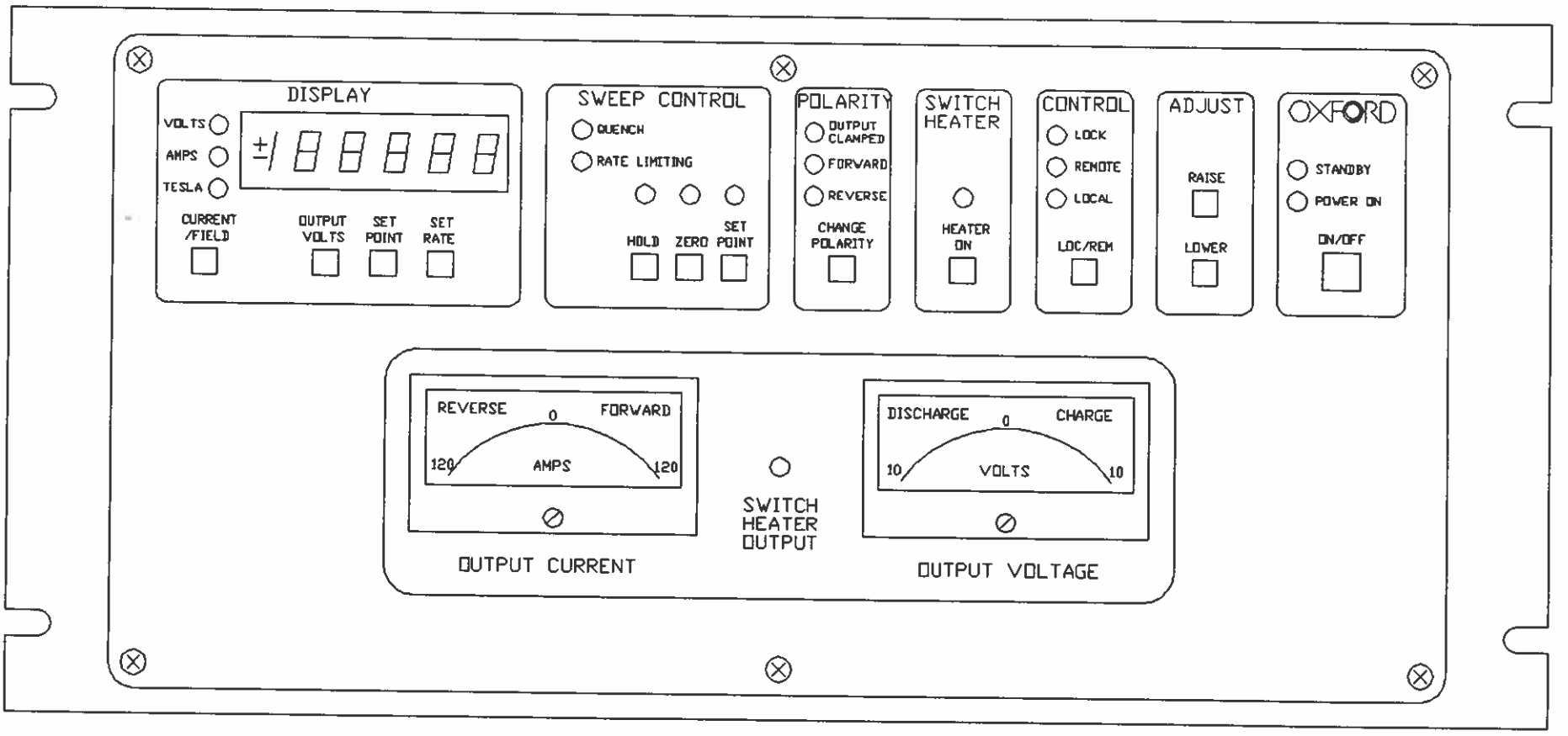
MINIATURE CIRCUIT BREAKER:
110Vac 40A SLOW
220Vac 20A SLOW

MACJ	7/11/89	ADD SUPRESSOR & T2 VOLTAGE LINKS
MACJ	5/6/89	COMPONENTS SHOWN OUTSIDE THE DOTTED LINE ,..... ARE NOT ON CBD1600.

PS120-10 POWER SUPPLY
MAINS PCB (AND WIRING).

OXFORD

DRAWING NUMBER
A4/ CBD1602

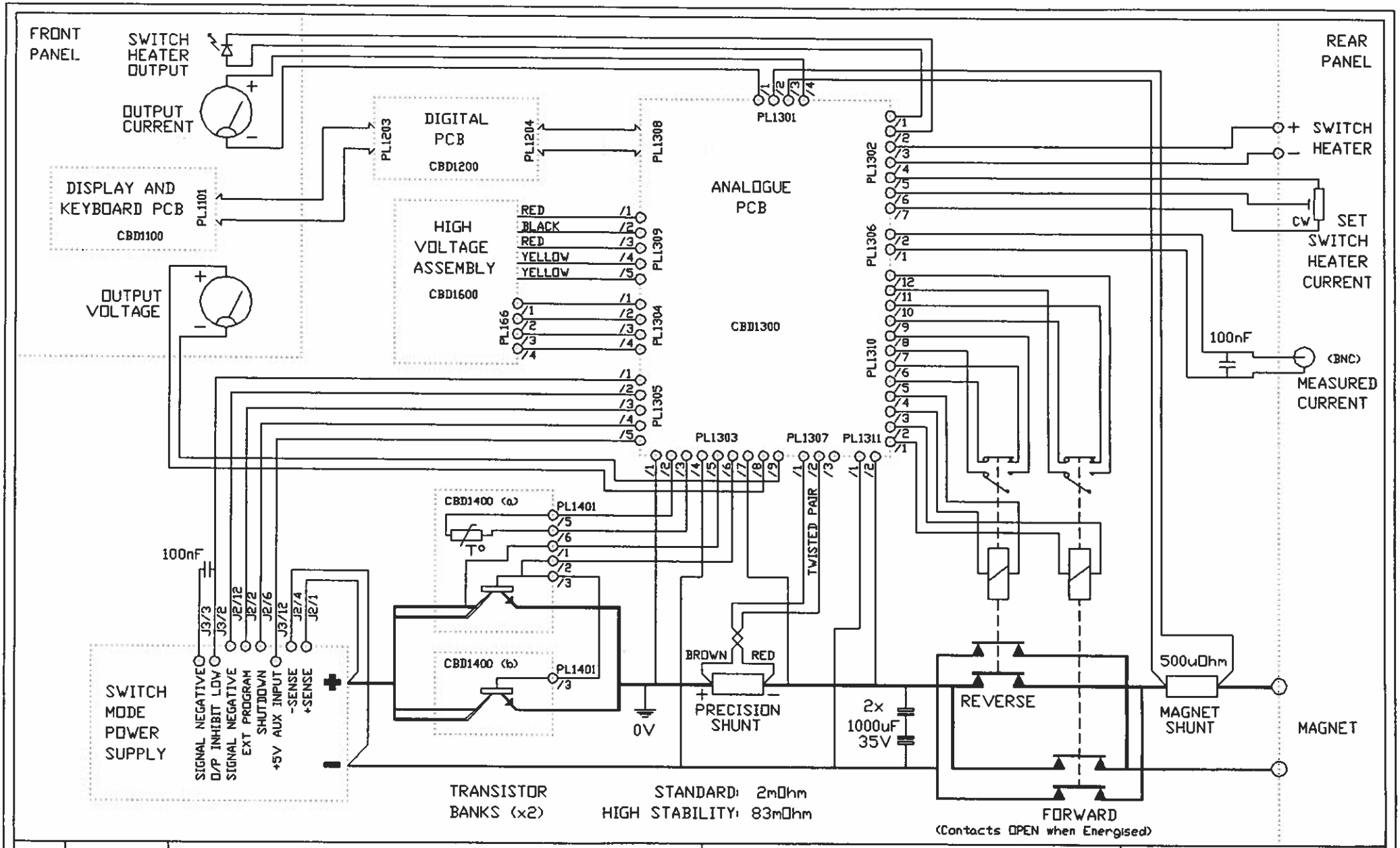


MACJ	24/5/89	SCALE 1:2

PS120-10 POWER SUPPLY
FRONT PANEL ASSEMBLY

OXFORD

DRAWING NUMBER
A4/ CBD2100



MACJ	26/2/91	
MACJ	7/11/89	EXTEND ZOBELS
MACJ	24/7/89	

PS120-10 POWER SUPPLY
WIRING LOOM

OXFORD

DRAWING NUMBER
A4/ CBD2902